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The effect of knowledge collaboration on business model reconfiguration

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ABSTRACT

This study examines whether and to what extent the presence and intensity of knowledge collaboration across different partners affects business model reconfiguration (BMR). We build on the business model (BM) literature and operationalize BMR by introducing the presence and intensity of collaboration and firm size effects as main explanatory factors in affecting the propensity of incremental and radical BMR. We analyze a large sample of UK firms during 2002–2014 to capture the effect of knowledge collaboration and firm size on BMR. Positively incremental forms of BMR will be influenced by the *presence* and *intensity* of knowledge collaboration, while radical forms of BMR are affected by the intensity of collaboration with customers and the collaboration with suppliers by large firms. Furthermore, firms of different sizes do not equally benefit from knowledge collaboration with suppliers for both incremental and radical BMR, while they do equally benefit from collaboration with other partner types.

1. Introduction

In today's increasingly turbulent and uncertain economic and business environment, continuous innovation is crucial if firms wish to achieve and maintain at least a temporary competitive advantage (Bouncken, Fredrich, Ritala, & Kraus, 2018; Bouwman, Nikou, & de Reuver, 2019; D'Aveni et al., 2010; Foss & Saebi, 2018). Firms can use in-house, open, or collaborative approaches (Chesbrough & Appleyard, 2007; Chesbrough & Schwartz, 2007; Rachinger, Rauter, Müller, Vorraber, & Schirgi, 2019) in order to innovate with their products, services, processes, and organizational structures (Gesing, Antons, Piening, Rese, & Salge, 2015; Nieto & Santamaría, 2007). This will allow them to search for new business models (BMs) and ways of commercialization (Bouncken & Fredrich, 2016).

Firms are increasingly engaging in innovating their BMs through business model innovation (BMI) (Santos, Spector, & Van der Heyden, 2009), which allows them to either design new BMs (business model design (BMD)) or reconfigure existing ones (business model reconfiguration (BMR)) (Clauss, Bouncken, Laudien, & Kraus, 2020; Kraus, Filser, Puumalainen, Kailer, & Thurner, 2020; Massa & Tucci, 2014). This helps companies to move into new markets and industries, redefine them, or even create entirely new ones (Giesen, Berman, Bell, & Blitz, 2007). In this work, we focus on BMR pertaining to the reconfiguration of extant BMs (Massa & Tucci, 2014). Following the lead of Clauss et al. (2020), we recognize that BMR takes place in nuanced types and does not always lead to (radical) BMI. BMR itself can therefore include the incremental reconfiguration of individual components of BMs, the extension of the configuration of existing BMs, and configurations contemplating parallel BMs. It can even include configurations that entail the disruption of existing BMs (Khanagha, Volberda, & Oshri, 2014; Rachinger et al., 2019).

It is possible that firms that collaborate with multiple stakeholders (e.g., enterprise groups, suppliers, competitors, customers, universities, consultants, and the governments) (Kohtamäki & Partanen, 2016; Miller, McAdam, & McAdam, 2014) are more likely to innovate their BMs, and especially likely to carry out effective BMR of their activities. For example, collaboration with universities, which is exploration-oriented (Miller, McAdam, Moffett, & Brennan, 2011; Faems, Van Looy, & Debackere, 2005), may have a strong positive effect on exploration and innovativeness. This form of collaboration involves exploring new radical ideas with new products and services, and aims at positioning products in new industries and markets (March, 1991). On the other hand, exploitative forms of collaboration, such as collaboration with customers, suppliers, and consultants (Faems et al., 2005),

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may not involve the creation of radically new products, but focus instead on working with existing solutions and products that suppliers and customers already know in order to exploit them commercially.

To the best of our knowledge, to date, no studies have empirically examined how knowledge collaboration with partners affects different types of BMR (incremental or radical), or the effects of different levels of knowledge collaboration intensity. This study therefore aims to address the following overarching question: *To what extent do the presence and the intensity of knowledge collaboration with different partner types influence BMR?* Addressing this question is critical for several reasons. First, it is not clear whether firms' knowledge collaboration with partners influences BMR. Second, it is not clear whether it is the presence of collaboration per se or the intensity of collaboration that contributes to BMR. Third, it is not clear whether collaboration with specific partners can lead to more or less radical types of BMR (Clauss et al., 2020). Last, it is not clear whether all firms, irrespective of their size, would benefit equally from the presence and intensity of knowledge collaboration with partners for BMR.

To address our research question, we developed different models where variables, such as the presence and intensity of a firms' knowledge collaboration with different partner types can be used to explain BMR. Moreover, we also empirically examined the role of firm size in the relationship between the presence and intensity of knowledge collaboration as inputs and three distinct types of BMR as output. From a methodological viewpoint, to test our hypotheses we used probit estimation on an unbalanced panel of UK firms given the data availability on the incremental type of BMR, such as BMR for the exploration of new goods and services and exploration activity by entering new markets as well as the radical BMR—switching industry.

As such, this study makes several contributions to the BM innovation literature, and specifically the BMR literature. To begin with, to the best of our knowledge, this is the first study that contributes to the BMR literature (Foss & Saebi, 2018; Hacklin, Björkdahl, & Wallin, 2018; Massa & Tucci, 2014) drawing on both the *presence* and the *intensity* of knowledge collaboration with different types of partners. Secondly, we explore which partner types (e.g., universities, customers, suppliers, consultants, government, competitors) are more or less likely to change the propensity of each type of BMR—either incremental or radical. In doing so, this study contributes to the nascent literature on the types of BMR (Clauss et al., 2020) by revealing that the *presence* and *intensity* of collaboration between the focal firm and its stakeholders (i.e., other enterprises, suppliers, customers, competitors, consultants, universities, regional and national governments) positively affect incremental forms of BMR. This includes those underlying an increase and modification of the firms' range of products or services and the firm's move into new markets. However, the ability to introduce more radical forms of BMR, such as moving into new industries, is positively influenced by collaboration with universities (Miller et al., 2011, 2014) and negatively affected by collaboration with consultants. Thirdly, we control for firm size to understand whether and to what extent partner type affects a firm's BMR between small and large firms. Interestingly, our finding is that small and large firms do not equally benefit from knowledge collaboration with partners to enhance radical BMR. This extends previous studies which found that large firms do not appropriate more value than small firms through BMR (Bouncken & Fredrich, 2016), as large firms are often perceived to have a more stable and routinized regime of doing business (Audretsch & Fritsch, 2002). Furthermore, in line with the received differentiation between incremental and radical BMR (Clauss et al., 2020), it also suggests that firms of different sizes may benefit from knowledge collaboration with different partner types and for both incremental and radical forms of BMR.

2. Conceptual background

2.1. Business models, business model innovation and business model reconfiguration

Concurrently with the diffusion of the Internet and related digital technologies over the last two decades, the BM has become an increasingly relevant object of study in general management and specifically in innovation studies (Rachinger et al., 2019; Zott, Amit, & Massa, 2011). One of the earliest conceptualizations defines BM as a narration blending three main components: 1) customer groups (i.e., who is the customer?); 2) customer function (i.e., what does the customer value?); and technology (i.e., how can we make money in the focal business?). Consequently, the narration implies a justification of how economic actors can deliver value to customers at an appropriate cost (Magretta, 2002).

While BMs have been key to economic and business activities since pre-classical times (Osterwalder & Pigneur, 2010; Teece, 2010), scholarly attention to BMs has increased exponentially. This has occurred alongside the consolidation and expansion of information and communication technologies (ICTs), which have brought about many business opportunities for entrepreneurs and innovative firms (Afuah & Tucci, 2001; Amit & Zott, 2001; Foss & Saebi, 2018; Lambert & Davidson, 2013; Zott & Amit, 2017). Despite the many different definitions and conceptualizations of BM (for an overview, see Foss & Saebi, 2018), several management and innovation researchers have converged on the fact that the BM is a "system level concept, centered on activities and focusing on value" (Zott et al., 2011: 1037). This implies a recognition of how organizations and firms orchestrate their activities for value creation within value networks (Normann & Ramirez, 1993) that can include multiple stakeholders, such as suppliers, distributors, and economic actors beyond the perimeter of the aforementioned focal firms.

The BM notion has been embraced and deployed by entrepreneurship and technology management scholars who have examined how BMs can be leveraged by innovative firms to effectively commercialize new ideas and technologies. As such, the BM is a vehicle for innovation because it connects R&D activities to markets, and more generally links technology to value creation (Chesbrough & Rosenbloom, 2002; Massa & Tucci, 2014).

