Innovation in family firms: the Brittelstand

Innovation in Family Firms: The Brittelstand

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1. Introduction

As a network of established small and medium-sized companies in Germany, the 'Mittelstand' has long been heralded as the driving force behind the country's economic success (Pahnke et al., 2022). However, is this a uniquely German phenomenon? Small- and medium-sized enterprises (SMEs) play as big a role in economic development globally as they do in Germany, and in particular in the United Kingdom where over 99 percent of all firms are SMEs (BSD, 2019). The British version of the Mittelstand is decisively more heterogeneous, from longstanding family manufacturing firms (Kotlar et al., 2018) to retail chains and dynamic R&D companies (Schutte, 2015). Drawing on the family business literature, we define the Brittelstand as including firms which are small-to-medium in size, partly or fully controlled and owned by family members, and which aim for high growth. The Brittelstand is globally recognized for its innovation, especially product innovation. Among the characteristics that unite both the German Mittelstand and the British Brittelstand are the advantages offered by their scale, ownership and innovativeness (Pahnke et al., 2022), as well as their productive and dynamic collaboration with end-users (Saura et al., 2021).

To understand innovation in family-owned businesses, which Brittelstand enterprises certainly are (De Massis et al., 2013; 2018), academic research appealed to the resource-based

view (RBV) (Barney, 1991) and social-emotional wealth (SEW) theories (Hernández-Perlines et al., 2021; Gómez-Mejía et al., 2007; Rovelli et al., 2021; Zellweger et al., 2013) that explain the differences in innovation behaviour between family and non-family SMEs. While the family-firm innovation literature clearly shows a move of interest from the basic elements concerning family business (family ownership and management) to a more in-depth understanding of family firms' behavioural drivers (Rovelli et al., 2021), extant theoretical developments fall short of explaining the nature of the observable innovation collaboration behaviour of Brittelstand companies and the impact of this on their product innovation. Indeed, the RBV assumes that family (Brittelstand) firms have idiosyncratic resources as a result of family involvement, identified as the "familiness" of the firm (Chrisman et al., 2010; Habbershon and Williams, 1999; Mallon et al., 2018), which allow them to successfully govern external collaborations (Hadjielias and Poutziouris, 2015).

Meanwhile the SEW approach is based on the agency behavioural perspective, and asserts that family firms are unwilling to collaborate with external stakeholders to protect their business even if the financial rewards of collaboration are higher. Consequently, recent research has revealed the existence of paradoxes in the collaboration innovation behaviour of family firms, as these firms are less motivated to pursue innovation compared to their non-family counterparts even if their greater decision-making latitude enables them to successfully collaborate for innovation (Chrisman et al., 2015; Debellis et al., 2021). The superior innovation collaboration phenomenon observed in the Brittelstand remains only poorly explained. We believe that the Brittelstand context can reveal important insights into how family firms are able to successfully manage open innovation.

In order to enhance our understanding of innovation in the Brittelstand, we draw on the resource-based view (Barney, 1991) and customer innovation literature (Chesbrough, 2003; Greer and Lei, 2012; Ribeiro-Soriano et al., 2021) to explain the willingness and ability of

Brittelstand firms to innovate. We also borrow insights from the symbolic interaction theory (Aksan et al., 2009) in explaining the primacy of customer collaboration for innovation in family firms. This paper asks the following research question: How do Brittelstand firms use open innovation to achieve superior innovation output? We argue that although Brittelstand companies are less willing to engage in open innovation than other firms, drawing on familiarity with local customers and local embeddedness enables these Brittelstand firms to build and maintain successful customer collaborations over the long term (Cooper et al., 2005).

Our results show that Brittelstand firms are less willing to collaborate with customers and universities than non-Brittelstand firms. This contrasts with prior research on family firms, and distinguishes the innovation model of the Brittelstand from a family business model. The Brittelstand firms able to engage in collaboration with customers in domestic markets will outperform their non-Brittelstand counterparts in innovation outputs.

This study makes two important contributions. Firstly, we contribute to the open innovation and RBV literature on family firms by theorizing and empirically testing the open innovation model for Brittelstand firms. In relation to the type of collaboration partner, we demonstrate that close ties with customers, in addition to the local embeddedness of Brittelstand firms, are expected to facilitate returns to knowledge collaboration. This is particularly true regionally and nationally, where the organizational, institutional and cognitive characteristics of firms and customers can match. We also argue that Brittelstand firms should overcome this inertia of willingness to collaborate across heterogeneous external partners and convert their regional/national embeddedness with customers into strengths for greater product innovation.

Secondly, we contribute to the family business literature by explaining how and why Brittelstand firms are able to achieve greater innovation outputs. In doing so we draw on the concept of familiness and local embeddedness (Pahnke et al., 2022) in examining the willingness of Brittelstand firms to collaborate with different types of external partners and their

ability to do so and achieve economic returns from open innovation. This study also extends the family business literature by showing how open innovation can represent a proper context in which to explore the advantages of family-owned high-growth innovative firms—the Brittelstand—in building a relationship with customers domestically in order to achieve superior innovation performance.

2. Theory and hypotheses formulation

2.1. Open innovation model and the Brittelstand

Firms take advantage of their ability to draw on knowledge from several outside sources and combine this with their own human and financial resources (Chesbrough, 2003; Saura et al., 2021, 2022). Scholars have argued that collaboration acts as the main driver of innovation by enabling firms to leverage their resource limitations (Audrestch and Belitski, 2022). External collaboration on knowledge is of prime importance for family firms (Casprini et al., 2017; Feranita et al., 2017; Gamble et al., 2020; Pantano et al., 2020) which wish to support in-house innovation and grow their business but are constrained by the availability of resources for experimentation with new ideas. On the one hand, the resource-based view (RBV) could help explain the willingness and ability of Brittelstand firms to collaborate on innovation with external partners and be strongly embedded in local communities (Baù et al., 2019; Intihar and Pollack, 2012) while facing low levels of human and financial capital (De Massis et al., 2018; 2020). According to the RBV, their paucity of internal resources makes collaboration with customers a cost-efficient way to develop innovations.

