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A quantitative study on the influence of breadth of open innovation on SMEs product-service performance: The moderating effect of type of innovation

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Abstract: The study investigates the influence of breadth of open innovation strategy on product and service performance of UK SMEs and how the relationship is affected by the type of innovation. The respondents were 72 senior employees randomly sampled from SMEs in UK manufacturing sector. We collected primary data using survey questionnaire. Multiple regression technique through Statistical Package for Social Sciences (SPSS) version 21 was used to analyse the data. We found that breadth of open innovation have curvilinear relationship to both incremental and radical product performance. Also, results showed that incremental as well as radical innovation moderates the influence of breadth of open innovation on the product performance. We concluded that adoption of optimum breadth of open innovation strategy supports SMEs' product-service performance. We recommended that SMEs' policy-makers should adopt a balanced breadth of open innovation strategy in order to foster the achievement of their product performance goals, depending on the particular type of innovation they intend to achieve.

Subjects: Industry & Industrial Studies; Information / Knowledge Management; Innovation Management; Marketing Management; Service Industries

Keywords: open innovation; breadth of opennes; radical innovation; incremental innovation; UK; SMEs

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PUBLIC INTEREST STATEMENT

This study examined the breadth of open innovation and UK SMEs' Product and Service Performance: the moderating effect of type of innovation. Small and Medium Enterprises play pivotal roles in economic growth and development of most economies including the UK. However their survival is usually threatened by their inherent resource limitation which has necessitated the adoption of open innovation strategy so as to enjoy some complementarities with external knowledge. Engaging in collaborations with external firms will, no doubt, enhance the innovative performance of SMEs but collaborating with too many firms will impact negatively on the focal firm. We therefore recommend that SMEs should collaborate with optimum number of external partners depending on the type of innovation- radical or incremental- they intend to produce, in order to remain competitive. The study findings will help the UK SMEs' policy makers to come up with policies that will enhance effective SME collaborations.

1. Introduction

It is almost a globally recognized fact that small- and medium-scale enterprises (SMEs) play pivotal roles in addressing the unemployment situations, that are ravaging most economies of the world, through their job creation potentials which has earned SMEs a recognition as the engine of economic growth and development (Bruque & Moyano, 2007). In the UK, for instance, the number of private sector businesses at the beginning of 2013 was estimated at 4.9 million, employing 24.3 million people with combined turnover of £3,300 billion, of these 4.9 businesses, 99% were small (0–49 employees), 0.6% were medium (50–249 employees) and only 1% were large (250 or more employees). The total number of employees directly employed in either a small or medium enterprise (SME) is estimated at 14.4 million out of the 24.3 million total private sector employments. This implies that about 2 out of every 3 private sector employees in the UK are employed in an SME and the estimated combined turnover of the SMEs stands at £1,600 billion (BIS, 2014, https://www.gov.uk/government/organisations/department-for-business-innovation-skills/about).

However, despite this undisputable importance of SMEs in economic growth and development, many new ventures do not survive the first few years of existence (Bøllingtoft & Ulhøi, 2005), this is because it has been observed that the fast-changing and increasingly competitive global market Zeng, Xie, and Tam (2010) makes innovations for SMEs more complex (Diez, 2000). Thus Bullinger, Auernhammer, and Gomeringer (2004, p. 58) opined that "it necessary for SMEs to link different companies, research facilities, suppliers and customers in a dense innovation network that enables them to share knowledge and profit from complementary competencies" in order to collaborate innovations between SMEs and other stakeholders in the environment. Tomlinson and Fai (2013) have argued that successful small businesses are those that develop good understanding of their business environment and maintain strong business relationships with other stakeholders in the environment see also Gibb (1997). Building such collaborative innovation networks implies opening up the firms' innovation process to accommodate interactions with other firms, whether at the product development or firm level, a phenomenon referred to as Open Innovation (Chesbrough, 2003 in van de Vrande, de Jong, Vanhaverbeke, & de Rochemont, 2009). This paradigm shift from the traditional innovation model whereby firms organized innovation and product development activities internally through the establishment of large centralized research and development (R&D) units Vanhaverbeke, Van de Vrande, and Chesbrough (2008) and Lichtenthaler (2011) which is also referred to as closed model to an open process may be due to "the growing mobility of technical professionals and knowledge workers, the increasing role of private venture capital and the birth and expansion of a market for technologies" (Bianchi, Cavaliere, Chiaroni, Frattini, & Chiesa, 2011, p. 88).