Strategic management scholars have identified BMs as a source of innovation encompassing and going beyond more traditional forms of innovation—such as process, product, and organizational innovation. They have thus introduced the notion of BMI, which can be used to create and sustain competitive advantage (Mitchell & Coles, 2003; Zott & Amit, 2007) and to disrupt extant industries (Christensen, 1997). Some scholars have even argued that "a better BM will beat a better idea or technology" (Chesbrough, 2007: 12), as BMI has more relevant strategic implications than more traditional modes of innovation (i.e., product, process, organizational innovation) (Spieth, Schneckenberg, & Ricart, 2014; Schneider & Spieth, 2013). More specifically, BMI is a rather broad (and generic) circumlocution that can involve the modification of the firm's activities system (Zott & Amit, 2010, 2017), the linkage between innovation and value creation (Chesbrough & Rosenbloom, 2002), and the design of organizational structures (George & Bock, 2011) that can be conducive to translating innovation into commercial opportunities and value (Teece, 2010). Multiple definitions of BMI (e.g., Aspara, Hietanen, & Tikkanen, 2010; Khanagha et al., 2014: Markides, 2006; Massa & Tucci, 2014) have been put forward and developed over time (Foss & Saebi, 2018). In this paper we define BMI as initiatives to create novel value (Aspara et al., 2010) that "can range from incremental changes in individual components of business models, extension of the existing business model, introduction of parallel business models, right through to disruption of the business model, which may potentially entail replacing the existing model with a fundamentally different one" (Khanagha et al., 2014: 324).

Recent critical assessments of the BM and BMI literature have emphasized that while many theories—including transaction cost economics (TCE) (e.g., Zott & Amit, 2010); threat rigidity and prospect theories (e.g., Saebi, Nguyen, & Javidi, 2016); the resource-based view (RBV) theory (e.g., Mangematin, Lemari_e, Boissin, Catherine, & Corolleur, 2013); dynamic capabilities theories (Leih, Linden, & Teece, 2015); and entrepreneurship theories (e.g., Foss, Saebi, & Stieglitz, 2016, pp. 1–45)—have been deployed to make sense of BM and BMI in a number of contexts, there is still a lack of cumulativeness of theory-building and empirical testing due to a lack of construct clarity and the multiplicity of definitions (Foss & Saebi, 2018). Consistently with Foss and Saebi (2018) who draw on Teece (2010), BM and BMI as constructs relate to the mechanisms through which firms create, deliver and capture value. Different definitions of BMI have been adopted based on the context under analysis, such as competition (e.g., Velu & Jacob, 2016), leadership (Lindgren, 2012), sustainability and circular economy (Pieroni, McAloone, & Pigosso, 2019), managerial cognition (e.g., Tikkanen, Lamberg, Parvinen, & Kallunki, 2005), strategies and strategic flexibility (Hacklin et al., 2018; Miroshnychenko, Strobl, Matzler, & De Massis, 2020), performance (e.g., Zott and Amit, 2008; Kim & Min, 2015), digital technologies and digitalization (Rachinger et al., 2019; Zott & Amit, 2017), and replication (e.g., Winter & Szulanski, 2001). This applies also to the context of innovation (Chesbrough & Rosenbloom, 2002; Clauss et al., 2020; Massa & Tucci, 2014). More specifically, based on the literature at the intersection between BMs and innovation, Massa and Tucci (2014) suggest that BMI can take two different approaches: 1) BMD that relates to the design of novel BMs for newly formed organizations and 2) BMR that pertains to the reconfiguration of extant BMs.

In this paper, we focus on BMR that involves changing an existing BM, with different degrees of depth, by reconfiguring firms' resources and acquiring new ones. As the underlying assumption for reconfiguration is the existence of a BM, BMR entails a number of challenges, including management processes, modes of change and organizational learning, organizational inertia, and path dependency issues. In their study of the Xerox Corporation, Chesbrough and Rosenbloom (2002) observe that when Xerox invented the first photocopy machine, the technology was extremely expensive which made the product difficult to sell. The management solved the issue by leasing the machine, and thus reconfiguring the original BM. This made commercialization, and ultimately economic value creation, more effective.

According to Zott and Amit (2010), BMR can happen in three different and complementary ways: 1) by adding new activities in the value chain; 2) by identifying new linkages among extant activities; and 3) by modifying which party performs an activity (Zott and Amit, 2012). BMR is therefore made up of three elements: a) innovating the nature of the activities, b) the linkages and sequencing of activities; and c) the control/responsibility over an activity, or the activity system between a firm and its network (Zott & Amit, 2010, 2017).

Giesen et al. (2007) classified BMR into three groups: 1) industry model innovation, which implies innovating the industry value chain by moving into new industries, redefining existing industries, or even creating entirely new ones; 2) revenue model innovation, which pertains to innovation in the revenue models and thus in how revenues are generated, by reconfiguring the product/service value mix or by modifying the pricing models; and 3) enterprise model innovation, whereby the role that the firm plays in the value chain changes over time, and might imply changes in capability and asset configuration, and especially changes in the relationships with suppliers, customers, employees, and other external stakeholders. After analyzing each type of BMR, they found that each type of BMR is conducive to success, and that innovation in enterprise models focusing on external collaboration and partnerships are more effective in older firms.

In this paper, we embrace Giesen et al.'s (2007) notion of BMR, as we focus on firms that innovate in these three dimensions: 1) reconfigure the product/service value mix by increasing and modifying their range of products or services; 2) innovate their value chain by moving into new markets; and 3) innovate their value chain and the industry value chain by moving into new industries.

Recent literature (e.g., Clauss et al., 2020) suggests that not all BMR configurations are equal. Indeed, there are different types of BMRs that are a function of a combination of the three different components of BMs: value creation, value proposition, and value capture. While BMR is thus not homogenous, a study of 16 SMEs by Clauss et al. (2020) has made clear that there are different types of BMR, some of which are more or less radical or incremental. Overall, BMR can range from incremental reconfiguration of individual components of BMs, extension of the configuration of an existing BM, and configurations contemplating parallel BMs, up to configurations that entail the disruption of existing BMs (Khanagha et al., 2014; Rachinger et al., 2019). In our study, we include both types of BMRs in order to better understand their relationship with knowledge collaboration across different partner types.

2.2. *Knowledge partnerships and collaboration as a way to reconfigure BMs*

While a BM is conceptualized as the rationale of how a firm creates, delivers, and captures value (Osterwalder & Pigneur, 2010; Clauss, 2017; Clauss et al., 2020) in relation to a network of partners (Afuah & Tucci, 2001; Zott et al., 2011), BMR is a complex art and craft that requires "creativity, insight and a good deal of customer–competitor and supplier information and intelligence" (Teece, 2007: 1330). As such, it also implies an exchange of knowledge between the firm and its partners. How does this knowledge exchange take place?

Collaborative knowledge processes are the focus of large streams of literature, as well as our study. Chesbrough and Schwartz (2007) observe that co-development partnerships represent an increasingly effective means of innovating the BM of a firm to improve innovation effectiveness. These partnerships involve a professional "relationship between two or more parties aimed at creating and delivering a new product, technology or service" (Chesbrough & Schwartz, 2007: 55). More recent research by Bouncken and Fredrich (2016), Bouncken, Kraus, and Roig-Tierno (2019), and Foss and Saebi (2018) points to the role of knowledge collaboration with partners in BMR literature. Foss and Saebi (2018) argued that majority of the open innovation literature is concerned with what makes these collaborations successful; only a handful of studies discuss the BMs that support open innovation practices (Saebi & Foss, 2015). The BMs were found to be different in depth and breadth of collaboration with external knowledge sources, and directly affect firm innovativeness. Saebi and Foss (2015) demonstrated that the BM and external collaborations need to be aligned, as it prevents firms falling short in innovativeness.

Open innovation models for knowledge collaboration with partners in the research and/or development activities generate novel BM alternatives that can shorten time to market, enhance innovation capability, create greater flexibility and reduce the cost of R&D (Bouncken et al., 2019; Hacklin et al., 2018), open new markets, increase profitability (Chesbrough, 2003), as well as unveil new opportunities (Saebi & Foss, 2015) and enhance managerial capability to identify new opportunities to innovate (Pisano, 2006). Each of the objectives of co-development initiatives has implications for co-development design. For instance, if the objective is to enhance the innovation capability of a firm, then, it will be crucial to create strategic research partnerships with universities and research labs (Chesbrough & Schwartz, 2007).