On the other hand, the open innovation literature can also identify with whom Brittelstand firms will be more likely to collaborate on innovation, and explain why (Chesbrough, 2003; Saura et al., 2022). For example, the literature argues that small- and medium-sized family firms are more likely than non-family firms to focus on establishing close ties with customers when developing new products (Alberti et al., 2014). While prior research has paid attention to the

variety of external collaboration partners (van Beer and Zand, 2014; Audretsch et al., 2021), collaboration with customers remains an absolute priority for family-owned SMEs (De Massis et al., 2018) with the most recent evidence of such collaboration (Pahnke, Welter and Audretsch, 2022).

One of the core challenges for the Brittelstand in adopting the open innovation model is their ability to retain control over decision-making, as the potential loss of family ownership may lead to a loss in control over decision-making and management (Zattoni et al., 2015). This will compromise the important socioeconomic wealth (SEW) of family-owned firms (Gómez-Mejía et al., 2007; Brinkerink, 2018; Calabrò et al., 2019). Indeed, uncontrolled open innovation with external partners may threaten the very SEW values of the Brittelstand (Cassia et al., 2012; Nieto et al., 2015). The fear of loss of control and reduction in SEW prevents Brittelstand firms from collaborating with external partners (Hernández-Perlines et al., 2021).

As Kammerlander and van Essen (2017, p. 3) argued, "many family firms benefit from their "family-like" culture and their close relationships with a handful of partners, from suppliers to customers, who can help these firms develop their creative ideas, products, and processes.

Open innovation with customers is associated with a type of knowledge acquisition from customers that is not available within a firm (Bogers et al. 2018). This knowledge may include but is not limited to customer preferences, technology developments and infrastructure, and market needs (Audrestch and Belitski, 2020a; Stadler et al., 2021).

Open innovation with customers is shown to have the strongest impact on product innovation compared to other partners (suppliers, competitors, universities, etc.) (van Beer and Zand, 2014; Ribeiro-Soriano and Piñeiro-Chousa, 2021). The main argument for open innovation with customers is that customers have knowledge about their unfulfilled preferences

and needs and act as pilot users of new products, presenting opportunities for product innovation (Newman et al., 2016; Wixe et al., 2021).

Cohen, Nelson and Walsh (2002) found that 90% of firms they studied indicated that knowledge provided by customers also contributed to the initiation of their new R&D projects. This is because knowledge collaboration with customers enables the exchange of experiences and feedback from using the product, allowing the firm to develop new procedures and potentially customize their innovation output (van Beers and Zand, 2014). Collaboration with customers reveals the paradigm shift in our understanding of innovation from producer innovation to user-led innovation (Baldwin and Von Hippel, 2011; von Hippel and Cann, 2021; Ribeiro-Soriano and Piñeiro-Chousa, 2021). This literature emphasizes the importance of collaboration with customers, in particular lead users as sources of product and service innovations or ideas for future product development (Saura et al., 2021; Stanko and Allen, 2022). Multiple studies emphasize the key role of customers in reducing risks and costs, enhancing product quality, and promoting customer loyalty and delivery performance (Cappelli et al., 2014).

The family firm literature argues that family businesses have a particular interest in creating an image of a "superior" product or service and ensuring their customers are loyal to their product (Newman et al., 2016). Empirical studies show that establishing and maintaining a good image for customers is a key objective for family businesses (Tagiuri and Davis, 1992). In turn, customers are thus shown to place particular importance on the identity of the family firm as well as their reputation (Beck and Prügl, 2018). Personal relationships with customers wherever they appear are considered one of the top success factors in family firms (Hoover and Hoover, 1999).

2.2. Familiness and customer collaboration

The familiness of Brittelstand firms means they have a special relationship with their customers. Familiness refers to those difficult-to-imitate and value-generating capabilities, often locally embedded (Pahnke et al. 2022), which form the basis for the success of the Mittelstand in Germany outside Germany (Gedajlovic et al., 2012; Mallon et al., 2018). The familiness of Brittelstand firms and their orientation for innovation allows the Brittelstand to overcome difficulties related to the lack of resources and achieve greater innovativeness and customer orientation through local embeddedness, developing a trusted relationship with customers through generations. This increases the efficiency to greater efficiency of the firm's operations, boosts customer loyalty, and generates continuous demand for the Brittelstand's products.

Based on the family business literature, we know that Brittelstand firms are likely to possess specific characteristics that help them to effectively increase customer engagement. Brittelstand firms are more likely to develop strong long-term relationships with their customers through local embeddedness and a sense of belongingness (Pahnke et al., 2022). This is down to the distinct advantages they possess; for example, their privileged access to localized networks (Lester and Cannella, 2006; Pahnke et al., 2022), family-derived social capital (Arrègle et al., 2007), and their inclination to be visible with key stakeholders in communities (Basco and Suwala, 2021; Dunn, 1996).

Knowledge collaboration with customers may range from an informal exchange of ideas to formal co-development projects aiming to launch new products to the market, and can be strongest within localized communities and networks due to an increased level of trust (Pahnke et al., 2022).

An illustrative example of how a family business engages in open innovation with customers is the Agritech (manufacturers of agricultural machinery) (Fitz-Koch and Nordqvist, 2017). This is a family-owned business which builds close social relations with its customers

(farmers) who help this family business to raise awareness of what is needed in the market and stimulate tacit knowledge exchange about the community and industry.

Based on the arguments above, collaboration with customers is expected to positively contribute to the Brittelstand's innovation outputs. We hypothesize:

H1: Brittelstand firms are more likely than non-Brittelstand firms to engage in collaboration with customers on innovation.

2.3. Customer collaboration in the Brittelstand

Accessing knowledge for innovation from customers can be difficult for at least two reasons. Firstly, there is the challenge of obtaining tacit and complex knowledge from customers concerning their needs and preferences which may not be apparent even to them. Secondly, customers may not have the motivation to provide the firm with their knowledge or to interact with the firm's employees (Cappelli et al., 2014).

As explained earlier, family firms are concerned with preserving respect for the family name and their reputation, perceived trustworthiness, and goodwill (Blombäck and Botero, 2013). One common assumption in the literature is that customers often have positive associations with family-owned brands (Martínez-Sanchis et al., 2021). Reputation and trust accordingly give family firms, including Brittelstand firms, an essential advantage over their non-family counterparts, enabling them to develop idiosyncratic relationships with their customers that ease their access to knowledge for product innovation.

