SME Productivity and University Collaboration: Does Past Performance Influence Future Performance?

Purpose: As little is known about the productivity levels of SMEs engaging with universities and the relative changes in productivity of SMEs subsequent to these collaborations the paper examines the following questions: 1) does the relative productivity of SMEs engaging in university collaboration differ from those that do not? 2) are subsequent changes in firm productivity following university collaboration related to their initial levels of productivity?

Design/Methodology: The paper utilises data on 254 SMEs from the Longitudinal Small Business Survey (LSBS) and uses two statistical techniques: First, bivariate tests of difference were used to inspect the relationships between the productivity levels and whether the firm collaborated with a university to introduce its innovation. Second, OLS regressions were used to test whether future productivity of SMEs that collaborated with universities is related to initial productivity levels.

Findings: The analysis reveals that SME-university collaboration is unrelated to starting productivity. Furthermore, the analysis suggests a non-linear relationship exists between the starting productivity of SMEs and their subsequent productivity following a university collaboration. Therefore, higher levels of subsequent productivity are observed among those SMEs where starting productivity was either relatively low or high, suggesting that collaborations 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.

Practical Implications: Given the fact the extant literature also suggests that, overall, university collaboration is beneficial, policymakers should strive to encourage greater levels of collaborations involving SMEs. In light of evidence that SME-university collaborations can transform less productive firms it appears unjustified for practitioners and policymakers to only consider stronger performing firms to be included in such programmes.

Originality/Value: The study contributes new in theoretical and practical knowledge to the understanding of the role of firm productivity in predicting the proclivity of firms to collaborate

with universities. Furthermore, as few studies have examined the impact of these collaborations on the subsequent productivity of firms that collaborate with universities this paper fills an existing gap in the literature.

Key Words: University collaboration; SMEs; Innovation; Productivity

1. Introduction

SME-university collaboration is also acknowledged as an important means of promoting innovation within these firms (Dada and Fogg, 2016; Huggins, Prokop and Thompson, 2020; Apa *et al.*, 2021; Johnston and Huggins, 2021; Messeni Petruzzelli and Murgia, 2021). Indeed, university collaboration enables SMEs to leverage the knowledge and expertise they lack to enhance their competitiveness (Bishop, D'Este and Neely, 2011). As such, this type of collaboration has been found to have a significant impact on firms' R&D, patenting, learning, and scope of their activities (Hagerdoorn, Link and Vonortas, 2000; Fontana, Geuna and Matt, 2006; Lööf and Broström, 2006; Abreu *et al.*, 2008). Therefore, within the extant literature, there is evidence of a positive chain of causation from university collaboration to SME performance, through first stimulating their innovation activities (Vossen, 1999; Fontana, Geuna and Matt, 2006; Hughes and Kitson, 2012), which, in turn, boosts their overall competitiveness (Freel, 2000; McAdam and Keogh, 2004; Humphreys, McAdam and Leckney, 2005; Gunday *et al.*, 2011; Rosli *et al.*, 2018). This offers an explanation as to why SMEs benefit from higher levels of growth after receiving public funding for research projects than large firms (Vanino, Roper and Becker, 2019) and the positioning of universities as crucial members of entrepreneurial and innovation ecosystems (Theodoraki, Messeghem and Rice, 2018; Heaton, Siegel and Teece, 2019; Prokop, 2021).

Yet, while the extant literature has identified the benefits of university collaboration, less is known about the relationship between firm productivity and SME-university engagement. In particular, this paper focuses on the extent to which initial levels of firm productivity can be seen as a predictor of SME-university collaboration and any subsequent changes in productivity post-collaboration. In terms of the former, there exists substantial evidence of a positive relationship between productivity and innovation within SMEs (Crepon, Duguet and Mairesse, 1998; Griffith *et al.*, 2006; Hall, Lotti and Mairesse, 2009; Hall, 2011; Saunila, 2014; Baumann and Kritikos, 2016); therefore, SMEs that are more productive are, typically, more innovative. As pursuing an innovation is the key reason for university collaborations (Mindruta, 2013; Mindruta, Moeen and Agarwal, 2016), this outcome suggests that the SMEs engaging in collaborative links with universities are likely to be more productive overall. Yet, as collaborating with universities has been characterised as a strategic decision designed to enhance its competitiveness (Mindruta, Moeen and Agarwal, 2016), the act of forming a collaborative link with a university is interpreted as being motivated by a desire and ability to increase a firm's performance, and therefore productivity. Indeed, given the myriad of policy