Collaboration might involve activities upstream the value chain, such as R&D and manufacturing, and downstream activities, such as marketing (Czakon, Klimas, & Mariani, 2020; Mariani, 2016; Peng & Bourne, 2009). It can also be compatible with coopetition strategies and interactions, whereby firms simultaneously collaborate on specific activities or innovation projects while competing on other activities (Czakon, Mucha-Kuś, & Sołtysik, 2016; Czakon, Niemand, Gast, Kraus, & Frühstück, 2020; Mariani, 2007, 2016). Moreover, collaboration might involve different types of partners: for instance, vertical collaboration with customers might generate validated learning that could also be conducive to an improvement of the value proposition through discovery (Mariani, 2009; McGrath, 2010; Roper, Vahter, & Love, 2013, 2017; Wu, Guo, & Shi, 2013) and lean thinking techniques (Ries, 2011). Overall, while knowledge collaboration might be crucial as it allows the generation of traditional forms of innovation, such as products, process or organizational innovation, it is also especially important for BMR. Better knowledge acquired through partnerships might translate into BMR by transforming the nature of the firm's value activities, modifying the linkages and sequencing of activities, and also affecting the responsibility over activities between a firm and its network (Zott & Amit, 2010). As such, BMR could translate into firms' reconfiguration of the product/service value mix by increasing and modifying their range of products or services (Hacklin et al., 2018); innovation of the firm's value chain by moving into new markets; and innovation of the firm's value chain and the industry value chain by moving into new industries (Giesen et al., 2007).

In synthesis, we expect that knowledge collaborations will push firms to reconfigure their activities and thus affect BMR as defined by Giesen et al. (2007). Consequently, we hypothesize that:

H1. *There is a positive relationship between the presence of knowledge collaboration with different partner types and BMR.*

Studies in the strategy, entrepreneurship, innovation, marketing, and regional science fields have demonstrated that the intensity of cooperation plays a crucial role in innovativeness and innovation performance (e.g., Broekel, Brenner, & Buerger, 2015; Heiman & Nickerson, 2004; Klimas & Czakon, 2018; Lavie, 2006; Park, Srivastava, & Gnyawali, 2014; Trigo & Vence, 2012; Weber & Heidenreich, 2018). For instance, strategy scholars have found that alliances focused on conjoint R&D and manufacturing are likely to create more knowledge and innovation than alliances that involve only licensing agreements, or any other weaker forms of cooperation (Dyer & Singh, 1998; Heiman & Nickerson, 2004; Park et al., 2014) as technical collaboration promotes knowledge transfer, sharing, and spill-over (von Hippel, 1994; Lavie, 2006).

However, beyond alliances that are mostly horizontal forms of cooperation between competing or cooperating firms (Park et al., 2014), knowledge can also stem from collaborating with other organizations, such as suppliers, clients, consultants and mentors, universities, and the government. The strategic management and innovation literature has emphasized that cooperation intensity in different stages of the innovation process and with different partners can improve either a firm's innovation capabilities or its success (Gemser & Leenders, 2011). For instance, drawing on 154 German high-tech B-2-B companies, Weber and Heidenreich (2018) find that it is beneficial for a firm to cooperate at any stage of the innovation process and with any type of partner. Nonetheless, collaboration in concept and product development enhances a firm's innovation capabilities, while collaboration in the implementation stage mostly improves a firm's innovation success.

In relation to the type of partners, the higher the intensity of collaboration, the higher the innovation capabilities and success of a firm. Building on a sample of 2148 Spanish service firms, Trigo and Vence (2012) found that the nature of the activity affects the choice of the type of partner and also the cooperation intensity. The most innovative firms display tight relationships with academic centers and universities on the one hand, and clients on the other hand (Miller et al., 2014). Based on a sample of 1500 East German knowledge intensive firms, Lejpras and Stephan (2011) show that the intensity of cooperation with spin-offs is dependent on the closeness to research institutions, and also that the higher the intensity (with both local and nonlocal academic partners), the higher the innovativeness of the firm.

Interestingly, the marketing management literature has found that vertical collaboration with clients is conducive to knowledge exchange at the stage of the firm's diagnosis of customer needs and when collecting information from the customer (Gadrey & Gallouj, 1998), and can thus lead to lean innovation processes (Ries, 2011). Czakon et al.'s (2020b) experimental study of managers' preferences for the development of self-driving electric cars concluded that managers opt for network coopetition, using formal governance, and intensive knowledge sharing. Moreover, they found that by developing networks to achieve radical innovation, firms can focus on their own core competencies and extract benefits from the strengths of their partners. So far, collaborative partnerships have been used to explain how firms innovate their products, but according to recent studies, it appears that partnerships can be potentially used for BMR purposes. For instance, Ambroise, Prim-Allaz, and Teyssier (2019) focus on a specific variant of BMR whereby "the industrial provider changes its business model, as it no longer transfers the ownership rights of its products; its offerings become based on a use- or result-oriented proposal" (Ambroise et al., 2019: 4). In this case, both providers and customers change their involvement in each other's activity chain and modify their BMs and mutual organizational processes. The authors find that this type of BMR is driven by service culture (rather than customer interface and service delivery systems) and leads to higher profitability.

Based on the previous literature, we hypothesize that, beyond the presence of collaboration with business partners, collaboration intensity might impact differently not only traditional forms of innovation (e.g., product, process, organizational innovation), but also BMR. Indeed, the intensity of collaboration with partners captures the extent to which the focal firm learns from the partners and shares and acquires knowledge that can be used to reconfigure value activities. Accordingly, we hypothesize what follows:

H2. *There is a positive relationship between knowledge collaboration intensity with different partner types and BMR.*

2.3. Knowledge collaboration, BMR and firm size

Exchange and collaboration are crucial for BMR and firm innovativeness (Bouncken et al., 2019). However, these conditions might differ between large firms, and small- and medium-sized enterprises (SMEs) (Muñoz-Pascual, Curado, & Galende, 2019). Extant research in strategy, entrepreneurship, and innovation has shown that firm size plays a role and that there are systematic differences in the motivations and ways large vs. small firms cooperate to innovate (Acs & Audretsch, 1990; Kelley & Helper, 1999; Roper, Love, & Bonner, 2017).

SMEs today represent the largest share of firms globally and (with a cut-off size of 250 employees) employ over half of the total worldwide workforce, thus making a significant contribution to global GDP (Aga, Francis, & Meza, 2014). Both R&D partnerships and other knowledge partnerships and collaborations finalized to generate new knowledge are particularly relevant for small and medium enterprises that display a relevant liability: limited resources and a narrow range of capabilities. Indeed, smaller firms are more challenged by constantly adopting, adapting, modifying, implementing, and creating new knowledge across different partner types, as they have lower absorptive capacity (Cohen & Levinthal, 1990) to compensate for the lack of resources. Moreover, they display different features, as well as relevance and influence within and across industries (von Hippel, 2005). This requires them to enhance their absorptive capacity (Zahra & George, 2002) by partnering with different partners (Van Beers & Zand, 2014).

Absorptive capacity is an important construct that influences strategic flexibility and various forms of innovation and BMR (Miroshnychenko et al., 2020). Absorptive capacity, as the firm's ability to recognize, assimilate, and apply valuable, new, and external information, is critical for its innovation capabilities (Cohen & Levinthal, 1990). Substantial empirical research shows that a firm's absorptive capacity influences its innovation and performance (Ali, Seny Kan, and Sarstedt, 2016), as well as its ability to experiment and innovate new BMs. Large firms can use their resources to conduct in-house R&D or purchase it elsewhere and are able to hire highly qualified workers in a number of functions and can appropriate their innovation within the enterprise or by means of strategic alliances (Dyer & Singh, 1998; Heiman & Nickerson, 2004; Narula, 2004; Park et al., 2014). Unlike these firms, SMEs can rely on external knowledge collaboration from partners (Kelley & Helper, 1999) and knowledge spillovers (Acs & Audretsch, 1990; Audretsch & Belitski, 2020a).

Smaller firms have fewer resources than large firms and are less able to commercialize new products and services (Lindgren, 2012; Bouwman et al., 2019). They will therefore i) aim to collaborate with partners as a key source for innovation and ii) will lack absorptive capacity to do so (Miroshnychenko et al., 2020). Consequently, it appears that partners will be crucial for firms willing to reconfigure their BMs and to capture the value created through BMR (Bouncken & Fredrich, 2016).