Open innovation is defined as the use of purposive inflows and outflows of knowledge to accelerate internal innovation and expand the markets for external use of innovation (Chesbrough 2006, cited in Chesbrough, 2012). It comprises both outside-in and inside-out movements of technologies and ideas, also referred to as "technology exploration" and "technology exploitation" (Chesbrough & Crowther, 2006; Lichtenthaler, 2008). Chesbrough (2003) popularized the open innovation concept which had attracted an increasing scholarly interest by scholars in management, entrepreneurship and innovation disciplines with most of the studies focusing on large technology-based companies (Lee, Park, Yoon, & Park, 2010). More recently, some studies have demonstrated that open innovation is also being adopted by SMEs (Lee et al., 2010; van de Vrande et al., 2009). Previous studies in the literature had found a positive relationship between open innovation adoption and innovation performance (Faems, De Visser, Andries, & Van Looy, 2010; Faems, Van Looy, & Debackere, 2005; Miotti & Sachwald, 2003; Nieto & Santamaría, 2007). They argued that those firms which practised open innovation tended to produce more innovative products than those that do not. Faems et al. (2010) particularly argued that the more the number of external partners used, the more innovative the resultant products. However, it had been argued that firms should be careful in deciding the number of collaborators they used in the product innovation process because the benefits to open innovation were subject to decreasing returns, suggesting that there was a point where employment of additional collaborators would become unproductive (Laursen & Salter, 2006).

This therefore creates a gap in the literature on the relationship between the breadth of inbound open innovation adoption and product performance. This study is aimed at filling this existing gap. The study is domiciled in SMEs of the UK's manufacturing sector. Also, it intends to investigate how the relationship is influenced by the type of innovation that SMEs pursue. Against this background, the main purpose of this study is to empirically investigate the influence of the breath of open innovation on SMEs' product and service performance in the light of the specific type of product innovation being pursued by the SMEs. The study will contribute to the existing stock of knowledge on open innovation by achieving some specific research objectives, including to identify the breadth of inbound open innovation that SMEs adopt, examine the product performance goals they achieve, identify the specific types of innovation (radical or incremental) SMEs' pursue, evaluate how the adoption of breadth dimension of inbound open innovation strategy affects SMEs' product performance and determine how this relationship is moderated by the type of innovation. The remaining parts of the paper are organized as follows: in Section 2, we examined the theoretical background of the study, followed by discussions into the concept of open innovation in general and open innovation adoption in SMEs. Thereafter, we briefly discussed the concept of product performance and then we examined the conceptual framework and the hypotheses formulated in the study through the analysis of the relationships between the independent and dependent variables of the study as well as their relationships with the moderating variables. Subsequently, in Section 3, we discussed the research methodology employed in carrying out the study. This is followed by presentation and analysis of the data obtained for the study in Section 4. In Sections 5 and 6, we discussed the findings, conclusions, recommendations, suggestions for further studies and the managerial implications of the study.

2. Theoretical background

Open innovation concept is not entirely new (Trott & Hartmann, 2009), but rests on some well-established management theories, Christensen, Olesen, and Kjær (2005), including the user innovation theory, von Hippel (1986), dynamic capability concept Teece, Pisano, and Shuen (1997), absorptive capacity concept, Cohen and Levinthal (1990), and transformative capacity concept (Garud & Nayyar, 1994). According to von Hippel (1986), users and consumers are the real creators of innovation. They argue that majority of new products are produced at the interface between knowledge obtained from within the firm and external sources such as customers. Teece et al. (1997) propounded dynamic capability concept, which is the ability of the firms to "integrate, build, and reconfigure internal and external competencies to address rapidly changing environments". They argued that the dynamic capability enabled firms to absorb and utilize unavailable resources from external sources to create unique products to ensure survival in the business environment. Brockman opined that dynamic capability of firms encompasses the firms' absorptive capacity, Cohen and Levinthal (1990), and transformative capacity (Garud & Nayyar, 1994). According to Cohen and Levinthal (1990) absorptive capacity is the internal competence that firms developed for obtaining external knowledge and manage the internal processes involved in product innovation. They argued that firms need to build their internal R&D capacity so as to enhance their absorptive capacity. The transformative capacity referred to the ability of firms to convert the information and knowledge obtained from the environment into a desired output, Garud and Nayyar (1994), and they argued that firms need to build internal competence that not only enabled them to absorb knowledge, but also helped to transform the knowledge to meaningful output.

2.1. The concept of open innovation

Open innovation has been most recently defined as a distributed innovation process based on purposively managed knowledge flows across organizational boundaries, using pecuniary and non-pecuniary mechanisms in line with the organizations' business model (Chesbrough & Bogers, 2014 cited in West, Salter, Vanhaverbeke, & Chesbrough, 2014). This implies that obtaining knowledge from or exporting knowledge to external partners do not happen by chance, but takes a conscious efforts of the focal firm through financial and non-financial motivation strategies depending on the firms' business model because firms were naturally designed in such a way that their operations affected and are affected by other entities within the business environment (Spithoven, Vanhaverbeke,

& Roijakkers, 2013). West and Gallagher's (2006) open innovation models stressed the importance of using knowledge obtained from many sources, including customers, rivals, academics and firms in unrelated industries for firms' innovation activities while simultaneously using creative methods to exploit firms' Intellectual Property (IP) in order to improve firms' learning effectiveness in absorbing external knowledge, provide access to complementary knowledge residing in innovation partners, grant access to intangible tacit knowledge and know-how, exploit economies of scale and scope in both research and development and enhance the distribution of risks among the partnering firms (Spithoven et al., 2013).