initiatives that exist to promote such interactions (e.g. Innovate UK in the United Kingdom or Small Business Technology Transfer in the US), the question remains whether those SMEs collaborating with universities are those with relatively lower or relatively higher productivity levels?

Furthermore, while the extant literature has examined productivity of SMEs from engaging in university collaboration, less is known about how this relates to starting levels of productivity. Therefore, while access to university knowledge promotes the development of firms' capabilities through leveraging skills, knowledge, and resources into the business that it previously did not possess (Rutten, Boekma and Kuijpers, 2003; Bishop, D'Este and Neely, 2011; Huggins, Johnston and Stride, 2012; Kauffeld-Monz and Fritsch, 2013) and 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, D'Este and Neely, 2011), less is known about whether any post-collaboration productivity differences within SMEs related to their starting levels of productivity.

Therefore, this paper augments the extant literature in SME-university collaboration by examining the relationship between SME productivity and university engagement. As little is known about the productivity levels of SMEs engaging with universities and the relative changes in productivity of SMEs subsequent to these collaborations the paper examines the following questions: 1) does the relative productivity of SMEs engaging in university collaboration differ from those that do not? 2) are subsequent changes in firm productivity following university collaboration related to their initial levels of productivity? The paper's contribution to the extant literature is two-fold: first, the analysis reveals no statistically significant differences in productivity levels among SMEs that collaborate with universities and those that do not. Second, the existence of a curvilinear, U-shaped, relationship between initial productivity and subsequent productivity of collaborating SMEs suggests that higher levels of subsequent productivity are observed among those SMEs where starting productivity was either relatively lower or higher. Therefore, university collaboration 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.

The paper is organised as follows: Section 2 outlines the conceptual and theoretical background. 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. Conceptual and Theoretical Background

2.1 SMEs and University Collaboration

Universities are portrayed as key nodes within innovation process and 'anchors' of the system (Goddard *et al.*, 2014; Ghio, Guerini and Rossi-Lamastra, 2016; Cunningham, Menter and Young, 2017) and 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; Couchman, McLoughlin and Charles, 2008; Wilson, 2012; Guerrero, Cunningham and Urbano, 2015; Rossi, Rosli and Yip, 2017; OECD, 2019). For example, in the UK, collaborative research projects between firms and universities receive around £800m of public money annually (Johnston and Huggins, 2021). Consequently, universities are increasingly placed at the forefront of economic development, for example being a crucial element of the Triple Helix model of industry-university-government interactions (Ranga and Etzkowitz, 2013; Lawton Smith, 2015; Zhuang *et al.*, 2021).

University engagement can instil significant performance advantages within SMEs (Sher, Shih and Kuo, 2011; Fogg, 2012; Apa *et al.*, 2021; Messeni Petruzzelli and Murgia, 2021; Audretsch *et al.*, 2023). While these firms have been often regarded as less likely to engage in collaboration with universities, such links have been shown to boost their innovation capability (Wang and Altinay, 2012). In addition, the benefits to the firm from such collaborations, such as improving understanding, gaining knowledge, problem solving, and training the workforce, are found in both SMEs and larger firms (Bishop, D'Este, and Neely 2011). Indeed, SME-university collaborations are marked by two key characteristics; first, SMEs are more likely to engage in informal interaction with universities (Bodas Freitas et al. 2013). Second, SMEs tend to focus on longer term projects, centred on organisational learning that is less hurried and more deliberate in nature (Broström 2010). Finally, the intensity of collaborations with universities is higher for small firms when compared to medium or large firms (Lazzarotti *et al.*, 2023). Given these findings, universities are regarded as important sources of external knowledge for SMEs (Rosli *et al.*, 2018; Apa *et al.*, 2021; Johnston, 2021; Johnston and Huggins, 2021; Messeni Petruzzelli and Murgia, 2021)