Miroshnychenko et al. (2020) investigated the role of realized absorptive capacity in BMR adoption. A firm's ability to innovate its BM could thus strongly depend on how well it is able to combine existing and new knowledge (Zahra & George, 2002). We thus expect that realized absorptive capacity enhances BMR (Miroshnychenko et al., 2020), which means that larger firms have often better visibility and higher bargaining power than small firms (Bouncken & Fredrich, 2016), while they may also be limited in value capture. Based on this reasoning, we hypothesize:

H3. *Large firms will benefit to a greater extent than SMEs from the presence and intensity of knowledge collaboration with different partner types for BMR.*

3. Data and method

3.1. Data

For our research purposes, we collected data on the UK innovators focusing on BMR activities for two main reasons. First, UK has implemented a rich policy mix (R&D tax credits, support for start-ups, and many others) similarly to what has happened in other developed countries (Miroshnychenko et al., 2020). Second, we focus on innovative firms because it is widely acknowledged that they are the backbone of the economic growth and development (Massa & Testa, 2008). Following prior research on BMR (Saebi & Foss, 2015; Foss & Saebi, 2018; Pieroni et al., 2019; Rachinger et al., 2019; Zott and Amit, 2017), we matched three different datasets: 1) the UK Innovation Survey (UKIS), 2) the Business Expenditure in Research and Development (BERD), and 3) the Business Registry (BSD). Firstly, we gathered and matched six sequential UKIS waves conducted every second year by the UK Office of National Statistics (ONS): from wave 4 (related to 2002–2004) to UKIS 9 (related to 2012–2014). Secondly, we deployed BERD and BSD data for every second year from 2002 to 2012. The data were matched to a correspondent UKIS wave for the initial year of the UKIS period. From the BERD dataset, we gathered data about the number of researchers with university degrees and above employed by the firm and in-house and bought-out R&D. From the BSD dataset, we collected information about industry, employment, firm size, ownership, and firm age.

Direct measures of BMR, such as an increase in a range of products/services, and entering new markets are included in the UKIS. Additional measures that were included in the study pertain to partner types, human capital, collaboration networks, and barriers to innovation.

We work with three samples of 1) 24,211 observations available for the first proxy of BMR (Exploration goods—Model 1); 2) 7020 observations available for the second proxy of BMR (Exploration markets—Model 2); 3) 21,140 observations available for the third proxy of BMR (Industry switch—Model 3). The availability of data was based on non-missing values for our BMR-dependent variables: explorations goods = 1 if introducing an increasing range of goods or services was important in a decision to innovate, zero otherwise; explorations markets = 1 if entering new markets was important in a decision to innovate, zero otherwise; industry switch = 1 if since the establishment and until 2017 (conditional on survival) a firm has changed its two-digit Standard Industrial Classification (SIC) sector. The condition for firms to be included in a sample was the absence of missing values for the variables of interest. Table 1 illustrates the sources of data and descriptive statistics.[1]

Table A1 in Appendix illustrates the distribution of three samples by industry, region in the UK and firm size over 2002–2014 (six waves of UKIS) and provides information on the number of observations.

3.1.1. Dependent variables

We build on Giesen et al. (2007) that conceptualize BMR as reconfiguration of the product/service value mix by 1) increasing and modifying the firms' range of products or services; 2) innovation of the firm's value chain by firms' moving into new markets; and 3) innovation of the firm's value chain and the industry value chain by moving into new industries. Accordingly, we use three different dependent variables to operationalize the three aforementioned conceptualizations: exploration goods, exploration markets, and industry switch (Table 1).

The availability of data was based on non-missing values for our BMR-dependent variables. "Exploration goods" and "Exploration markets" can be classified as incremental BMR, while switching the industry (modification in the two-digit SIC sectors based on general classification of SIC 2007) can be considered as radical BMR.

3.1.2. Explanatory variables

We followed Salge, Bohné, Farchi, and Piening (2012) and Gesing et al. (2015) and included a number of binary variables for each of the seven partners to measure the **presence** of collaboration with partners (see Table 1). For each partner type, respondents were also asked to specify, not only whether the firm has been engaged in collaboration over the last 3 years or not, but also the **intensity** of such collaboration (Laursen, 2012). Therefore, we measure the intensity of collaboration using seven variables by each partner type using the original survey question: "How important (on a scale from zero—not used to 1—low importance, 2—important and 3—highly important) was your collaboration with enterprise group/suppliers/clients/competitors/consultants /universities/government?"

Looking at the patterns of collaboration with different types of partners reveals interesting results in the overall sample. While the share of firms that collaborate with different partner types vary across three samples associated with Models 1–3, we showed that vertical cooperation (suppliers and clients) is the most common type of partnership with 75–87% of firms that collaborate with suppliers. In the original sample, which includes all firms who replied to knowledge collaboration question, on average 79% of respondents answered "yes" for collaboration with suppliers. On average, 77% of all respondents also answered "yes" for collaboration with customers as this value varies between 76% (Model 3) and 92% in Model 2.

Horizontal cooperation with competitors and partners, such as government and universities, is likely to be less common due to specific risk concerns, for example, a threat of leakage of sensitive information in collaboration with competitors. That said, on average, 75% of all firms in the original sample collaborated with competitors with the value varying between 70% in Model 3 and 87% in Model 2. High research and knowledge barriers when collaborating with universities or high requirements barriers when collaborating or even applying for a government grant or collaborate with government resulted in a smaller share of firms compared with other partners who have ever over 3-year period collaborated with universities (41%) and government bodies (42%).

The intensity of collaboration also varies between different partner types with suppliers reporting 1.70 out of 3 on the scale from 0 to 3 on

[1] Because of space constraints, we did not include the correlation tables that we can provide upon request.

Table 1
Descriptive statistics.

Variables	Description (source of data)	Obs. In sample	Mean	Std. Dev.	Mean	Std. Dev.	Mean	Std. Dev.	Mean	Std. Dev.
Three samples for three DVs		Overall sample			Exploration goods N = 24,211 obs		Exploration markets N = 7020 obs		Switching industry N = 21,140 obs	
Exploration Goods	Binary variable = 1 if introducing an increasing range of goods or services was important in a decision to innovate, zero otherwise (UKIS)	40,411	0.74	0.44	0.71	0.45	0.87	0.34	0.73	0.44
Exploration Markets	Binary variable = 1 if entering new markets was important in a decision to innovate, zero otherwise (UKIS)	20,832	0.78	0.41	0.82	0.39	0.82	0.39	0.82	0.38
Industry switch	Binary variable = 1 if since the establishment and until 2017 (conditional on survival) a firm has changed its two-digit SIC sector, zero otherwise (BSD)	52,550	0.25	0.43	0.36	0.48	0.28	0.45	0.36	0.48
Age of firm	Age of a firm (years since the establishment) (BSD)	64,192	18.32	10.80	18.20	9.86	18.79	10.83	19.19	9.82
Employment	Number of full-time employees (FTEs), taken in logs (BSD)	89,505	4.09	1.52	4.12	1.51	4.09	1.48	4.12	1.52
High-tech manufacturing	Binary variable equal one if SIC2007 (two digits): 21, 26, 30, zero otherwise(UKIS)	89,518	0.01	0.09	0.001	0.06	0.01	0.08	0.001	0.06
Med-tech manufacturing	Binary variable equal one if SIC2007 (two digits): 20, 22–25, 27–29, 32, zero otherwise (UKIS)	89,518	0.07	0.25	0.06	0.23	0.08	0.27	0.06	0.23
Risk	How important were the following factors in constraining innovation: excessive perceived economic risks (0—not experienced; 3—high) (UKIS)	67,951	1.16	1.17	1.23	1.11	1.56	1.05	1.11	1.11
Cost	How important were the following factors in constraining innovation: cost of finance (0—not experienced; 3—high) (UKIS)	68,162	1.13	1.14	1.14	1.07	1.45	1.07	1.03	1.05
Technology constraint	How important were the following factors in constraining innovation: lack of information on technology (0—not experienced; 3—high) (UKIS)	67,752	0.80	0.88	0.79	0.81	0.94	0.79	0.73	0.81
Scientist	The proportion of FTEs holding a degree in science and engineering at BA/BSc, MA/PhD, PGCE levels (UKIS)	66,559	6.79	16.26	7.44	16.94	9.27	18.65	7.30	16.60
Exporter	Binary variable = 1 if a firm sells its products in foreign markets, 0 otherwise (UKIS)	89,518	0.31	0.46	0.40	0.49	0.45	0.50	0.41	0.49
Survival 2017 year	Binary variable = 1 if a firm survived as an independent unit or as a part of a group until year 2017, 0 otherwise) (BSD)	89,518	0.49	0.50	0.56	0.50	0.64	0.68	0.56	0.50
HHI	The Herfindahl–Hirschman index, HHI, is a measure of the size of firms in relation to the industry by employment at two-digit SIC 2007 (0–1) (BSD)	89,518	0.05	0.07	0.05	0.06	0.06	0.09	0.04	0.06
Foreign	Binary variable = 1 if a firm has headquarters abroad, 0 otherwise (UKIS)	64,211	0.32	0.47	0.47	0.50	0.36	0.48	0.45	0.50
Reporting unit	Number of local units (subsidiaries or branches within the enterprise group, both in the country and abroad) (BSD)	64,192	8.96	94.85	11.33	107.3	10.66	136.0	12.21	116.3
Enterprise group	Binary variable = 1 if firm cooperates on innovation with any of other businesses within enterprise group, 0 otherwise (UKIS)	48,979	0.76	0.43	0.76	0.43	0.90	0.30	0.72	0.45
Suppliers	Binary variable = 1 if firm cooperates on innovation with any suppliers of equipment, materials, services, 0 otherwise (UKIS)	49,942	0.79	0.41	0.77	0.42	0.87	0.34	0.75	0.43
Customers	Binary variable = 1 if firm cooperates on innovation with any clients or customers, 0 otherwise (UKIS)	42,720	0.77	0.42	0.79	0.41	0.92	0.28	0.76	0.43
Competitors	Binary variable = 1 if firm cooperates on innovation with competitors or businesses in industry, 0 otherwise (UKIS)	49,038	0.75	0.43	0.73	0.44	0.87	0.37	0.70	0.46
Consultants	Binary variable = 1 if firm cooperates on innovation with consultants, commercial labs or private R&D institutes, 0 otherwise (UKIS)	49,117	0.54	0.50	0.50	0.51	0.62	0.48	0.46	0.51
Universities	Binary variable = 1 if firm cooperates on innovation with universities or high educational institutions, 0 otherwise (UKIS)	49,217	0.41	0.49	0.34	0.47	0.46	0.50	0.31	0.47
Government	Binary variable = 1 if firm cooperates on innovation with regional or national government, 0 otherwise (UKIS)	48,807	0.42	0.49	0.35	0.48	0.47	0.50	0.33	0.47
Enterprise group intensity	How important was firm cooperation with (0–3) any of other businesses within enterprise group, 0—not used; 3 very important (UKIS)	48,820	1.99	1.30	1.79	1.19	2.25	0.97	1.68	1.21
Suppliers' intensity	How important was firm cooperation with (0–3) any suppliers of equipment, materials, services0—not used; 3 very important (UKIS)	52,061	1.70	1.16	1.56	1.07	1.78	0.98	1.50	1.07
Customers' intensity	How important was firm cooperation with (0–3) any clients or customers, 0—not used; 3 very important (UKIS)	49,925	1.82	1.19	1.87	1.16	2.28	0.94	1.79	1.16
Competitors' intensity	How important was firm cooperation with (0–3) competitors or businesses in industry, 0—not used; 3 very important (UKIS)	42,720	1.49	1.13	1.37	1.04	1.67	0.95	1.31	1.04
Consultants' intensity	How important was firm cooperation with (0–3) consultants, commercial labs or private R&D institutes, 0—not used; 3 very important (UKIS)	49,038	0.88	0.99	0.74	0.88	0.93	0.90	0.69	0.85
Universities' intensity		49,217	0.60	0.86	0.47	0.75	0.63	0.80	0.44	0.74