More so, it has already been established in the literature that there is a positive relationship between open innovation adoption and innovation performance (Faems et al., 2005, 2010; Miotti & Sachwald, 2003; Nieto & Santamaría, 2007). These sources argued that those firms which practised open innovation tended to produce more innovative products than those that do not. Faems et al. (2010) particularly argued that engaging a higher number of external collaborators resulted in a more innovative product and services. Koschatzky (2001) cited in Enkel, Gassmann, and Chesbrough (2009) warned that in extreme cases, firms which do not engage in collaborations reduced their knowledge base on a long-term basis and may risk losing their ability to enter into future innovative collaborative relationships. Laursen and Salter (2006) had however argued that though open innovation enhanced product innovativeness firms must be cautious in deciding the number of collaborators they used in the innovation process because the benefits to open innovation were subject to decreasing returns, suggesting that as firms increased the number of collaborators, there would be a point where engaging additional collaborator(s) becomes unproductive. This was because open innovation was usually associated with some costs and risks including the costs and risks of finding new and useful avenues to exploit internal innovation, incorporating external innovation into internal development and motivating outsiders to supply an ongoing stream of external innovation, loss of knowledge, higher coordination costs, loss of control and higher complexity (Enkel et al., 2009; West & Gallagher, 2006).

However, Dahlander and Gann (2010) suggested that firms can adopt both formal, e.g. patent, trademark or copyright protection and informal, e.g. lead times, first-mover advantages, lock-ins appropriate strategies to prevent the risk of knowledge loss, but it had been argued that such protective strategies should be applied moderately because firms' that were too conscious of protecting their IP may risk suffering from what they called "Myopia of protection" (Laursen & Salter, 2014). Consequently, Faems et al. (2010) suggested that firms should consider both the benefits and costs of openness when taking a decision on the number of collaborators to employ in new product development process.

2.2. Open innovation and SMEs

There is no universally acceptable definition for SMEs. van de Vrande et al. (2009) and Narula (2004) defined SMEs as firms which has fewer than 500 employees. This study adopted the definition by the European Commission and the Organisation for Economic Co-operation and Development which according to EU and OECD (2005) cited in Spithoven et al. (2013) defined SMEs as firms that employed fewer than 250 persons. By this definition, small firms were those which employed between 10 and 49 employees, while medium firms were those which employed between 50 and 249 employees. SMEs could also be defined in terms of size, which is measured by the number of employees or in terms of turnover or capital base. It has been observed in the literature that innovation by SMEs were constrained by insufficient resources and other complementary assets like manufacturing facilities, financial resources, scanty opportunities to recruit specialized workers, small innovation portfolios, lack of protection for intellectual property, marketing channels and global contacts to access internal and external knowledge (Lichtenthaler & Ernst, 2007; Narula, 2004; Vanhaverbeke, Duysters, & Noorderhaven, 2002). This scenario therefore made it imperative for SMEs to engage in collaborations with external firms (Lee et al., 2010; van de Vrande et al., 2009; Zeng et al., 2010).

This was supported by other studies which was aimed at complementing their deficient resources with resources and expertise from other stakeholders in the environment to foster their chances of survival (Chesbrough, 2012; Dahlander & Piezunka, 2014; van de Vrande et al., 2009). However, it was further argued that resource deficiencies necessitated collaborative relationships for SMEs and could also hinder SMEs from attracting innovation partners due to lack of value to offer the external partners in return for values obtained (Narula, 2004). This condition therefore puts SMEs in a daisy situation whereby they are almost always stuck between the "devil" of been in dire need of engaging in inbound open innovation due to their resources limitations thereby becoming prone to future liabilities in the development of absorptive and transformative capacities thereby perpetuate their dependence on external parties, and the "deep blue sea" of lacking the requisite resources of executing such higher needful collaborations thereby putting their survival at risk (Fosfuri, 2006; Spithoven et al., 2013).

Laursen and Salter (2004) had asserted that "it was not statistically evident that larger firms were better than SMEs in breaking new grounds in innovation, which meant that SMEs may as well have capacity for innovation, especially radical innovation". Bianchi et al. (2011) studied ways of identifying promising applications for commercially exploiting a proprietary technology and they found that timely identification of opportunities for out-licensing firms' technologies outside their core business was a critical success factor in the practice of open innovation. Christensen et al. (2005) found that SMEs explored potential collaborations and knowledge exchange with smaller firms in the early stages of their technology development while progressively choosing larger firms when their technology was more mature. Spithoven et al. (2013) found that SMEs were more dependent on open innovation than large companies. However, we are interested in finding out how the type of product innovation being pursued by the SMEs influenced the effect of open innovation adoption on their product and service performance.