The extant literature also highlights the fact that family firms have greater social capital than non-family firms (Neubaum, Kammerlander and Brigham, 2019). This is largely influenced by the family dynamic (Arrègle et al., 2007, 2012; Mani and Lakhal, 2015). Previous studies have argued that the social capital of family firms is likely to help them achieve

successful collaborations (DeBellis et al., 2021; Pahnke et al., 2022) as it increases their access to resources such as information, technology, and distribution networks. A high level of social capital within a collaboration is expected to enhance the development of trust and norms of reciprocity (Arrègle et al., 2007; Erdogan et al., 2020), which will in their turn incentivize the partners to share their knowledge.

Finally, according to the symbolic interaction theory (Aksan et al., 2009), social capital also has a symbolic meaning for family firms in the way that shared activities help build emotional bonds (Nordstrom and Steier, 2015) and allow Brittelstand firms to develop cognitive proximity with their customers based on their shared values and norms (Balland et al., 2015). Social values and norms as forms of informal institutions are spatially bounded (region, country) which adds to the localization strategy of the Brittelstand when collaborating on knowledge with customers. Brittelstand firms will build on the cognitive and spatial proximities (Balland et al., 2015) to facilitate social bonds with the customers as an intangible asset, and use their familiness to create social capital and develop long-term collaborative models with customers. This strategy allows Brittelstand firms to achieve a unique resource combination of social capital, local embeddedness and familiness which grants higher returns to knowledge collaboration with customers. We hypothesize:

H2: Brittelstand firms that engage in collaboration with customers will increase their innovation output to a greater extent than non-Brittelstand firms that engage in such collaborations.

3. Method

3.1. The Brittelstand

The Confederation of British Industry (CBI) first introduced the Brittelstand term aiming to capture the most powerful and growth-oriented family firms (Financial Times, 2015) with between £10m and £100m turnover. In 2015 this described fewer than 1% of businesses, with these firms generating 22% of the UK's economic revenue and providing 16% of all jobs. This study focuses on those Brittelstand firms that innovate (DeBellis et al., 2021) and invest in R&D (Brinkerink and Bammens, 2018).

As high-growth orientation criteria, we selected firms with annual revenues between 1 million and 10 million pounds sterling which had displayed continuous sales growth for at least 3 years and had fewer than 250 employees.

The Brittelstand Symposium (2019) posits that almost 14 million people employed by Brittelstand companies in the UK.

It is also important to note that in 2014 there were nearly 5 million small- and medium-sized businesses in the UK – defined as companies with fewer than 250 employees and a turnover of under £12.9 million ($20.6 million)—with family ownership (Ellyat, 2014). Furthermore, it is not uncommon to find that some large Brittelstand firms use the "Brittelstand" term to describe themselves as part of the Brittelstand, perhaps to distinguish themselves for their quality and focus on family values such as SEW, growth orientation and innovation. In 2018, Brittelstand firms accounted for more than 35% of the UK's private-sector turnover and 40% of the private-sector jobs (Brittelstand Symposium, 2019).

3.2. Data and sample

To test our research hypotheses, we use unbalanced longitudinal data based on eight waves of the community innovation survey in the UK (2004-2020) and the Business Structure Database (BSD) (Office for National Statistics, 2021a). The BSD is conducted annually by the Office of National Statistics (ONS) for the years 2004, 2006, 2008, 2010, 2012, 2014, 2016 and

2018 (Office for National Statistics, 2021b). We matched each correspondent CIS survey wave with the data from the BSD (2004, 2006, 2008, 2010, 2012, 2014, 2016, 2018) taken for each UKIS period's initial year. The match was made using the enterprise unit indicator and year shared by both BSD and UKIS. The responses have been consistent between different waves; however, the missing values of innovation sales across waves vary, with more missing values in the aftermath of the global financial crisis (2010-2014).

Tables 1 illustrates the sample distribution by industry and region in the UK, as well as firm size over 2004-2020 (six waves of UKIS), and also provides information on the number of observations. The final sample includes 13,876 firms with 24,286 observations over 2004-2020, with 8,089 firms observed only once during 2004-2020, 3,061 firms observed twice, 1715 firms observed 3 times, 497 firms observed 4 times, 273 firms observed 5 times, 134 firms observed 6 times, 75 firms observed 7 times, and 32 firms observed 8 times (all UKIS waves).

Most of the firms in our sample are from the South East England (10.78%), London (9.46%), North West England (9.35%), and East England (9.19%). Firms from Northern Ireland (7.25%), Wales (6.62%), and North East England (5.91%) are least represented. Most of the firms in our sample are from the other manufacturing (23.61%), wholesale and retail (15.28%), and professional and scientific (11.46%) industries. The least represented industries are other services (0.64%), education (0.44%) and admin services (10.59%).

The majority of businesses (45.96%) are small firms with 10-49 full-time employees (FTEs), followed by large firms (250 FTEs and more) which constitute 20.29% of the sample, and medium-small firms (50-99 FTEs) with 15.44% of the sample. Medium-large firms (100-249 FTEs) constitute 11.68% of the sample, while 6.63% of the total are micro firms (1-9 FTEs).

Most firms were observed during 2004-2006 (34.94%), while the least observed firms were during 2016-2018 (4.51%).

The distribution of firms by industry, region, firm size and wave of UKIS-BSD matched survey is illustrated in Table 1.

TABLE 1 ABOUT HERE

3.3. Measures

Dependent variable. We required two different dependent variables to test our H1 and H2. In order to test the likelihood of collaboration with customers, we employ a binary variable taken from UKIS which equals one if the firm collaborates with customers (e.g., across four potential geographical dimensions—regionally, nationally, Europe, and internationally), zero otherwise. Customers often require very reliable and efficient processes and services, and they engage in collaboration with producers of innovation to improve these aspects. We are only interested in companies that collaborate with customers externally and aim to create new-to-market products (Giovannetti and Piga, 2017).