(*continued on next page*)

Table 1 (*continued*)

Variables	Description (source of data)	Obs. In sample	Mean	Std. Dev.	Mean	Std. Dev.	Mean	Std. Dev.	Mean	Std. Dev.
Three samples for three DVs		Overall sample			Exploration goods N = 24,211 obs		Exploration markets N = 7020 obs		Switching industry N = 21,140 obs	
	How important was firm cooperation with (0–3) universities or high educational institutions, 0—not used; 3 very important (UKIS)									
Government's intensity	How important was firm cooperation with (0–3) regional or national government, 0—not used; 3 very important (UKIS)	48,807	0.61	0.84	0.48	0.75	0.64	0.80	0.44	0.73

Number of observations is different across three models based on availability of observations for our three dependent variables.
Department for Business, Innovation and Skills, Office for National Statistics, Northern Ireland. Department of Enterprise, Trade and Investment, (2018). *UK Innovation Survey, 1994–2016: Secure Access*. [data collection]. 6th *Edition.* UK Data Service. SN: 6699, http://doi.org/10.5255/UKDA-SN-6699-6 hereinafter named UKIS—UK Innovation Survey (2002–2014).
Source:Office for National Statistics. (2017). *Business Structure Database, 1997–2017: Secure Access*. [data collection]. 9th *Edition.* UK Data Service. SN: 6697, http://doi.org/10.5255/UKDA-SN-6697-9, hereinafter named BSD—Business Register (2002–2014).

the importance of collaboration and collaboration with customers is 1.82 out of 3 (with the latter being the maximum possible importance of collaboration). The intensity of collaboration with competitors is lower than vertical collaboration type (1.49 out of 3) and the intensity of collaboration with universities (0.60 out of 3) and government (0.61 out of 3) are the lowest. Interestingly from Table 1, we observe that both less firms collaborate with universities and government compared with other partners, and that firms also perceive collaboration with universities and government less important. The variable full-time employment (transformed in logarithm) is a proxy of firm size. We test how it moderates the relationship between knowledge collaboration (presence and intensity) and radical and incremental BMR. Firm size is likely to influence firm's ability to engage in BMR as well as to manage a variety of partners as well as the intensity of collaboration (Faems et al., 2005; Laursen & Salter, 2006; 2014; Gesing et al., 2015). It is known that internationalization facilitates adaptability (Narula, 2004): accordingly, we control for firms' export activity as well as whether a firm has headquarters abroad.

3.1.3. Control variables

Human capital is proxied by a share of full-time employees (FTEs) with university degree and above and represents a control variable (Hall, 2011; Hagedoorn & Wang, 2012). This measure is also used as a control for absorptive capacity (Cohen & Levinthal, 1989). The average proportion of scientists in a firm ranged between 1 and 85% from FTE. We deploy the variable "foreign" that is a dummy taking a value 1 if the firm is foreign-owned, that is, with the headquarter outside of the UK. Interestingly, up to 43% of firms across our three samples are foreign owned. We control for firm age as it can enhance firm's ability to leverage on collaborators' knowledge for innovation. High- and medium-tech manufacturing is often viewed as a vehicle to bring product innovation to markets and we use two binary variables should the firm belong to one of those sectors (Hall, 2011; Laursen, 2012). Existing constraints such as risk, technology access, uncertainty in markets may impede firm's flexibility (Markides & Charitou, 2004), search and innovativeness, which will affect BMR. We include obstacles that firms face when innovating as control variables based on Ireland et al. (2002). Finally, we use region, year and industry fixed effect controls. Among 128 city regions, our reference category is Norwich, industry reference category is agriculture, and reference year is 2002–2004.

3.2. Data analyses

We used probit estimation on an unbalanced panel with three distinctive samples given the data availability for three dependent variables of BMR to test our research hypotheses. We start by first analyzing the unbalanced panel sample of Model 1 (exploration goods) which has 24,211 observations with a panel element, firms that observed at least twice 3087. This estimation will analyze the factors that affect the propensity of a firm to explore new goods. Second, we estimate Model 2 (exploration markets) with includes 7020 observations and 1488 firms that observed at least twice. This Model 2 analyses the factors that affect the propensity of a firm to explore new markets. Finally, we estimate Model 3 (industry switch) using an unbalanced panel of 21,140 observations and a panel element of 2890 firms observed at least twice. This Model 3 analyses the factors that affect the propensity of a firm to switch to new industry, unlike previous models that focused on firm exploring new goods or new markets.

The following econometric model has been estimated:

$$y_{it} = \beta_0 + \beta_1 x_{it} + \beta_2 size_{it} + \beta_3 size_{it} \ x_{it} + \beta_4 z_{it} + \varepsilon_{it} \quad (1)$$

where I is a firm, t is time. The dependent variable y_{it} is BMR by firm i at time t, which can be either exploration of goods, markets, or industry switch. Our explanatory variables represented by x_{it} include collaborations with each partner both the presence of such collaboration and the intensity of collaboration. By including all types of partners, we solve the issue of collinearity between the DVs and iVs and control for potential important partner types that may determine other forms of collaboration, resulting in omitted variable bias. We interact each explanatory variable x_{it} with firm size ($size_{it}$), while other control variables representing firm-specific characteristics exogenous to innovation are z_{it}. Finally, ε_{it} is an error term which consists of:

$$\varepsilon_{it} = \mu_i + \nu_{it} \quad (2)$$

where μ_i, denotes the random effect controlling for unobserved heterogeneity and ν_{it} is the error term.

We deployed a multicollinearity test to analyze the *variance inflation factor* (VIF) for the variables: each is lower than 10 (Wooldridge, 2009). In addition, all the Pearson correlation coefficients were statistically significant in the full sample (5% significance level and <0.70 to address multicollinearity concerns). Across all three samples, no multicollinearity was detected in the correlation coefficients. We analyzed all the variables' histograms and found that errors are identically and independently distributed with constant variance. Stata 15 was used to fit unbalanced panel data probit models with the outcome variable being binary: 1 = introduced reconfiguration of BM, zero otherwise.