2.3. Product performance

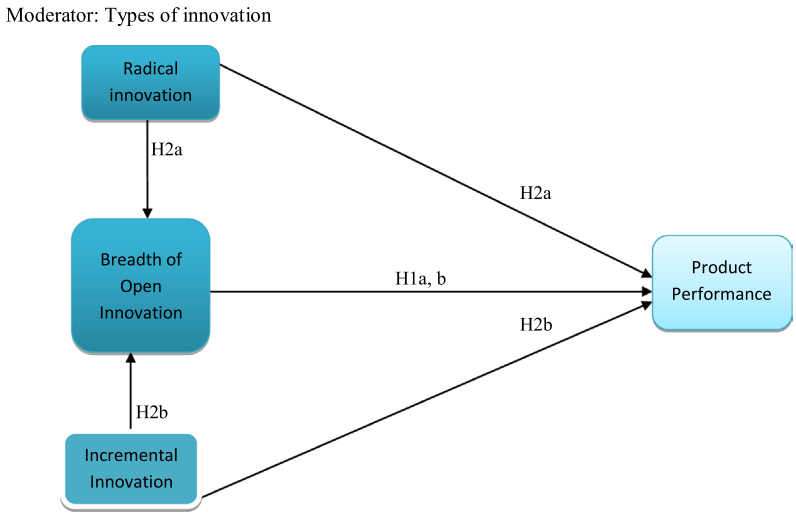
Product performance is the extent to which the firms' products fulfilled their objectives (Laursen & Salter, 2006). In this study, product performance is divided into radical and incremental product performance. Radical Product Performance is defined as products that are perceived by the market as being entirely new Laursen and Salter (2006), Faems et al. (2010), Zeng et al. (2010), while the incremental product performance refers to the product innovation which is new to firms but is always not considered as new by the market (Faems et al., 2010; Laursen & Salter, 2006; Zeng et al., 2010).

2.4. Conceptual framework and hypotheses

Figure 1 represents the proposed relationships of the study variables and we posit that there is a relationship between the breadth of open innovation strategy and the product performance of SMEs. We proposed in this study that the nature of this relationship is contingent on the type of innovation that the SMEs are pursuing as depicted by the moderating role of the types of innovation—radical or incremental—in the model. The contingency theory lays down that the effect of a given variable on another will depend on the conditions that surround the relationship between the variables (Galbraith, 1973). This therefore follows that the adoption of breadth dimension of open innovation strategy by SMEs will affect their product performance depending on whether they intend to produce radical or incremental innovation (Garriga, von Krogh, & Spaeth, 2013). Studies in the literature had found positive and significant influence of the type of innovation on the effect of factors that shape product innovativeness on product performance (Garcia & Calantone, 2002). The types of innovation include radical innovation like the microchip, and incremental innovation like improving an existing product (Henderson & Clark, 1990). An innovation is referred to as radical if it is perceived as being entirely new by the market. While an innovation that is only perceived as new by the producing firm is termed incremental (Marsili & Salter, 2005). Furthermore, in order to precisely determine the effect of independent variables on the dependent variables of the model, the effect of some environmental factors were anticipated and controlled for including market turbulence, technological turbulence, competitive intensity and technical synergy (Song & Parry, 1999; Wang, Chen, & Chen, 2012).

Figure 1. Research model.

Source: Research study (2015).



2.4.1. Breadth of open innovation strategy and product-service performance

The inbound strategy of open innovation involved enriching firms' own knowledge base through the integration of knowledge from external sources like customers, suppliers, universities, research institutes and open innovation intermediaries (Enkel et al., 2009). This was because other external firms or individuals could provide complementary knowledge needed in the focal firms' product development process which can be accessed through formal collaborations with external firms or mere search for knowledge from the external environment (Chiaroni, Chiesa, & Frattini, 2011). Previous studies in the literature had found a positive relationship between inbound open innovation and innovation performance (Faems et al., 2005, 2010; Laursen & Salter, 2006; Miotti & Sachwald, 2003; Nieto & Santamaría, 2007). Du, Leten, and Vanhaverbeke (2014) found that R&D projects with open innovation partnerships were more innovative. The inbound strategy is divided into breadth and depth dimensions, but more specifically our study dealt with the breadth dimension. The breadth of open innovation is defined as "the number of different types of external parties involved in the innovation process" (Bahemia & Squire, 2010). Laursen and Salter (2006) found that firms that searched widely and deeply tended to be more innovative than those that do not. Their findings however revealed that over-searching was curvilinearly (taking an inverted U-shape) related to product performance. This implies that as firms engaged in external search for knowledge, their product innovativeness were enhanced and would continue to improve with every additional search for more knowledge until an optimum point was reached and thereafter marginal increase in the search for additional sources of knowledge would start impacting negatively on the product performance possibly due to increase in risks and costs of obtaining knowledge from large number of sources (Enkel et al., 2009; West & Gallagher, 2006). However, Laursen and Salter (2006) mainly focused on knowledge search from 16 external sources but said nothing about establishment of formal innovation collaborative relationships. Therefore, we proposed that establishing collaborative innovation relationships with external partners would result in an initial enhancement of product innovativeness of the focal firm. We expect that collaboration with more partners would lead to more innovative products and these trends would continue till the point when additional collaborations with more partners would start producing negative effect on the product innovativeness. Hence, we hypothesize that:

H1a: Breadth of collaboration with external partners will have a Curvilinear (Inverted U shape) relationship with the incremental product performance of SMEs.