To test our second hypothesis, we used the share of new-to-market products in total sales taken from UKIS (Kleinknecht et al., 2002). This is the most appropriate measure of innovative performance and knowledge commercialization (Audretsch and Belitski, 2020b; Berchicci, 2013; Frenz and Ietto-Gillies, 2009).

Explanatory variables. To measure the effect of innovation collaboration on innovation, we included four binary variables which equal one if the firm collaborates with customers across four geographical scopes: regionally, nationally, in Europe and internationally, and zero otherwise (van Beer and Zand, 2014; Chirico and Salvato, 2016). At this step, collaboration with customers is an explanatory variable.

Our Brittelstand identifier is a binary variable which equals one if the firm is fully or partly family-owned, has an annual revenue between 1 and 10 million pounds sterling, and is a SME and has been growing in sales for the last three consecutive years, and zero otherwise.

Operationalization of the Brittelstand variable was a long process, and required an additional matching exercise between Company House information on firms and the BSD data by each individual survey year. We used the selection criteria for the Brittelstand explained above (Financial Times, 2015) (turnover, firm size, growth ambition, family ownership). In addition, we would like to explain the firm ownership criteria used for this study. We used 25 percent family ownership as a cut-off point for the family ownership criteria. There was an issue with indirect ownership, e.g., via holding structures and firm cross-holdings which we did not consider to come under family ownership. The surname of owners in the UK could change after marriage, and we could not track family ownership in this case. In the same vein, we were unable to establish family relations between, for example, children and grandparents on the mother's side who had different surnames. Having applied all three criteria, we end up with 15% of Brittelstand companies in our sample. One could argue that 40% is a good average for UK family businesses, and that our analysis of accounting for 35-40% of the family businesses is biased. Given that we study Brittelstand firms, the use of selection reduces the number of such firms in the sample because not every family firm (whether partly or fully owned) is a Brittelstand firm.

One would expect there to be a time gap between innovation collaboration and innovation output, so the time frame opens three years prior to the survey (e.g., survey 2005 for the 2002-2004 period). This enables us to interpret our finding as causal (Williams et al., 2003). The time frames do not overlap as the survey takes place every 3 years.

Control variables.

We include several control variables that previous research has identified as driving innovation. First, we control for knowledge collaboration with other partners (enterprise groups, suppliers, local and national governments, consultants, universities, competitors). Collaboration with external partners is expected to bring new knowledge and increase the speed

and depth of innovation (Giovannetti and Piga, 2017). To control for the level of absorptive capacity, we used 'in-house R&D expenditure' (Nooteboom, 2000; Brinkerink and Bammens, 2018), while we also controlled for purchases of R&D (external R&D) which we expected to increase the innovation performance of a firm (Kleinknecht et al., 2002). Smaller firms are known to innovate more, as well as engage in open innovation. We use binary variables of firm size, starting from small (FTEs <50) and followed by medium (between 50 and 249 FTEs) and large firms (>250 FTEs). Large firms are a reference category.

We use a binary variable 'Process innovation internal' which indicates whether a firm introduces process innovation, as this can be an important determinant of whether a company is developing new products and services (Audretsch et al., 2021). We control for 'Firm age' measured as log of firm age, capturing potential decreasing marginal returns to firm age. More mature firms are known to innovate less as they exploit their business models. We control for the share of employees with BSc degree and above in total employment ('Scientist') and a proxy for human capital that positively affects the development of new ideas (Santamaria et al., 2009). Other knowledge intensity controls include 'design intensity' and 'training intensity' that increase a firm's capability to experiment with and implement new ideas (Belitski et al., 2020). We use a firm's 'Legal status' as a binary variable for sole-proprietorship, not-for-profit, and partnership with limited liability companies as a reference category. We also control for sales abroad to measure internationalization with a binary variable 'Exporter,' and 'Foreign' if the firm has headquarters abroad.

Finally, to capture the fixed effects between and within industries, we include 70 industry dummies (SIC 2-digit codes) (mining and quarrying is a reference category), although they are suppressed to save space. We include 128 region-city fixed effects where firms are located (Aberdeen is a reference category) and six-year fixed effects (2002-2004 period as a reference category). We would have liked to be able to include a control variable of prior firm

performance, as per Chrisman and Patel (2012), showing that firm performance substantially drives family firms' innovation investiture. However, our dependent variable is innovation sales as a share of total sales, and we were limited in the use of sales indicators on both sides of the equation to avoid endogeneity issues.

A full list of variables can be seen in Table 2, while the descriptive statistics for collaboration variables across four geographical regions can be seen in Table 3.

TABLE 2 ABOUT HERE

TABLE 3 ABOUT HERE

3.4. Econometric model

We first estimate the logistic regression model with knowledge collaboration across four geographical dimensions and seven collaboration partners as dependent variables (step 1).

In the reduced form function of collaboration φ_{it} (binary variable =1 if firm engages in collaboration across geographical scope or with any specific partnership type, zero otherwise) is estimated as:

$$\varphi_{it} = \pi_0 + \beta_i x_{it} + \pi_i \varrho_{it} + v_{it} \quad (1)$$

Where x_{it} is a vector that represents Brittelstand firms and ϱ_{it} is other exogeneous control variables which predict the propensity to collaborate across different geographies and partner types (van Beer and Zand, 2014; Srholec, 2010).

We applied the multilevel mixed-effects logistic model in step two by using a generalized estimation equation (Papke and Wooldridge, 2008). The bounded dependent variable y_{ijt} was between [0,1] and we used a truncated distribution and the independent variable x_{ijt} such that:

$$y_{ijt} = \beta_0 + \beta_1 x_{ijt} + \beta_2 \tau_{ijt} + \varepsilon_{ijt} \quad (2)$$

where i is the firm level-1, j is the region level-2, and t serves to index the wave survey level-3. The dependent variable y_{ijt} – innovation output. The explanatory variables and interactions are in x_{ijk}. Other control variables, which represent the firm-specific characteristics described in Table 2, are presented in τ_{ijt}, while ε_{ijt} is the error term:

$$\varepsilon_{ijt} = \gamma_i + \mu_j + t + \nu_{ijt} \quad (3)$$

Where γ_i represents the omitted variables that vary across firms but not over regions and waves, $\mu_{ij.}$ denotes the omitted variables that vary over regions but are constant across firms and time, t represents omitted variables which vary across waves but not across firms and regions, while finally ν_{ijt} is the error term.