3.2.1. Selection bias issue

As not all firms report BMR (Table A1), out of 89,518 observations in the initially received responses from the UKIS, we work with three samples: 24,211 observations for Model 1 (exploration goods), 7020 observations for Model 2 (exploration markets), and 21,140 observations for Model 3 (industry switch). Therefore, when estimating equation (1), it was necessary to control for a sample selection bias. Our robustness check included carrying out a two-stage Heckman, 1979. In the first stage of the analysis (selection equation), a probit selection model was estimated when we regressed the observed dependent variable BMR (one at a time for each of three models) on firm characteristics, which could explain why a firm will (not) report innovation. This selection step consisted of identifying, through a probit regression on the total number of observations those partnerships that reconfigured the BMs or not. Inverse Mills' ratios were calculated when running Heckman command in Stata. When included in the second stage, the inverse Mills' ratios were not statistically significant in all the three models, which means that whether or not all firms who responded to the BMR question but then not included in the final sample, this did not affect the estimation values and the overall significance of the three models. Given that the inverse Mills' ratios were not statistically significant, we did not include them in the final regressions for Models (1–3).

4. Results

We start by estimating equation (1) using probit panel data estimation. Results are reported in Table 2 (for Model 1), Table 3 (for Model 2), and Table 4 (for Model 3) in four steps. At the first step (specification 1, Tables 2–4), we included only control variables, and in the second step (specification 2, Tables 2–4), we added our explanatory variable controlling for the presence of partner collaboration. In the third step (specification 3, Tables 2–4), we used the intensity of collaboration as explanatory variables and control variables. Finally, in the fourth step (specification 4, Tables 2–4), we performed the interaction analysis by interacting the firm size variable with the intensity of collaboration with each partner type.

The findings illustrated in Table 2 fully support H1, which predicted a positive relationship between knowledge collaboration across different types of partners and BMR in the form of incremental BMR. Collaboration with all partners increases the exploration search and expanding a range of products and services by a firm leading to BMR (Chesbrough, 2003, 2006). H2 states that there is a positive relationship between a firms' knowledge collaboration with their partners and BMR. This is supported when looking at incremental BMR, except in collaboration with local and regional governments where the coefficient is not statistically significant ($\beta = 0.05$, $p > 0.10$). An increase in the intensity of knowledge collaboration with all partners (except government) leads to an increase in the range of products and services offered by a firm. Our H3 (Table 2, specification 4), which states large firms will benefit to a greater extent than SMEs from the presence and intensity of knowledge collaboration with different partner types for BMR, is not supported for incremental BMR. This is because the negative interaction coefficient for suppliers and employment ($\beta = -0.03$, $p < 0.01$) suggests that larger firms are less likely to collaborate with suppliers in BMR than small firms.

Other factors that lead to BMR via an increase in the range of new products and services include excessive perceived economic risks (β = 0.15–0.35, $p < 0.01$), and lack of information on technology used in the industry (β = 0.31–0.58, $p < 0.01$). Interestingly, exporters are more likely to reconfigure their BMs for new markets by experimenting with new product development (β = 0.44–0.64, $p < 0.01$).

While the size of the coefficient is smaller in Table 3 than in Table 2, we support H1 and H2 on the positive relationship between knowledge collaboration across different types of partners and BMR measured as exploring and entering new markets. The fact of collaboration with partners, as well as the intensity of such collaboration, facilitates new market entry except when a firm collaborates with local and national governments (β = 0.04–0.08, $p > 0.10$). Our H3 is not supported, as Table 3 (specification 4) illustrates that benefits from knowledge collaboration at different levels of collaboration intensity do not differ with firm size when exploring new markets. This finding complements prior research by Bouncken & Fredrich (2016) on the impact of BMR on financial performance.

Table 2
Results of probit regressions for BMR through exploring new products and services (Model 1) Dependent variable: introducing products and services which are new to market.

Specification	(1)	(2)	(3)	(4)
Enterprise group		0.83*** (0.05)	0.36*** (0.02)	0.39*** (0.05)
Suppliers		0.37*** (0.05)	0.18*** (0.02)	0.31*** (0.06)
Customers		0.72*** (0.06)	0.29*** (0.02)	0.27*** (0.06)
Competitors		0.57*** (0.05)	0.24*** (0.02)	0.32*** (0.07)
Consultants		0.22*** (0.04)	0.09*** (0.02)	0.03 (0.08)
Universities		0.31*** (0.06)	0.18*** (0.04)	0.32*** (0.10)
Government		0.13** (0.05)	0.05 (0.02)	0.02 (0.11)
Enterprise group x β1				0.01 (0.00)
Suppliers x β1				−0.03** (0.01)
Customers x β1				0.01 (0.00)
Competitors x β1				−0.02 (0.01)
Consultants x β1				0.01 (0.00)
Universities x β1				−0.03 (0.01)
Government x β1				0.02 (0.01)
Age	−0.01 (.08)	−0.01 (.08)	−0.01 (.08)	−0.01 (.04)
Age squared	0.01 (.01)	0.01 (.00)	0.01 (.01)	0.01 (.01)
Employment (β1)	0.08* (.01)	0.04 (.02)	0.04 (.02)	0.04 (.02)
High-tech manufacturing	0.44 (.33)	0.02 (.49)	0.01 (.10)	0.01 (.05)
Mid-tech manufacturing	−0.04 (2.10)	0.81 (1.90)	1.11 (2.01)	1.32 (1.50)
Risk	0.35*** (.01)	0.16*** (.01)	0.15*** (.01)	0.15*** (.01)
Cost	0.17*** (.02)	0.02 (0.02)	0.02 (0.02)	0.02 (0.02)
Technology constraint	0.58*** (.02)	0.26*** (.02)	0.31*** (.02)	0.31*** (.02)
Scientist	0.001* (0.00)	0.01 (.01)	0.01 (.01)	0.01 (.01)
Exporter	0.64*** (.04)	0.44*** (.04)	0.40*** (.04)	0.44*** (.04)
Survival 2017 year	0.07* (.03)	0.06 (.03)	0.06 (.03)	0.06 (.03)
Foreign	−0.07 (0.05)	−0.07 (0.05)	−0.07 (0.05)	−0.05 (0.05)
Reporting units	0.01 (.01)	0.01 (.01)	0.01 (.07)	0.01 (.01)
Constant	−2.01*** (0.21)	−3.01*** (0.24)	−2.79*** (0.24)	−3.04*** (0.25)
Industry controls	No	Yes	Yes	Yes
City and year controls	No	Yes	Yes	Yes
N	24,211	24,211	24,211	24,211
Log-likelihood	−12490.2	−9799.3	−9729.3	−9152.2
Chi2	6592.1	9025.2	9136.2	9069.5

Note: reference category for legal status is Company (limited liability company), industry (mining), region (North East of England). Instead of industry dummies in this estimation employment (in logs is used).
Robust standard errors are in parenthesis. Significance level: *$p < 0.05$; **$p < 0.01$, ***$p < 0.001$.
Source: UKIS—UK Innovation Survey; BSD—Business Structure Database.

Other factors that lead to BMR via entering new markets are excessive perceived economic risks (β = 0.18–0.36, $p < 0.01$), as well as a lack of information on technology applied in the industry (β = 0.38–0.64, $p < 0.01$) (Table 3, specifications 2–4). Interestingly, exporters are more likely to reconfigure their BMs by changing markets (β = 0.73–0.89, $p < 0.01$) (Table 3, specifications 2–4). Although these three factors are also related to obstacles for innovation and firm internationalization for BMR, the size of the impact of these factors is larger for BMR via entering

Table 3
Results of probit regressions for BMR through exploring new markets (Model 2). Dependent variable: exploring new markets for goods and services.