H1b: Breadth of collaboration with external partners will have a Curvilinear (Inverted U shape) relationship with the radical product performance of SMEs.

2.4.2. Effect of type of innovation on the relationship between breadth of open innovation and product-service performance

2.4.2.1. Radical innovation and breadth of open innovation strategy. Radical innovation performance is the result of the introduction and acceptance in the marketplace of firms' new products and services that is unusual (Voss, Sirdeshmukh, & Voss, 2008). The production of such products required novel types of knowledge often not available in innovating firms and only possessed by specific specialized external entities like specialized universities or lead-users (Lettl, 2007). Feller et al. argued that radical innovation can only be produced by consciously establishing collaboration relationship with key knowledge producers and consistently maintaining such relationships. Existing empirical research supports that the type innovation could be a determining factor in deciding the breadth of collaboration with external partners. Tödtling, Lehner, and Kaufmann (2009) found that radical innovations drew heavily on new scientific knowledge, generated in universities and research organizations. Riggs and von Hippel (1994) showed that a majority of innovations in the scientific instruments industry came from lead users, whereas radical innovations in the biotechnology sector were mainly triggered by university research (Hall & Bagchi-Sen, 2007). However, Feller et al. showed that "radical innovators that did collaborate with actors who possessed less similar and complementary knowledge resources performed significantly well". Nieto and Santamaría (2007) found that the greatest positive impact on the degree of innovation novelty came from collaborative networks comprising different types of partners. Similarly, Tether (2002) concluded that inter-firms cooperation was more frequent for pursuing higher level rather than incremental innovations among firms in the UK. Following the above arguments, we expect that the more radical the innovation, the higher would be the effect of breadth of collaborations on the product innovativeness of firms. Hence, we hypothesized that:

H2a: the more radical the innovation, the more significant will be the influence of breadth of external collaborations on the product performance.

2.4.2.2. Incremental innovation and breadth of open innovation strategy. Incremental innovations are said to take place more in interaction with partners from the business sector often located at higher spatial levels beyond the region (Tödtling et al., 2009). Feller et al. showed that incremental innovators collaborated with a wider and more internationalized range of external actors. Garriga et al. (2013) found that both breadth and depth as exogenous variables are statistically significant for incremental innovation. Laursen and Salter (2006) found that the more incremental the innovation, the more positive will be the influence of search breadth on product performance. However, Yun-Hwa and Kuang-Peng (2010) proposed that search breadth influences radical innovation performance more than incremental. In the light of the foregoing discussion from previous studies, we expect that production of incremental innovation will influence the effect of breadth of collaboration with external partners on the product performance of firms in the UK (Table 1). Thus we hypothesized that:

H2b: the more incremental the innovation, the more significant will be the influence of breadth of external collaboration on the product performance.

3. Methodology

3.1. Research design

The positivist philosophical stance was taken in this study because we viewed open innovation as a purposive knowledge management activity (Chesbrough & Bogers, 2014; West et al., 2014). Moreover, we defined open innovation in terms of collaboration with external partners. Furthermore, the cross-sectional survey approach was adopted in this study because the data was obtained from the activities of SMEs within the last three years to enable the researchers answer the broad

Table 1. Constructs and definitions

Construct	Definitions	Source(s)
Radical innovation	Products new to the world market (INNWORLD)	Laursen and Salter (2006), Faems et al. (2010)
Incremental innovation	Products new to the firm (INNFIRM)	Laursen and Salter (2006), Faems et al. (2010)
Breadth of openness	The number of sources of knowledge used by a firm	Laursen and Salter (2006)
Radical product performance	Measured as the fraction of the firm's turnover relating to products new to the world market (INNWORLD)	Laursen and Salter (2006); Faems et al. (2010), Zeng et al. (2010)
Incremental product performance	The fraction of the firm's turnover pertaining to products new to the firm (INNFIRM)	Laursen and Salter (2006), Faems et al. (2010), Zeng et al. (2010)

Source: Survey data (2015).

research questions, is there a relationship between the breadth of open innovation and product performance of SMEs and how is it influenced by the type of innovation that SMEs pursue? The target population for this study are all SMEs in the manufacturing sector of the UK that are registered with the Office of Statistics. From the population, a randomly selected sample of 802 SMEs was obtained from Dun and Bradstreet. The eventual respondents were 72 senior employees made up of managers, IT executives and supervisors of those selected SMEs. These groups of people were selected because they were considered as those that were directly responsible and knowledgeable about the firms' knowledge management activities.