Yet, there are risks for SMEs engaging with universities; firstly, the probability of failure has been found to be higher with university partners than for other organisations and, indeed, collaborations can end in failure, (Lhuillery and Pfister, 2009; Johnston and Huggins, 2021). Secondly, there is evidence that collaboration with universities does not have a significant effect on the level of R&D or innovation within firms (Okamuro, 2007; Albats, Fiegenbaum and Cunningham, 2018). In addition, the 'two-worlds paradox' suggests that organisational and cognitive differences may constrain these collaborations (Hewitt-Dundas, Gkypali and Roper, 2019). Therefore, there may be benefits for SMEs from external collaborations but there is no guarantee that they will be successful and firms may have to learn to prevent failure (Love, Roper and Vahter, 2023).

2.2 University Collaboration and Productivity in SMEs

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 and Subramanian, 2014; Scandura, 2016), or process factors such as project management, trust, balancing priorities, and collaborative environment (Barnes, Pashby and Gibbons, 2002; Bruneel, D'Este and Salter, 2010; Perkmann, Neely and Walsh, 2011; Schofield, 2013; Rybnicek and Königsgruber, 2019).

The evidence of a positive relationship between productivity and innovation within SMEs has established that more productive firms are more innovative (Crepon, Duguet and Mairesse, 1998; Griffith *et al.*, 2006; Hall, Lotti and Mairesse, 2009; Hall, 2011; Saunila, 2014; Baumann and Kritikos, 2016). Furthermore, there is evidence that higher levels of open innovation also have a positive effect on firm productivity (Greco *et al.*, 2021). Therefore, not only innovative firms but those firms that are more open in nature are more likely to exhibit higher rates of productivity. Yet, despite this evidence, productivity has not been examined as a predictor of open innovation activities. Indeed, as the pursuit of innovation is the key reason for university collaborations (Mindruta, 2013; Mindruta, Moeen and Agarwal, 2016), this suggests that the SMEs engaging in collaborative links with universities are likely to be those that are more productive overall. We formalise these arguments in the following Hypothesis:

> **Hypothesis 1:** SMEs collaborating with universities will exhibit higher levels of productivity than those that do not.

While the literature is clear on the positive relationship between innovation and productivity, less is known about any subsequent changes in productivity of SMEs from engaging in open innovation activities such as university collaboration. Indeed, the potential for increases in firm performance for 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, Boekma and Kuijpers, 2003; Bishop, D'Este and Neely, 2011; Huggins, Johnston and Stride, 2012; Kauffeld-Monz and Fritsch, 2013; Audretsch *et al.*, 2023). Second, 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, D'Este and Neely, 2011). Consequently, collaborating with universities has been found to promote increased sales, 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, Link and Vonortas, 2000; Fontana, Geuna and Matt, 2006; Lööf and Broström, 2006; Abreu *et al.*, 2008; Eom and Lee, 2010).

Given these findings, university collaboration should provide a significant boost to SME productivity as increased sales and scope of activities suggest higher revenues will be generated as the firm captures a greater market share. Furthermore, the access to additional knowledge and increased learning from a university collaboration suggest that the firm becomes more agile and flexible through engaging with a university, increasing efficiencies and competitiveness, and ultimately productivity.

However, the evidence does not suggest which firms will benefit from these gains. Indeed, the empirical evidence regarding productivity changes from university collaboration is mixed, suggesting that any gains from university collaboration may not be guaranteed. There is evidence that smaller firms are subject to greater productivity gains from university collaboration than larger firms (Motohashi, 2005), suggesting that SMEs may stand to gain more than their larger counterparts. However, other studies report a lack of productivity gains following university collaboration (Eom and Lee, 2010). Importantly, these assertions tend to ignore initial levels of firm prior to the collaboration.