4. RESULTS

Table 4 illustrates the results of estimation (1). The odds ratio is less than one with collaboration with customers, which means that Brittelstand firms are less likely to engage in collaboration with customers on innovation than other firms. H1 is not supported.

Brittelstand firms are also 65.2% less likely to collaborate with universities (β=0.348, $p<0.05$) than non-Brittelstand firms, and surprisingly 75.9% (β=0.241, $p<0.05$) less likely to collaborate with customers on innovation. This finding extends the prior research on the role of universities for innovation (Audretsch and Belitski, 2021), demonstrating that collaboration with universities could be subject to a specific firm type. According to prior research on the role of customers for innovation (Cappelli et al., 2014) and in family firms (Blombäck and Botero, 2013; Martínez-Sanchis et al., 2021), Brittelstand firms may have most of their customers not in the UK, while they continue benefiting most from innovation collaboration with local customers (β=1.121, $p<0.05$)..

Furthermore, Brittelstand firms are less likely to employ open innovation models nationally (β=0.842, $p<0.05$) (specification 2, Table 4), in Europe (β=0.866, $p<0.05$)

(specification 3, Table 4) and globally (β=0.531, $p<0.05$) (specification 4, Table 4). We conclude that the geography of collaboration helps Brittelstand firms to overcome the gap in external collaboration. Indeed, local embeddedness favours contact with customers within close geographical proximity, which is associated with cognitive and special relatedness and culture, helping Brittelstand firms to understand what their customers need. Brittelstand firms are as likely as non-Brittelstand firms to collaborate with different partners, demonstrating they both have the same willingness to collaborate (specifications 5-10, Table 4).

Brittelstand and other firms have a similar likelihood of collaborating with all types of external partners, except for universities and customers. Brittelstand firms prefer to collaborate within close spatial proximity in an attempt to maintain their close relationship with local communities and balance their economic goals (innovation and growth) with their SEW considerations. While open innovation facilitates firm growth (Saura et al., 2022), the regional focus of collaboration with external partners allows them to keep control over their business and to communicate their regional attachment (Banalieva and Eddleston, 2011). This argument is confirmed by the lower likelihood of Brittelstand firms (compared to non-Brittelstand firms) to collaborate with partners at the national, European, and global levels.

TABLE 4 ABOUT HERE

Our findings also demonstrate that localized customer knowledge could generate additional returns to innovation for the Brittelstand with all coefficients positive and statistically significant (specifications 1-8, Table 5). Knowledge collaboration with customers increases innovation sales on average by 39% for regional collaboration and by 79% for national collaboration. The Brittelstand firms' coefficient is insignificant, meaning that Brittelstand firms are on average as innovative as non-Brittelstand firms. Once we perform the interaction

analysis (specifications 5-8, Table 5), our results partly support H2. Knowledge collaboration with customers regionally increases innovation sales of Brittelstand firms on average by 70% (β=0.70, $p<0.01$) (specification 5, Table 5), whereas collaboration with customers in national markets increases innovation sales for Brittelstand firms on average by 75% (β=0.75, $p<0.01$) (specification 6, Table 5). Knowledge collaboration with customers internationally does not result in additional innovation for Brittelstand firms compared to non-Brittelstand firms (specification 7-8, Table 5).

TABLE 5 ABOUT HERE

Taken together, our results reveal the existence of a specific innovation model in Brittelstand firms which focuses on open innovation with regional partners, while the benefits of knowledge collaboration emanate from collaboration with national and regional customers. Brittelstand firms limit their willingness to collaborate on knowledge with universities, and are as likely as other firms to collaborate on innovation with other types of external partners. The open innovation model with local and national customers emerges as an attractive and economically-efficient strategy for the Brittelstand, and extends what we know at a micro-level perspective about returns and limits to open innovation (Saura et al., 2021, 2022).

The additional returns from domestic partners in the Brittelstand can be explained by the ease of knowledge transfer facilitated by, among other things, the community embeddedness of Brittelstand firms (Intihar and Pollack, 2012). Their local focus allows Brittelstand firms to benefit from their good reputation and superior social capital in the local market, and to access tacit customer knowledge in order to improve their innovation processes and outcompete non-Brittelstand firms.

Interestingly, while they have high export ambitions, Brittelstand firms remain less able to innovate with European and global customers than their non-Brittelstand counterparts.

Robustness check

We start our robustness check by controlling for potential nonlinearities in the relationship between the propensity to collaborate and returns to collaboration for Brittelstand firms. In line with Lind and Mehlum's (2010) approach, we calculated predictive margins to test the likelihood of collaboration with regional, national, European and other international partners for Brittelstand firms and non-Brittelstand (other) firms. (Figures 1A-1D). Our results confirm the analysis of Table 5 (specifications 1-4) as we found Brittelstand firms are more likely to choose regional collaboration partners, and are less likely to choose collaboration partners beyond their region (national market) as well as in Europe and other world countries. All relationships with 95% confidence intervals are significant and robust.

We also calculated the predictive margins to test the difference in the likelihood of collaboration within the enterprise group, as well as open knowledge collaboration with suppliers, customers, competitors (coopetition), consultants, universities, and governments between Brittelstand firms and non-Brittelstand firms. We found significant differences in the propensity to collaborate with customers and universities, which contrasts with prior research on the role of customers in innovation in family firms (Figure 2A-2G). While this result is surprising, it demonstrates that Brittelstand firms are different from family firms and other firms that liaise with customers to co-develop their products. Brittelstand firms have a strong feeling of belongingness to an organization and place, which may define with whom and to what extent they are likely to collaborate. Our findings also demonstrate that willingness to collaborate may be associated with Brittelstand culture of open innovation.

5. Discussion and conclusion

Recent studies have suggested that the Mittelstand innovation culture may extend beyond Germany (Pahnke et al. 2022), with only a small fraction of family firms that experience international recognition benefiting from open innovation and growing rapidly via experimentation and innovation (Financial Times, 2015; Brinkerink and Bammens, 2018; DeBellis et al., 2021).