3.2. Data collection and analysis techniques

The primary data were obtained using survey instrument and the questionnaire was structured using scales of measurement from previous studies. The content validity was carried out with the assistance of notable researchers, thereafter comments were incorporated. Instrument reliability was ascertained using Cronbach's alpha (α). The values obtained were: breadth of openness: 0.81; depth of openness: 0.71; incremental innovation: 0.80; radical innovation: 0.77. Incremental product performance: 0.71; radical product performance: 0.78; market turbulence: 0.84; technological turbulence: 0.76; competitive intensity: 0.88 and technical synergy: 0.82. These values indicates that the constructs and their respective measurement items had strong internal consistency and suitable for the study. Five hundred and seventy-seven sets of questionnaire were administered to the respondents through their email addresses. The data were measured using five-point likert ordinal scale and analysed using multiple regression analysis technique aided with SPSS version 21. The analyses were carried out at 95% level of significance ($\alpha = 0.05$) and the decision rule is to reject the null hypothesis if the computed statistic is less than 0.05 and accept the alternative hypothesis and vice versa.

3.3. Measurement of variables

3.3.1. Dependent variable

The dependent variable of this study is product performance. The product performance of SMEs was divided into radical product performance and incremental product performance. Both the radical and incremental performance outcomes were measured with three items in this study, namely sales, market share and profits. The radical product performance was measured against competitors' product performance, while the incremental innovation was measured against the SMEs' previous products. All the items were measured on a five-point Likert scale ranging from far below expectation to far above expectation as adapted from Song and Parry (1999).

3.3.2. Independent variable

The independent variable of this study is the breadth of open innovation. The breadth was measured by the number of collaborators that SMEs used in their product development efforts. It was constructed using 16 collaborating external partners. The respondents were asked to indicate either yes or no against each external partner. Yes meant that firms collaborated with external partners and no meant that SMEs did not collaborate with the external partners. The number of yes and no were counted and if the firm had a total of 0 yes, it meant it did not collaborate with any of the 16 external firms. On the other hand, if the total yes is 16, that meant the firm collaborated with all 16 external partners. Higher number of collaborators meant higher breadth of openness. The measure was adapted from Laursen and Salter (2006).

3.3.3. Moderating variable

The type of innovation that SMEs pursued was used as moderating variables of the study. These types of innovation were defined as either radical or incremental innovation. Both radical and incremental innovation were measured by five items on a five-point Likert scale ranging from very low to very high as adapted from Kim, Kumar, and Kumar (2012).

3.3.4. Control variables

The control variables were competitive intensity, market turbulence, technological turbulence, Wang et al. (2012) and technical synergy (Song & Parry, 1999). Competitive intensity was defined as the rate of competition for the share of the customers' available resources. This construct was measured with five items on a five-point Likert scale ranging from very low to very high as adapted from Wang et al. (2012). Market turbulence referred to the rate at which the composition and preference of customers change. It was measured with four items on a five-point Likert scale ranging from very low to very high as adapted from Wang et al. (2012). Technological turbulence refers to the rate of technological advancements in the industry. It was measured with three items on a five-point Likert scale ranging from very low to very high as adapted from Wang et al. (2012). Technical synergy refers to balance between the set of skills and know-how an organisation possesses and resources needed to achieve its product development goals. This construct was used to measure the adequacy of R&D and technical resources in relation to the products the firm intends to produce. It was measured with four items on a five-point Likert scale ranging from very low to very high as adapted from (Song & Parry, 1999).

4. Data analysis and hypotheses testing

4.1. Data analysis

One hundred and twenty sets of questionnaire were returned, out of which 72 were dully completed and useable, representing 12.5% return rate. We started the analyses by establishing the effect of the control variables on the criterion variable. Table 2 shows that the R^2 increased from 0.616 in model 1 to 0.677 in model 2 with the introduction of the quadratic function. This implies that without the quadratic function, the breadth variable alone accounted for 62% of the changes in the outcome variable. However, with the introduction of the quadratic function, the combined effect of the two predictor variables—breadth and quadratic function—account for 68% of the changes in the outcome variable. Specifically, the figure of ΔR^2 for model 2 is 0.061 at $\Delta F = 10.7$, implying that the quadratic function alone accounted for about 6% of the change. This is significant at $F(1, 56) = 10.7$, $p < 0.05$. Also from the regression coefficients table, the standardized coefficients for the breadth of innovation and the quadratic function in model 2 changed to $\beta = -3.819$ and -3.044, respectively, though they are still significant. This implies that the trend in the quadratic effect will go up first, get to a point and begin to fall. The effect of the quadratic function therefore supports H1a.