Furthermore, there is evidence that greater levels of resources within a firm are positively related to the impact of university collaboration (Lai, 2011). If prior resources are an important

factor in the impact of university collaboration, then prior performance may also have a bearing. Therefore, higher levels of pre-collaboration productivity may signal that an SME has higher 'absorptive capacity' and 'knowledge readiness' and is therefore more able to utilise the collaboration to create new and improved products and services or utilise the new knowledge and learning experience more efficiently which suggests that university collaborations reinforce higher levels of productivity (Griffith, Redding and Van Reenen, 2003; Mathisen and Jørgensen, 2021). As such, productivity gains from university collaboration will be positively related to starting levels of productivity within the firm. This argument is formalised in Hypothesis 2.

> **Hypothesis 2**: the subsequent productivity of SMEs following a university collaboration is positively related to the starting levels of productivity within the firm.

However, a positive relationship assumes that those SMEs most likely to see positive changes in productivity are only those with relatively higher levels of productivity. This argument rules out the fact that collaborating with universities may be the result of the firms' needs and abilities, with the strategic decision to engage with a university is based on the need to address its weaknesses, or consolidate its strengths (Mindruta, 2013; Mindruta, Moeen and Agarwal, 2016). For example, lower productivity levels may simply signal the fact that firms lack capabilities to do so alone and require a university partner to obtain the knowledge and expertise necessary to innovate. Therefore, those firms with lower levels of productivity are seeking to consolidate and extend their knowledge base with the external knowledge and expertise from universities to boost productivity (Cassiman and Veugelers, 2006; Muscio, 2007). Given these arguments, in addition to higher productivity firms, those firms with lower relative productivity at the start of a university collaboration could be likely to see significant productivity gains from university collaborations. This is formalised in Hypothesis 3.

> **Hypothesis 3**. There is a 'U-shaped' relationship between the subsequent productivity of SMEs collaborating with universities and starting levels of productivity.

3. Methodology

3.1. Data Sources

This section sets out the data sources and variables used to test the hypotheses set out 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) and used widely in the analysis of SME innovation activities (Johnston and Prokop, 2021; Gkypali and Roper, 2024). The LSBS data used in this analysis 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. SME is defined here as a firm with employment ranging from 0 to 249, as is standard in the UK and EU.

The paper focuses on SMEs that collaborated with universities in the course of their innovation activities; therefore, we select SMEs that report developing an innovation through a university collaboration in the previous 3 years. As collaborations take time to develop, not to mention resulting in useful knowledge and outputs (Johnston and Huggins, 2021), we argue that 2015 represents the base year. Examining productivity in the following years allows us to examine changes after the collaboration. As the study also focuses on the productivity of such firms, there are further limitations imposed on the data availability (given non-respondents). Therefore, through including all cases where the SME collaborated with a university, and where complete data exists, we identified a sample of 289 SMEs for 2016 and 159 for 2017.

3.2. Dependent and independent variables

As the focus of the paper is examining changes in productivity, the first task is to capture this variable. Consequently, productivity for firm *i* in year *t* is a simple and standard measure that captures turnover per employee (Johnston and Prokop, 2021) – i.e. output over input (Chew, 1988; Fisher, 1990; Jurison, 2007) in some studies also referred to as labour productivity (Criscuolo *et al.*, 2012; Hitt, Wu and Zhou, 2014). Whilst it is more desirable to use labour hours rather than number of employees, the limitations of our dataset prevent us from this specification. We define the productivity of firm *i* as its turnover in year *t* divided by employment in the same year:

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

In the regression analysis it is expressed as a natural logarithm to correct distributional properties. Productivities used are reported in real terms using ONS deflators with 2015 as the

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

base year. In addition, SqProductivity represents its squared term to examine non-linear relationships.