As a result, researchers, practitioners and policymakers have focused on understanding how innovation models in family firms work in Europe and globally (Hernández-Perlines et al., 2021; Rovelli et al., 2021; Daspit et al., 2021). This study draws attention to the conceptualization and empirical test of the Brittelstand innovation model, yet distinct from - the Mittelstand innovation model in Germany (Schutte, 2015; Pahnke et al., 2022).

To answer this research question, we examine a novel matched dataset from the BSD and the UKIS during 2004-2020 which includes 13,876 firms with 24,286 observations. Drawing on the extant literature on RBV (Barney, 1991; De Massis et al., 2018; Baù et al., 2019), as well as open innovation (Chesbrough, 2003; Saura et al., 2021, 2022), we argue that Brittelstand firms are more likely to collaborate with customers in open innovation setting than non-Brittelstand firms due to their family ownership and embeddedness in communities, and in doing so are likely to achieve greater innovation output. These results align with previous studies emphasizing the local embeddedness of family firms (Audretsch et al., 2021; Arrègle et al., 2007; Basco and Suwala, 2020; Dunn, 1996). While the Brittelstand has the scale and growth orientation needed to operate globally and develop innovative new products, there is a paucity of knowledge regarding how Brittelstand firms innovate and which theory can explain the Brittelstand phenomenon (Brittelstand symposium, 2019).

Building on the recent pervasive critique of open innovation (Audretsch et al., 2020a; Saura et al., 2021, 2022), our study emphasizes the existing heterogeneity of external partners for knowledge collaboration and the importance for the Brittelstand firms of carefully choosing

whom, when and to what extent they will collaborate on knowledge. In doing so, this study draws attention to the boundary conditions or factors that provide a market advantage for Brittelstand firms and increase the success of knowledge collaboration. When engaging in open collaboration with customers, Brittelstand firms develop strategic alliances through community embeddedness, trust, and customer loyalty through generations (Neubaum and Micelotta, 2021), which is unlikely to be achieved by non-Brittelstand, non-family-owned firms.

We argue that Brittelstand firms which aim to promote innovation should pay more attention to external collaborations with customers regardless of their size and age.

Unlike prior research that focused on the paucity of human and financial capital in family firms (Intihar and Pollack, 2012; De Massis et al., 2018, 2020), building on the resource-based view of family firms (Barney, 1991), this study introduces a new dynamic of family firm innovation by explaining the extent to which Brittelstand firms are willing to collaborate with external knowledge partners and across different geographical proximities. We also examined the benefits of this open innovation model, in particular for external collaboration with customers and main users.

As such, we advance the consideration of innovation in high-growth family firms such as the Brittelstand which has been emphasized by practitioners (Financial Times, 2015; Brittelstand Symposium, 2019) and policymakers (Hernández-Perlines et al., 2021; Rovelli et al., 2021), but which has been largely absent from the scholarly discourse examining theories of innovation in high-growth family firms. The conceptual implications of this study related to understanding the phenomenon of Brittelstand's innovation are as follows.

Firstly, we demonstrated that Brittelstand firms use open innovation models in domestic markets, creating certain cognitive, institutional, and spatial boundaries of innovation. It is important to note that firm specificities do not affect the way Brittelstand firms weigh

partnerships with their customers and the risk of engaging in open innovation with them, as echoed by the family-firm literature (DeBellis et al. 2021).

Secondly, expanding upon Pahnke et al. (2022), our study illustrates that family-firm innovation occurs at the intersection of firm-, institutional- and spatial-level conditions in explaining how Brittelstand firms employ the open innovation model of collaboration and identifying the perspective outputs of such collaboration. Our findings expand our understanding of both why firms innovate (Chrisman et al., 2015; Kotlar et al., 2018; Audretsch and Belitski, 2020b) and how they do it.

Thirdly, our research advances the view of De Massis et al. (2018) and Pahnke et al. (2022) that adopting an open innovation strategy will enable high-growth family firms to overcome resource limitations and fully explain their willingness and ability to engage in open innovation (Chrisman et al., 2015; Debellis et al., 2021). In this vein, by applying our conceptual lens to factors that promote knowledge collaboration for Brittelstand, we discuss theories that facilitate or impede firm innovation such as open innovation (Chesbrough, 2003), the resource-based view (Barney, 1991; Mallon et al., 2018) and the symbolic interaction theory (Aksan et al., 2009). Specifically, to provide a more nuanced conceptualization of innovation by Brittelstand firms, we offer a two-step model of Brittelstand firm innovation and estimate it using econometric methods. Collaboration with customers was hypothesized to be a key factor for innovation in the Brittelstand, as the extent to which the Brittelstand and Mittelstand rely on and perceive a commitment to their communities as a sense of belongingness (Pahnke et al., 2022) and externally though innovation is astonishing (Lumpkin and Bacq, 2021).

Fourthly, our results also add to the prior research on the role of geographical proximity in knowledge spillovers and innovation efforts (Ardito et al., 2019; Wixe et al., 2021) by demonstrating that an increase in geographic distance hinders returns to knowledge collaboration with customers, potentially due to limits to open innovation, an increase in

transaction costs (Audretsch and Belitski, 2022), and potential cognitive distance between produces and customers (Balland et al., 2015). The concepts of familiness and SEW could be very helpful in understanding why returns to customer collaboration regionally and nationally are positive for Brittelstand innovation. This would expand the earlier works of Habbershon and Williams (1999) on the roles of familiness and family involvement, and the works of Gedajlovic et al. (2012) and Mallon et al. (2018) on the Mittelstand firm growth success. Our study also expands on the embeddedness of families and their firms in local territories (Basco and Suwala, 2021) and the body of research that considers family firms embeddedness in a broad context as a precondition for growth and innovation (Daspit et al., 2021).

Entrepreneurial and managerial implications

Our findings also have practical implications for top managers and entrepreneurs in Brittelstand firms who manage existing or young ventures, and who thus need to understand the conditions and consequences of the two boundary conditions for innovation in the Brittelstand. First, Brittelstand firms are less likely to employ open innovation models nationally and with customers. However, those Brittelstand firms who decide to collaborate with customers nationally are more likely to increase their innovation sales compared to firms which do not engage in such collaborations. This is an interesting and unexpected finding, and means that Brittelstand firms' low willingness to engage in cross-country and cross-regional collaboration is not optimal, and that engagement in collaboration with customers in domestic markets is beneficial for innovation. Managers and policymakers may use this finding to design and re-design their open innovation strategies with customers within and across regions in the UK.