Specification	(1)	(2)	(3)	(4)
Enterprise group		0.55*** (0.12)	0.20*** (0.03)	0.20*** (0.11)
Suppliers		0.38*** (0.11)	0.15*** (0.04)	0.28* (0.12)
Customers		0.94*** (0.14)	0.32*** (0.04)	0.46* (0.13)
Competitors		0.74*** (0.11)	0.31*** (0.04)	0.25 (0.13)
Consultants		0.47*** (0.09)	0.19*** (0.04)	0.24 (0.16)
Universities		0.64*** (0.13)	0.40*** (0.08)	0.32 (0.25)
Government		0.04 (0.13)	0.08 (0.07)	0.25 (0.21)
Enterprise group x β1				0.001 (0.02)
Suppliers x β1				−0.03 (0.03)
Customers x β1				−0.03 (0.03)
Competitors x β1				−0.01 (0.00)
Consultants x β1				0.01 (0.00)
Universities x β1				−0.02 (0.05)
Government x β1				0.08 (0.04)
Age	−0.03 (.04)	−0.04 (.05)	−0.05 (.12)	−0.05 (.03)
Age squared	0.01 (.01)	0.01 (.01)	0.01 (.01)	0.01 (.01)
Employment (β1)	0.04 (.03)	0.04 (.03)	0.04 (.03)	0.04 (.03)
High-tech manufacturing	0.01 (.05)	0.01 (.05)	0.01 (.05)	0.01 (.05)
Mid-tech manufacturing	1.21 (.90)	1.22 (.61)	1.21 (.64)	1.21 (.62)
Risk	0.36*** (.03)	0.18*** (.04)	0.18*** (.04)	0.18*** (.04)
Cost	0.10** (.03)	0.02 (0.02)	0.03 (0.03)	0.03 (0.02)
Technology constraint	0.64*** (.04)	0.28*** (.02)	0.36*** (.02)	0.38*** (.02)
Scientist	0.001* (0.00)	0.01 (.01)	0.01 (.01)	0.01 (.01)
Exporter	0.89*** (.07)	0.72*** (.05)	0.72*** (.04)	0.73*** (.04)
Survival 2017 year	0.11 (.07)	0.11 (.07)	0.12 (.07)	0.12 (.07)
Foreign	−0.12 (0.08)	−0.13 (0.08)	−0.13 (0.08)	−0.15 (0.09)
Reporting units	0.01 (.01)	−0.01 (.02)	−0.01 (.06)	−0.01 (.03)
Constant	−1.39** (0.48)	−1.23* (0.60)	−0.98 (0.63)	−1.22 (0.69)
Industry controls	No	Yes	Yes	Yes
City and year controls	No	Yes	Yes	Yes
N	24,211	24,211	24,211	24,211
Log-likelihood	−3813.2	−2405.3	−2472.3	−2468.7
Chi2	1697.5	1898.5	1739.6	1748.6

Note: reference category for legal status is Company (limited liability company), industry (mining), region (North East of England). Instead of industry dummies in this estimation employment (in logs is used).
Robust standard errors are in parenthesis. Significance level: *p < 0.05; **p < 0.01, ***p < 0.001.
Source: UKIS—UK Innovation survey; BSD—Business Structure Database.

new markets than for BMR via experimenting with new products. This is to say that industry and technology risks as well as BM internationalization will be more likely to facilitate new market entry, but less likely to develop new products.

Table 4 illustrates the factors that affect the propensity of a firm to switch sector (radical BMR). By changing the two-digit sector, BMR is associated with entry in a significantly different market with different customers, technologies, and time for BMR available. Our H1, which states that presence of knowledge collaboration positively affects BMRs, is partly supported as collaboration with universities has a positive effect on BMRs (switching industry). The presence of collaboration with consultants has a negative effect on BMR. The intensity of collaboration with various types of partners does not affect BMR, not supporting H2, while the extent of collaboration with customers is likely to increase the propensity of radical BMR when controlling for interactions with firm size (specification 4, Table 4).

Table 4
Results of probit regressions for BMR through switching the industry where it manufactures and sells (two-digit SIC) (Model 3). Dependent variable: Switching to other industry (two-digit SIC).

Specification	(1)	(2)	(3)	(4)
Enterprise group		0.05 (0.03)	0.02 (0.03)	0.06 (0.11)
Suppliers		0.05 (0.05)	0.02 (0.03)	0.06 (0.03)
Customers		0.03 (0.06)	0.02 (0.02)	0.21** (0.6)
Competitors		0.12 (0.07)	0.01 (0.02)	0.02 (0.06)
Consultants		−0.12* (.06)	−0.02 (.02)	−0.08 (.06)
Universities		0.14** (0.04)	0.06 (0.02)	−0.03 (0.07)
Government		−0.02 (.05)	−0.04 (.03)	−0.10 (.09)
Enterprise group x β1				−0.01 (0.02)
Suppliers x β1				−0.04** (0.01)
Customers x β1				−0.01 (0.01)
Competitors x β1				0.01 (0.00)
Consultants x β1				0.02 (0.02)
Universities x β1				−0.01 (0.01)
Government x β1				0.01 (0.00)
Age	−0.01 (.08)	−0.01 (.08)	−0.01 (.04)	−0.03 (.04)
Age squared	0.01 (.01)	0.01 (.01)	0.01 (.01)	0.01 (.01)
Employment (β1)	−0.09*** (.01)	−0.11*** (.01)	−0.11*** (.01)	−0.10*** (.01)
High-tech manufacturing	0.45* (.19)	1.07** (.26)	1.07** (.26)	1.08** (.28)
Mid-tech manufacturing	1.05** (.11)	1.06** (.11)	1.05** (.15)	1.07** (.16)
Risk	0.01 (0.05)	0.01 (0.05)	0.01 (0.02)	0.01 (0.02)
Cost	0.01 (.01)	0.01 (.01)	0.01 (.01)	0.01 (.01)
Technology constraint	0.03 (.03)	0.02 (.01)	0.03 (.02)	0.03 (.02)
Scientist	−0.01 (.01)	−0.01 (.01)	−0.01 (.03)	−0.01 (.03)
Exporter	0.22** (.03)	0.22** (.04)	0.23** (.03)	0.23** (.04)
Survival 2017 year	0.30*** (.04)	0.29*** (.04)	0.29*** (.04)	0.28*** (.03)
Foreign	−0.29** (0.03)	−0.26** (0.03)	−0.26** (0.03)	−0.29** (0.04)
Reporting units	0.01 (.01)	0.01 (.01)	0.01 (.02)	0.01 (.02)
Constant	1.55*** (0.21)	1.52*** (0.25)	1.55*** (0.25)	1.56*** (0.26)
Industry controls	No	Yes	Yes	Yes
City and year controls	No	Yes	Yes	Yes
N	24,211	24,211	24,211	24,211
Log-likelihood	−15818.3	−11488.2	−11494.2	−11486.7
Chi2	11477.3	7467.2	7453.0	7463.2

Note: reference category for legal status is Company (limited liability company), industry (mining), region (North East of England). Instead of industry dummies in this estimation employment (in logs is used).
Robust standard errors are in parenthesis. Significance level: *p < 0.05; **p < 0.01, ***p < 0.001.
Source: UKIS—UK Innovation survey; BSD—Business Structure Database.

Larger firms will be less likely to change the industry if they are biased toward certain suppliers. Rigidities in a supply chain are stronger for larger firms, who fine-tune their production lines and input-output configurations, making them less likely to switch industry (Magretta, 2002). Our H3 is partly supported, as collaboration with any other type of partner benefits large and small firms equally, extending prior research (Bouwman et al., 2019; Lindgren, 2012; Miroshnychenko et al., 2020).

Other factors that force companies to reconfigure their BMs via switching industry are export orientation ($\beta = 0.22–0.23$, $p < 0.01$), the likelihood of survival (β = 0.28–0.30, $p < 0.001$), and being a firm located in the medium-tech manufacturing (β = 1.05–1.07, $p < 0.01$) and high-tech manufacturing industries (β = 0.45–1.08, $p < 0.01$) (specifications 2–4, Table 4). Interestingly, large firms will be less likely to reconfigure their BMs via industry change (β = −0.09–(−0.10), $p < 0.01$). Not surprisingly, large firms are less likely to switch sector, as many of them have rigid supply chains and secured customers. Larger firms will stay in the market unless they are creatively disrupted by new firm entrants (Audretsch & Belitski, 2013), or the market starts shrinking, with customers moving away and limiting opportunities to sustain the market.

In addition, there is a positive association between sector change and firm survival rates, as switching sector may be considered a survival strategy. Finally, foreign owned firms will be less likely to change industry (β = 0.29, $p < 0.001$) (specifications 3–4, Table 4), as they are usually highly specialized and co-located in clusters near to the sources of knowledge from local firms (Driffield, Love, & Yang, 2014). A certain degree of specialization in doing business limits the degree of industry maneuvering and BMR they can engage in.

5. Discussion and conclusion

5.1. Theoretical implications

A variety of drivers behind BMR have been considered in the BM innovation and reconfiguration literature (Foss & Saebi, 2018; Hacklin et al., 2018; Massa & Tucci, 2014). However, our understanding of a) the difference between the intensity of collaboration and simple presence of collaboration and b) the role of firm size in this relationship have remained largely unexplored. Our work follows a recent call in the BMR literature (Giesen et al., 2007; Bouncken & Fredrich, 2016; Clauss et al., 2020) to pay attention to the importance of partner types and the boundary conditions for different types of BMR. In line with the BM innovation literature and the concept of knowledge collaboration (Audretsch & Belitski, 2020b; Van Beers & Zand, 2014), we draw scholarly attention to two boundary conditions of the radical and incremental types of BMR—firm size and partner type.