3.3 Control variables

In order to build a robust model several independent variables were used. 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 (Lawton Smith and Bagchi-Sen, 2006; D'Este and Patel, 2007; Giuliani and Arza, 2009; Johnston and Huggins, 2016) 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. Given the limited sample size, the firms were assigned into broad sectoral groups as follows: 1) production and construction (accounting for 23.4% of firms in the sample), 2) transport, retail and food (23.2%), 3) business services (34.0%), 4) other sectors (19.4%). The reference category in each case is other sectors. Thirdly, given that substantial evidence that exporters are more innovative in general (Roper and Love, 2002; Love and 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 (Blake and Hanson, 2005; Fuentes-Fuentes, Bojica and Ruiz-Arroyo, 2015; Mari, Poggesi and De Vita, 2016), we included a dummy variable taking 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 (Wang and Altinay, 2012; Nathan and Lee, 2013). Therefore, a dummy

taking value of 1 if the firm belongs to an ethnic minority business owner and 0 otherwise was included.

3.4 Location characteristics

We also control for the location characteristics of the firms to account for the influence of their spatial context (Huggins, Johnston and Stride, 2012; Tödtling and Kaufmann, 2016). 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 region) 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 Prokop et al. (2019) and calculates the industrial specialisation of a region across 14 sectors in comparison to the rest of the country (Fotopoulos, 2014; Prokop, Huggins and Bristow, 2019). It enables us to control for the industrial structure of an SME's region, which may influence its productivity (e.g. benefits of clustering).

[Table 1 around here]

3.6. Analytical approach

Two statistical techniques were employed in this study. First, bivariate tests of difference were used to inspect the relationships between the productivity levels and whether the firm collaborated with a university to introduce its innovation. Given that diagnostic tests established that these variables were not normally distributed, non-parametric tests were used (Chapple *et al.*, 2005). The results are reported in Table 2.

An Ordinary Least Squares (OLS) regression was used to analyse relationships between SMEs' subsequent productivity following a university collaboration and their initial 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) (Johnston, Jones and Manley, 2018; Prokop and Thompson, 2022). 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 models (1) and (2) 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:

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

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:

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

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

Table 2 presents the results of bivariate tests that examine the relative productivity of SMEs with respect to whether they have recently collaborated with a university. The evidence suggests that initially (2015) there is no statistical difference in the mean productivity of SMEs that report collaborating with a university and those that did not. Therefore, we reject Hypothesis 1. However, in subsequent years (2016 and 2017), significant differences are

observed as the mean productivity of collaborating SMEs is around 22% lower than that of those SMEs that did not collaborate with a university.

[Table 2 around here]

The data also reveals that over the period 2015-17, SME productivity has declined. However, the relative decline was statistically different for collaborators and non-collaborators as productivity for latter firms was 0.58% lower than in 2015 compared with 3.3% lower for the former firms. Therefore, in terms of productivity, the data suggests there is a significant divergence in performance between those SMEs that collaborated with universities and those that did not.

Importantly, Table 1 also highlights statistically significant differences in mean turnover of SMEs depending on whether they collaborated with a university or not. Those in the former group registered a higher turnover than those in the latter group in both 2015 and 2016. However, by 2017 there was no significant difference between the two groups in terms of turnover. Given these findings, it appears that SMEs with greater financial resources have a higher propensity to engage with universities. Conversely, while they may possess greater financial resources, they are less productive.

Table 2 presents the results of the OLS regression models assessing the factors underpinning the subsequent productivity levels of SMEs that collaborated with universities. The results show estimates for a 1-year lag on productivity using data from 2016 as the dependent variable (Models 1 and 2) and estimates for a 2-year lag on productivity, using data from 2017 as the dependent variable (Models 3 and 4). 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. Therefore, we accept Hypothesis 3 and reject Hypothesis 2.

Thus, while the subsequent productivity 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 lower or higher. As such, this evidence suggests that for 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 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 SMEs.

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 the effects are only observed over the course of one year (Models 3 & 4). 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. Finally, the analysis reveals that characteristics of the SMEs' size, number of directors, and the gender/ethnicity of the manager have no influence on its subsequent productivity. Furthermore, there is no evidence to suggest that the socio-economic characteristics of the SMEs' location has an influence on subsequent productivity, ruling out any spatial variations in changes.