Table 3 shows $R^2 = 0.810$ and $\Delta F = 212.957$ in model 1, the values of R^2 and ΔF changed to 0.871 and 23.356, respectively, in model 2. The results show $\Delta R^2 = 0.61$ which implies that the quadratic function specifically accounts for about 6% of the change in the predictor variable. The results also show that quadratic function has a significant relationship with the product performance at $F(1, 49)$

Table 2. Breadth of inbound open innovation and incremental product performance

Model	Description	*M*	SD	*B* (SE *B*)	*β*
1	Constants			17.071* (0.733)	
	Ibreadth			−1.598* (0.167)	−0.785
	Market turbulence	13.7778	2.82455	0.277* (0.118)	0.335
	Competitive intensity	17.0833	3.89203	0.249 (0.086)	0.415
	Technological turbulence	9.5972	2.14712	0.279 (0.063)	0.256
	Technical synergy	13.6667	2.89244	0.014* (0.111)	0.018
	R^2			0.616	
	ΔF			91.324	
2	Constants			29.897* (3.986)	
	IBreadth	4.20	1.256	−7.775* (1.898)	−3.819
	IBreadth_Squared	19.2203	11.39127	0.684* (0.209)	−3.044
	IProduct performance	10.29	2.334		
	R^2			0.677	
	ΔR^2			0.061	
	ΔF			10.661	

Note: The values reported represent the unstandardized coefficients (*B*) centred with standard error (SE *B*) in parentheses and β is the standardized coefficients. IBreadth is the breadth of openness for incremental innovation, IBreadth_Squared is the quadratic function. To examine the effect of breadth of inbound open innovation on radical product performance, we computed the quadratic function (RBreadth_Squared) by multiplying the breadth of openness for radical product innovation by itself. The non-linear effect of the quadratic function on the product performance was therefore determined by entering the breadth for radical innovation and the quadratic function into the multiple regression equation.

*$p < 0.05$ (2 tailed test).

Source: SPSS multiple regression analysis (2015).

= 23.356, $p < 0.05$. Furthermore, the regression coefficient table shows that the breadth of innovation, $\beta = -3.175$ which suggests the trend of a curvilinear relationship and therefore supports H1b.

Subsequently, we examined the moderating effect of radical innovation on the relationship between the breadth of openness and product performance of the SMEs. Also, we entered the variables for the breadth of openness in the first model and a combination of the breadth variable and radical innovation variable in the second model as the predictor variables and the product performance variables as the criterion variable. The results in Table 4 show that in model 1, $R^2 = 0.810$ and the $\Delta F = 212.957$, implying that the breadth of openness alone could predict about 81% 0f the change in the criterion variable. However, with the introduction of the moderating effect of radical innovation, R^2 increased to 0.952, indicating that the combination of the effect of breadth and radical innovation had more impact on the change on the criterion variable. More specifically, the $\Delta R^2 = 0.142$ in model 2 implies that the introduction of the moderating effect of radical innovation contributed about 14% of the changes in the criterion variable. Also, the result revealed a significant relationship at F (2, 49) = 276,675, $p < 0.05$. This therefore supports H2a.

The moderating influence of incremental innovation on the relationship between the depth and breadth of inbound open innovation and product performance was investigated. Firstly, we examined the influence of incremental innovation on the effect of the depth of inbound open innovation on the product performance of the SMEs. As usual, we first entered the variables for depth of innovation and product performance into the spaces for the independent and dependent variables, respectively, in the multiple regressions as model 1.

Subsequently, we examined the moderating influence of incremental innovation on the effect of breadth of open innovation on the product performance of SMEs. In model 1, we first entered the

Table 3. Breadth of inbound open innovation and radical product performance

Model	Description	*M*	SD	*B* (SE *B*)	*β*
1	Constants			4.141* (0.466)	
	RBreadth			2.432* (0.167)	0.900
	R^2			0.810	
	ΔF			212.957	
2	Constants			18.914 (3.081)	
	RBreadth	2.65	0.883	−8.583* (2.283)	−3.175
	RBreadth_Squared	7.8077	5.26192	1.852* (0.383)	−4.833
	R^2			0.871	
	ΔR^2			0.061	
	ΔF			23.356	

Note: The values reported represent the unstandardized coefficients (*B*) centred with standard error (SE *B*) in parentheses and β is the standardized coefficients. RBreadth is the breadth of openness for radical innovation, *R*Breadth_Squared is the quadratic function.

*$p < 0.05$. (Two tailed test).

Source: SPSS multiple regression analysis (2015).

Table 4. Moderating effect of radical innovation on the relationship between the breadth of openness and product performance of SMEs

Model	Description	*B* (SE *B*)	*β*
1	Constants	4.141* (0.466)	
	RBreadth	2.432* (0.167)	0.900
	R^2	0.810	
	ΔF	212.957	
2	Constants	−0.969* (0.483)	
	RBreadth	1.145* (0.136)	0.424
	Radical innovation	0.469 (0.039)	0.608
	R^2	0.952	
	ΔR^2	0.142	
	ΔF	146.518	

Notes: The values reported represent the unstandardized coefficients (*B*) centred with standard error (SE *B*) in parentheses and β is the standardized coefficients. RBreadth is the breadth of open innovation.

*$p < 0.05$ (2 tailed test).