Distinguishing between the presence and the intensity of knowledge collaboration, as well as finer-grained firm size, we were able to examine the effects of vertical and horizontal collaboration with partners on the extent of BMR of the most innovative UK firms. Aiming to establish whether knowledge collaboration presence and intensity predict BMR type and the size of the effect when exploring new products, entering new markets and switching industries, our findings shed light on whether and how *firms reap collaboration benefits from different partner types and across firms of different size*. Our findings demonstrate the high importance of the presence and the intensity of knowledge collaboration across different types of partners for incremental BMR. The results for radical BMR compared to those for incremental BMR differ in regard to the presence and intensity of knowledge collaboration. First, we found that the presence of collaboration with suppliers, customers, competitors, and enterprise groups does not add to the propensity of radical BMR. We also found that the extent of collaboration with customers positively affects the propensity of switching industry, and that larger firms are less likely to switch industry if their intensity of collaboration with suppliers is high.

Beyond considering the intensity and presence of knowledge collaboration and the typology of different partners, this study demonstrates that firm size negatively moderates the relationship between intensity of collaboration with suppliers and exploring new products and switching industry. This demonstrates that firms who rely on suppliers as their knowledge inputs will be less likely to experiment with new products, as they can obtain ready-made solutions from suppliers and will be less likely to switch industry. Our results also indicate that small and large firms reap equal benefits from collaboration with different partner types, with the exception of suppliers where larger firms benefit more.

Our study thus makes several contributions to the BMR literature. First, by furthering research on knowledge collaboration and BM innovation (Giesen et al., 2007; Bouncken & Fredrich, 2016; Foss & Saebi, 2018; Saebi & Foss, 2015) by empirically examining the links between partner type and two types of BMR. Secondly, by exploring which partner types can influence BMR and whether the effect is driven by the fact of collaboration, or how much firms collaborate. In this way, we contributed to the research stream on the types of BMR (Clauss et al., 2020) as well as the types of partners for innovation. Our findings are different from the literature that researches the relationship between cooperation intensity and innovation (e.g., Park et al., 2014; Trigo & Vence, 2012; Weber & Heidenreich, 2018; Audretsch & Belitski, 2020b) as we measure the existence of the effect and the size of the effect of knowledge collaboration for the radical and incremental BMR propensity and for three BMR strategies. Thirdly, we contribute to investigate if and to what extent the intensity of small and large firms' business partnerships affects their BMR. The fact that both small and large size firms benefit equally from collaboration with partners is new, as prior research would assume knowledge collaboration is more important for small firms due to the financial constraints they face (Bruderl & Schussler, 1990). This also extends previous studies that found that large firms do not appropriate more value than small firms through BMR (Bouncken & Fredrich, 2016), in line with the received differentiation between incremental and radical BMR (Clauss et al., 2020). Our finding that firm size does not moderate the relationship between BMR and knowledge collaboration types is in contrast with prior research on firm size and firm innovation. We differ in particular on the moderating effects between knowledge collaboration, spillovers and product and process innovation (Amara, Landry, Becheikh, & Ouimet, 2008; Cohen & Klepper, 1996), and also for smaller firms and startups (Audretsch, 2014).

5.2. Policy and managerial implications

Receiving government support for innovation in prior research was found to increase the intensity of R&D by 2.3 percentage points (Garcia & Mohnen, 2010), while it was mainly national support which was significant leading to a total effect on the share of new to market innovative sales of 3.4%. Government support is often related to covering R&D costs or R&D tax credits, as well as innovative public procurement. However, only firms that invest in internal R&D can benefit. Firms that do not invest in R&D are not eligible, and will need to market and promote new products, as well as enter new markets, without government support. This study demonstrates that the use of external sources of innovation could be important. In particular, the presence and intensity of knowledge collaboration between different partner types were found to facilitate incremental BMR, and universities and customers support more radical forms of BMR.

The presence of collaboration with regional and national governments (Mariani, 2009, 2018) as well as other partners is important for both small and large firms and will affect the exploration of new products and markets first. The concept of the presence and the intensity of collaboration with government may not be applicable, as once a firm has received a government grant it does not engage with the government, apart from providing regular reports and updates throughout the duration of the project, and engaging with stakeholders. While this may be one reason why we found that the intensity of collaboration with government is unlikely to change BMR, the presence of collaboration may be important for new product development. Collaboration with universities and customers may change the propensity of radical BMR, making firms explore different industries. Supporting the Triple helix model of government-industry and university collaboration may therefore become an important policy agenda (Audretsch & Belitski, 2021) for radical BMR.

5.3. Limitations and further research

This study is not without limitations. Firstly, due to the anonymous nature of the UKIS, no additional sources for information on partners could be added to the database, which could have been used to supplement the data. In particular, we are unable to track the number of contacts and the length of engagements between partners. Secondly, a cross-country comparative approach in understanding the relationship between knowledge collaboration and BMR could have provided more robust and generalizable results. While we were able to use data between 2002 and 2014, further research might extend the sampling window and gather more recent data. The use of unbalanced panel dynamic data is rather common in many studies deploying innovation survey data (see Audretsch & Belitski, 2020b; Ebersberger, Galia, Laursen, & Salter, 2021; Giovannetti & Piga, 2017). Finally, our research focuses on three types of BMR. Further research could therefore employ a more fine-grained operationalizations of BMR.

Future research should follow on expanding the longitudinal setup of the database. The inclusion of lagged values of firm collaboration enabled us to develop insights explaining the consequences of collaboration over time, and to understand whether firm collaboration with partners persists and has short- and long-term implications. Using different lags for industries where R&D and knowledge collaboration effects are short- or long-term may allow further research to measure the inter-temporal dynamics of BMR. Further research may also entail a cross-country study in order to capture if and how differences in regulation and institutional environment across countries (North, 1991) change firms' BMR practices and the forms of engagement with their knowledge partners.

In addition, future research will expand on the joint estimation of internal and external capabilities, including the capability to create and manage multiple knowledge collaborations (Van Beers & Zand, 2014). Subsequent research will also merge qualitative and quantitative measurements for the degree of collaboration among firms and the triangulation techniques. Moreover, the share of firms who engage in external collaboration vary between partner types, and are particularly low for universities and government. Future research might therefore investigate why potentially beneficial collaborations with government and universities as well as coopetition strategies have not been adopted by a majority of innovators, unlike collaboration with suppliers and customers. Future research should further explain under what conditions firms of different sizes could differentiate their returns from partnerships. It is likely that the relationship between firm size, BMR and collaboration intensity is non-linear, as firms which expand beyond a certain size may become less flexible with regards to changing their BMs while also being more constrained by resource allocation.

APPENDIX

Table A1
Industrial / Regional and Firm size distribution across the three samples.

Industry distribution	Model 1		Model 2		Model 3	
	Firms	Share, %	Firms	Share, %	Firms	Share, %
1 - Mining & Quarrying	197	0.81	40	0.51	166	0.79
2 - Manufacturing basic	1465	6.05	393	5.60	1282	6.06
3 - High-tech manufacturing	4779	19.74	1362	19.40	4106	19.42
4 - Electricity, gas and water supply	210	0.87	89	1.27	167	0.79
5 - Construction	2291	9.46	524	7.46	2220	10.50
6 - Wholesale, retail trade	3678	15.19	972	13.85	3422	16.19
7 - Transport, storage	1384	5.72	361	5.14	1151	5.44
8 - Hotels and restaurants	1203	4.97	361	5.14	1150	5.44
9 - ICT	17.55	7.25	528	8.29	1437	6.80
10 - Financial intermediation	898	3.71	237	3.38	692	3.27
11 - Real estate and other business activity	3198	13.21	1160	16.62	2669	12.63
12 - Public admin, defence	2471	10.24	767	10.93	2133	10.09
13 – Education	98	0.40	28	0.40	80	0.38
16 - Other community, social activity	584	2.41	144	2.05	465	2.20
Total	**24211**	**100**	7020	**100**	21140	**100**
Regional distribution						
North East	1406	5.81	414	5.90	1147	5.45
North West	2243	9.26	647	9.22	1984	9.39
Yorkshire and The Humber	1974	8.15	585	8.33	1750	8.28
East Midlands	2002	8.27	579	8.25	1704	8.06
West Midlands	2159	8.92	617	8.79	1861	8.80
Eastern	2147	8.87	640	9.12	1912	9.04
London	2290	9.46	677	9.64	1981	9.37
South East	2625	10.84	814	11.60	2348	11.11
South West	2034	8.40	604	8.60	1796	8.50
Wales	1640	6.77	461	6.57	1350	6.39
Scotland	19.35	7.99	593	8.45	1671	7.90
Northern Ireland	17.56	7.25	389	5.54	1636	7.74
Firm size distribution						
small firms	10183	42.05	2962	42.19	11588	54.82
Medium	6817	28.15	1991	28.36	5680	26.87
Large	7211	29.78	2067	39.14	3872	18.32
Total	**24,211**	**100**	7020	**100**	21140	**100**

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

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