[Table 3 around here]

5. Discussion and Conclusions

5.1 Implications for Research

Using data from the Longitudinal Small Business Survey (LSBS), this paper examined the relative productivity levels of SMEs engaging in university collaboration. The paper's first contribution is to show that there are no significant differences in initial productivity levels among those SMEs that do or do not collaborate with universities. The second contribution of the paper is to demonstrate that starting levels of productivity are positively related to the subsequent productivity of SMEs that collaborate with universities. Furthermore, the observed non -linear 'U' shaped relationship suggests that future productivity is higher for those SMEs with starting levels that were either relatively lower or relatively higher than others. Therefore, the analysis suggests that university collaboration can be transformative for those SMEs that have lower initial levels of productivity, while for those SMEs with higher relative productivity, university collaboration maintains their competitiveness.

The extant literature it clear on the benefits of university collaboration to participating firms, leveraging skills, knowledge, and resources into the business (Rutten, Boekma and Kuijpers, 2003; Bishop, D'Este and Neely, 2011; Huggins, Johnston and Stride, 2012; Kauffeld-Monz and Fritsch, 2013; Messeni Petruzzelli and Murgia, 2021; Audretsch *et al.*, 2023). In the case of less productive SMEs, we postulate that these benefits are magnified within these firms as

their lack relative lack of productivity signals a lower level of capabilities and innovative capacity. Therefore, for less productive SMEs, university collaborations are potentially transformational in nature provide through boosting subsequent productivity levels. In the case of more productive SMEs, we postulate that the infusion of skills, knowledge, and resources is a signal of higher productivity and therefore allows these firms to build on this further in the course of the collaboration.

While scholars have previously examined the relationship between university collaborations and productivity (Motohashi, 2005; Eom and Lee, 2010), these results enhance our understanding of the longer-term effects of these linkages. Indeed, the results suggest that the impact of university collaboration on SMEs may be more complex than just inducing changes in the business as the starting performance of the firm will influence its subsequent performance. Furthermore, given the evidence of the importance of starting levels of productivity to subsequent productivity following a university collaboration, more attention should be paid to starting levels of knowledge, innovation activity, sales, and capabilities to assess the true impact of these collaborative links on SMEs.

In addition, the observation that SMEs collaborating with universities have a higher average turnover than those that do not suggests that greater financial resources may influence the firm to engage with a university. Therefore, those SMEs that engage with universities may do so because they regard themselves as possessing the resources to successfully undertake such a collaboration, mirroring the influence of financial performance on R&D decisions (Teirlinck, 2017). However, this result may also mask the fact that the firms are in fact less efficient. Given this evidence, it may be the case that SMEs estimate their strength and competitiveness in accounting terms, i.e. turnover and profits, rather than economic terms, i.e. productivity and efficiency, which then determines whether they collaborate with a university.

At first glance, these findings appear to justify the institutionalisation of the Triple Helix approach whereby university collaboration is built into official policy activities to promote innovation among firms (Reischauer, 2018) as it appears that SME-university collaborations can be a useful policy tool to boost firm productivity. However, there is an important caveat to this argument; the productivity of SMEs collaborating with universities subsequently lags that of those firms that have not collaborated in this way. Given these results, we propose two possible explanations: Firstly, SMEs engaging in university collaborations may simply be less competitive and efficient firms, suggesting that it is weaker firms that are engaging with

universities. Secondly, the lower levels of subsequent productivity among collaborating SMEs could be explained by the fact that university collaboration has been found to consume scarce resources within the firm as SMEs dedicate time, workers, and knowledge towards research and development activities in the course of a collaborative project (Johnston & Huggins, 2021). Therefore, there may be a time lag between collaborating with a university and reaping the benefits in terms of productivity gains. Given these results, there appears to be a need to look at SMEs over a longer time frame to definitively assess the effects of university collaboration on productivity to decide whether this may be a temporary divergence or a permanent effect.