Source: SPSS multiple regression analysis (2015).

variables for the breadth of openness and product performance as predictor and criterion variables, respectively, so as to obtain their relationship without the influence of the moderating variable. Then we introduced the variable for incremental innovation and entered it together with the breadth of openness in the second model in order to determine the moderating influence of incremental innovation on the effect of breadth of open innovation on the product performance of the SMEs.

The results in Table 5 show that in model 1, $R^2 = 0.616$ and in model 2, it changed to 0.959, while $\Delta F = 91.324$ in model 1 and changed to 469.855 in model 2. This implies that the introduction of the moderating variable changed the effect of the predictor variables on the criterion variables from 62 to 96%. This showed a very significant influence and the $\Delta R^2 = 0.343$ in model 2 shows that the moderating variable accounted for about 34% of the changes in the criterion variable and the relationship is significant at F (1, 56) = 469.855, $p < 0.05$ and supports H2b.

5. Discussion of findings and conclusions

H1a predicted that the breadth of open innovation will have a curvilinear (inverted U shape) relationship with the incremental product performance of SMEs. The findings supported this hypothesis. This implies that the adoption of inbound open innovation by SMEs in their product development produce will generate an initial enhancement of product innovativeness Faems et al. (2010) until the optimum number of collaborators. Beyond this point, subsequent collaborations could impact negatively on firms' product performance, thereby resulting in an inverted u-shape relationship between the breadth of open innovation and product performance. This could simply be because collaborating with more partners after the optimum point could result in a loss of control and competences (Enkel et al., 2009). This finding is consistent with Katila and Ahuja (2002) and partly answers the research question: How does the breadth of open innovation affect the product performance of SMEs? The results support **H1b**. This may be due to the fact that firms that want to produce radical products require new knowledge that is often only obtained through collaboration with specialized external entities such as specialized universities or lead-users (Lettl, 2007).

However, as firms increase in the number of collaborators, the uniqueness of the products will begin to dwindle, especially when firms are collaborating with commercial or market-based partners (Du et al., 2014). This finding supports Laursen and Salter (2006), though their study investigated sources of knowledge, whilst ours focuses on collaborations. The findings support **H2a** which implies that radical innovation moderates the relationship between the breadth of open innovation and product performance of the SMEs. This finding is consistent with Lettl (2007), who found that the production of radical innovation required specialized knowledge that is not always available in the firm, but only possessed by specialized external partners such as universities or lead-users, meaning that radical innovation affected the decision to go into collaborative agreements with external partners, but contradicts Nieto and Santamaría (2007) that the degree of novelty came from collaborative networks comprising different types of partners. **H2b** found support in this study that incremental innovation moderates the relationship between breadth of open innovation and the product performance of the SMEs and consistent with (Garriga et al., 2013; Tödtling et al., 2009). This further answered the question, "How does the type of innovation moderate the relationship between breadths of collaboration with external partners and product performance?" Based on the study's findings, we concluded that the decision to collaborate and the breadth of the collaboration must be aligned with the type of innovation being pursued, Zang, Zhang, Yang, and Li (2014) after recognizing and controlling the influence of environmental factors such as market turbulence, competitive intensity, technological turbulence and technical synergy.

Table 5. Moderating influence of incremental innovation on the effect of breadth of open innovation on product performance

Model	Description	*B* (SE *B*)	β
1	Constants	17.071* (0.733)	
	IBreadth	−1.598* (0.167)	−0.758
	R^2	0.616	
	ΔF	91.324	
2	Constants	−6.935* (1.133)	
	IBreadth	0.516* (0.112)	0.253
	Incremental innovation	0.856 (0.040)	1.192
	R^2	0.958	
	ΔR^2	0.343	
	ΔF	469.855	

Note: The values reported represent the unstandardized coefficients (*B*) centred with standard error (SE *B*) in parentheses and β is the standardized coefficients. IBreadth is the breadth of openness for incremental innovation.

*$p < 0.05$ (2 tailed test).

Source: SPSS multiple regression analysis (2015).

6. Implications and recommendations of the study

The contributions of the study are relevant to SMEs in the UK manufacturing sector. Policy-makers and future researchers on SMEs breadth of open innovation, more specifically the primary beneficiaries of the study, are SMEs in the UK. The findings of the study if adopted will enable SMEs to know the appropriate breadth of open innovation, that is the number of collaborators to engage in to achieve a particular type of innovation. It is believed that knowing and adopting the most appropriate breadth of open innovation for the appropriate type of innovation by the SMEs will result in successful adoption and by extension economic prosperity. To policy-makers, because the findings of this study will also enable policy-makers to make informed and relevant polices that will make open innovation adoption by SMEs more effective and efficient in order to enhance their performance and meaningful contribution to the viability of the economy. To academics, the findings of this study have contributed to the existing stock of knowledge in open innovation and will serve as reference material to future researchers. More so, the study has empirically established the evidence of the existence of a curvilinear relationship between breadth of inbound open innovation and product performance while also supporting existing findings. We suggest that similar study be replicated in other sectors using large sample size in order to determine the overall impact of open innovation dimensions on the product performance of firms in the UK.

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