Second, decision-makers may benefit from the integrated view on the two drivers of firm innovation: collaboration with customers, and the local embeddedness of such collaboration. Managers wishing to further reduce the uncertainty and volatility of the innovation process and

add value may wish to pay attention to the tensions between type and proximity of external partners in the open innovation model, carefully considering why and with whom to collaborate and within what geographical dimension,. Another implication for managers around firm innovation pertains to encouraging organizations to experiment with new competitive areas or 'blue oceans' locally, nationally, and even internationally.

Third, while collaboration is also associated with additional costs, local and national governments may want to subsidize and incentivize national collaboration with customers as well as ad-hoc international collaborations across different customer types. This would allow companies to tap into diverse knowledge and acquire more radical innovation inputs and ideas (Audretsch et al., 2021), and to leverage resource limitations (Feranita et al., 2017; Gamble et al., 2020; Pantano et al., 2020). Brittelstand firms on their own may not be willing or able to engage in such collaborations due to their short-term strategies and high costs of collaborationHowever, family firms which are able to overcome these resource and mental constraints should be able to gain greater access to knowledge and increase their innovation outputs (Intihar and Pollack, 2012; De Massis et al., 2018, 2020).

While this study's focus goes beyond firm characteristics to explore innovation outputs, there is still the need for more work exploring how these forces work in tandem with industrial and regional factors to enable firm innovation. In this vein, further research should explore multi-level factors which have the potential to jointly enable transitions from non-innovator to innovator. Nonetheless, future research may address this interplay in further detail by predicting how various firm-, meso- and macro-factors combine to affect firm innovation for Brittelstand firms vs. non-Britellstand firms, as well as performing cross-country comparisons of high-growth and innovative family-owned firms.

This study's contribution to theory and practice is in identifying the Brittelstand's open collaboration with customers as an important boundary condition that may fill the gap in

innovation in high growth and innovative family firms such as the Mittelstand in Germany and the Brittelstand in the UK (Financial Times, 2015; Brittelstand symposium, 2019). We also extend the family business literature by showing not only why but how open innovation with external partners may convert into innovation outputs.

Limitations and directions for future research

As with all research, this paper has several limitations that present opportunities for future scholars wishing to replicate and/or extend this study. First, this study used unbalanced panel data, and some firms appear in the model only once from 2004-2020. Using a longitudinal study will allow future studies to enforce the causality of the relationship and examine the dynamics of open innovation in the Brittelstand.

Second, the indicator on the extent and mechanisms of collaboration with customers could be better explained and measured. For example, future research could use a scale indicator instead of a binary variable for knowledge collaboration across different types of partners and four geographical dimensions. Information on the forms, channels, and mechanisms of knowledge collaboration with customers and the intensity of such collaboration may also be required.

More research is needed to emphasize the specific characteristics of Brittelstand firms that help them overcome the motivational gap to engage in knowledge collaboration. These characteristics include their lower willingness to collaborate with universities or internationally.

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Table 1. Industry/regional and firm size distribution of a sample

Industry distribution Firms Share %			Regional distribution	Firms	Share %
1 - Manufacturing other	5733	23.61	North East	1435	5.91
2 - High-tech manufacturing	805	3.31	North West	2270	9.35
3 - Construction	2537	10.45	Yorkshire and The Humber	2016	8.30
4 - Wholesale, retail trade	3712	15.28	East Midlands	1948	8.02
5 - Transport, storage	1407	5.79	West Midlands	2149	8.85
6 – Accommodation and food	1259	5.18	Eastern	2231	9.19
7 – ICT	1873	7.71	London	2297	9.46
8 – Finance and insurance	869	3.58	South East	2617	10.78
9 - Real estate	474	1.95	South West	2050	8.44
10 – Professional and scientific	2783	11.46	Wales	1608	6.62
11 - Administration	2573	10.59	Scotland	1904	7.84
12 – Education	106	0.44	Northern Ireland	1761	7.25
13 - Other community, social activity	155	0.64	**Total**	**24286**	**100.00**
Total	**24286**	**100.00**			
Size distribution, including Brittelstand firms			Waves UKIS-BSD		
Micro-firms (1-9 FTEs)	1611	6.63	2004-2006	8486	34.94
small firms (10-49 FTEs)	11,161	45.96	2006-2008	5811	23.93
medium small (50-99 FTEs)	3750	15.44	2008-2010	2561	10.55
medium large (100-249 FTEs)	2836	11.68	2010-2012	2572	10.59
large (250 + FTEs)	4928	20.29	2012-2014	1423	5.86
Total	**24286**	**100.00**	2014- 2016	1177	4.85
			2016-2018	1095	4.51
			2018-2020	1164	4.78
			Total	**24286**	**100.00**

Source: Office for National Statistics (2021a). Department for Business, Innovation and Skills, Office for National Statistics, Northern Ireland. Department of Enterprise, Trade and Investment. (2021). UK Innovation

Survey, 1994-2021: Secure Access. [data collection]. 6th Edition. UK Data Service. SN: 6699, http://doi.org/10.5255/UKDA-SN-6699-6
Office for National Statistics (2021b). Business Structure Database, 1997-2021: Secure Access. [data collection]. 9th Edition. UK Data Service. SN: 6697, http://doi.org/10.5255/UKDA-SN-6697-9
Further source: UK Innovation Survey, 1994-2021 and Business Structure Database, 1997-2021: Secure Access. UK Data Service.