Finally, the significance of sector dummies for explaining variations in productivity across industrial sectors suggests that any observed changes among SMEs must be caveated in terms of the industry in which a firm operates. Thus, when assessing any changes to SME performance post-university collaboration the firms' sector must be considered as this may be partly driving the observed changes.

5.2 Implications for Practitioners and Policymakers

For practitioners and policymakers, these results raise important implications as to whether university collaboration reduces SME performance in the short run or whether participation in such collaborations is merely indicative of firms with lower productivity? However, given that SMEs are, overall, less likely to engage in collaborative links with universities it would not be sensible to discourage any university collaborations due to the underlying performance of the SME. Furthermore, given the fact the extant literature also suggests that, overall, university collaboration is beneficial to participants (Bishop, D'Este and Neely, 2011; Ankrah and AL-Tabbaa, 2015; Perkmann *et al.*, 2021) it appears sensible to encourage a greater number of SMEs to collaborate in this way as possible. In light of evidence that the outcomes of SME-university collaborations are broader than merely influencing performance (Johnston and Huggins, 2021), we call for practitioners and policymakers to not only consider stronger performing firms be included in such interventions but also those with relatively weaker performance.

In addition, if university collaboration does indeed reduce performance in the short-run, it may be pertinent to ensure additional resources are made available to the collaborating firms. Therefore, if the lag in subsequent performance reflects the redirection of resources during a university collaboration, then policymakers and practitioners need to encourage higher levels of funding to be allocated to these projects. This would ensure that SMEs can continue to

undertake their everyday functions effectively in the course of the collaboration. A university collaboration should not involve trading off current performance for future performance.

5.3 Limitations and Future Research

While the findings presented in this paper reveal important insights, there are several limitations that must be highlighted. Firstly, the exact time of the collaboration is unknown, only noted as the previous 3-year period. While the collaborations take time to conclude and their effects felt within the firm, a more precise date of collaboration could allow their potential effects to be evaluated more accurately. Indeed, it would also be useful to include measure of productivity levels in the years leading up to a university collaboration in order to assess any changes more clearly. Furthermore, due to missing data the sample size used in the paper is limited. Finally, and as noted previously, examining changes in SME productivity over a longer time period may provide greater insights into the resources used in the course of a collaboration and the effects on the firm.

In terms of future research directions, the findings presented within this paper pose an important question; if any gains in productivity are related to the SMEs' initial levels, establishing the chain of causation as to how university collaboration influences subsequent productivity requires further work. For example, the mechanisms through which the collaboration with a university enables higher levels of productivity within an SME should be explored further. Indeed, qualitative research could also be used to examine the SMEs' own assessments of changes in the productivity of the firm to compare their perceptions with quantitative measures.

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Table 1: Descriptive statistics

	Mean	Standard Deviation
Prod2015	131561.52	354025.72
Size (Employees)	36.68	45.41
No. of sites	2.20	10.56
Age	8.08	1.54
No. of directors and partners	7.25	246.21
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
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	
Women-led (0/1)	0.177	
MEG-led (0/1)	0.049	
Urban-based (0/1)	0.750	

Source: Table created by authors

Table 2: Bivariate tests of Productivity and university collaboration activity

Variable	University collaboration Yes	University collaboration No	Test coefficient		N
Mean Productivity 2015	115246.02	136875.20	1074482.00		4394
Mean Productivity 2016	103165.15	126129.93	366772.50	***	2626
Mean Productivity 2017	111496.05	136087.62	128114.00	***	1541
Mean Turnover 2015	3363714.07	2944145.40	1985705.50	***	5679
Mean Turnover 2016	3046585.28	2798334.67	661823.00	***	3283
Mean Turnover 2017	2896937.56	2862431.68	283003.50	*	1940

Note: All relationships tested with non-parametric Mann-Whitney U-test.

Source: Table created by authors

Table 3: OLS regressions of productivity with 1-year lag (2016) – models 1 and 2, and 2-year lag (2017) – models 3 and 4.

	Model 1			Model 2			Model 3			Model 4		
	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

Source: Table created by authors