Table 2. Descriptive statistics

Label		Description of variables	Survey used	Mean	Std. Dev.
Regional collaboration		DV for step 1: Firm collaborates with external partners on innovation regionally =1, 0 otherwise	UKIS	0.14	0.35
National collaboration		DV for step 1: Firm collaborates with external partners on innovation nationally (country)=1, 0 otherwise	UKIS	0.19	0.39
Europe collaboration		DV for step 1: Firm collaborates with external partners on innovation in European countries=1, 0 otherwise	UKIS	0.09	0.28
World collaboration		DV for step 1: Firm collaborates with external partners on innovation in other world countries =1, 0 otherwise	UKIS	0.08	0.26
Group		DV for step 1: Firm collaborates innovation with other businesses within enterprise group=1, 0 otherwise	UKIS	0.03	0.06
Suppliers		DV for step 1: Firm collaborates innovation with suppliers of equipment, materials, services=1, 0 otherwise	UKIS	0.09	0.09
Clients		DV for step 1: Firm collaborates innovation with clients or customers=1, 0 otherwise	UKIS	0.14	0.11
Competitors		DV for step 1: Firm collaborates innovation with competitors=1, 0 otherwise	UKIS	0.03	0.05
Universities		DV for step 1: Firm collaborates innovation with universities =1, 0 otherwise	UKIS	0.02	0.04
Government		DV for step 1: Firm collaborates innovation with local or national government =1, 0 otherwise	UKIS	0.02	0.03
Innovation sales		DV for step 2: Percentage of sales of products and services that are new to the market in total sales (0-100)	UKIS	0.40	0.12
Brittelstand		Binary variable equal one if firm is a Brittelstand firm: fully or partly owned by a family; is an SME; has revenue between 1 and 10 million pound sterling; has demonstrated growth over the last three years consecutively, zero otherwise	Brittelstand Symposium	0.15	0.35
Small size firm		Binary variable equal one if employment is 10-49 FTEs, zero otherwise	BSD	0.45	0.49
Medium size firm		Binary variable equal one if firm has employment is 50-249 FTEs, zero otherwise	BSD	0.28	0.45
Training		Binary variable=1 if firms does training activity for innovation, zero otherwise	UKIS	0.25	0.43
Design		Binary variable=1 if firms has had any form of design expenditure on innovation, zero otherwise	UKIS	0.43	0.49
Entrepreneurial climate		New methods of organising work responsibilities and decision making (use of a new system of employee responsibilities, teamwork, decentralisation, integration or de-integration education/ training etc.)	UKIS	0.21	0.41
Process innovation internal		Binary variable=1 if firm introduced any new or significantly improved processes for producing or supplying goods or services, zero otherwise.	UKIS	0.23	0.42
Process innovation external		Binary variable=1 if firm introduced any new methods of organising external relationships with other firms or public institutions, zero otherwise.	UKIS	0.26	0.43
Legal Status	Company	Binary variable=1 if firm's legal status is limited liability company, 0 otherwise	BSD	0.843	0.364
	Sole proprietor	Binary variable=1 if firm's legal status is Sole-proprietor, 0 otherwise	BSD	0.041	0.199

	Public corporation	Binary variable=1 if firm's legal status is Public corporation, 0 otherwise	BSD	0.001	0.028
	Non-for-profit body	Binary variable=1 if firm's legal status is Non for profit, 0 otherwise	BSD	0.013	0.114
In-house R&D expenditure		Internal Research and Development expenditure (£) in logs	UKIS	1.31	2.13
External R&D		Binary variable=1 if firm's buys R&D and other knowledge from external organizations, zero otherwise	UKIS	0.16	0.36
Scientists		The proportion of employees that hold a degree or higher qualification in science and engineering at BA / BSc, MA / PhD, PGCE levels	UKIS	7.47	17.26
Exporter		Binary variable=1 if a firm sells its products in foreign markets, 0 otherwise	UKIS	0.37	0.48
Foreign		Binary variable=1 if a firm has headquarters abroad, 0 otherwise	UKIS	0.41	0.49
Firm age		Age of a firm in logarithms	BSD	2.66	0.75

Source:
UK Innovation Survey, 1994-2021 and Business Structure Database, 1997-2021: Secure Access. UK Data Service; Brittelstand symposium (2019).

Number of observations 24286 observations and 13876 unique firms after controlling for missing values in all variables.

Table 3. Descriptive statistics for collaboration variables

Label		**Description of variables**	Mean	SD.
UK Regional Binary variable=1 if firm co-operates on innovation regionally	Group	Within enterprise group, 0 otherwise	0.055	0.228
	Suppliers	With suppliers, 0 otherwise	0.067	0.250
	Clients	With customers, 0 otherwise	0.083	0.276
	Competitors	With competitors in the industry, 0 otherwise	0.035	0.185
	Consultants	With consultants or private R&D labs, 0 otherwise	0.040	0.197
	Universities	With universities, 0 otherwise	0.044	0.204
	Government	With government, 0 otherwise	0.027	0.161
UK National Binary variable=1 if firm co-operates on innovation within national market	Group	Within enterprise group, 0 otherwise	0.063	0.243
	Suppliers	With suppliers, 0 otherwise	0.114	0.318
	Clients	With customers, 0 otherwise	0.129	0.335
	Competitors	With competitors in the industry, 0 otherwise	0.057	0.232
	Consultants	With consultants or private R&D labs, 0 otherwise	0.065	0.246
	Universities	With universities, 0 otherwise	0.048	0.213
	Government	With government, 0 otherwise	0.044	0.204
European Countries Binary variable=1 if firm co-operates on innovation within European countries	Group	Within enterprise group, 0 otherwise	0.038	0.191
	Suppliers	With suppliers, 0 otherwise	0.050	0.218
	Clients	With customers, 0 otherwise	0.052	0.221
	Competitors	With competitors in the industry, 0 otherwise	0.021	0.143
	Consultants	With consultants or private R&D labs, 0 otherwise	0.016	0.124
	Universities	With universities, 0 otherwise	0.010	0.100
	Government	With government, 0 otherwise	0.008	0.087
Other Countries Binary variable=1 if firm co-operates on innovation with other world (excluding Europe and UK)	Group	Within enterprise group, 0 otherwise	0.037	0.188
	Suppliers	With suppliers, 0 otherwise	0.037	0.189
	Clients	With customers, 0 otherwise	0.047	0.211
	Competitors	With competitors in the industry, 0 otherwise	0.017	0.130
	Consultants	With consultants or private R&D labs, 0 otherwise	0.013	0.115
	Universities	With universities, 0 otherwise	0.009	0.095
	Government	With government, 0 otherwise	0.007	0.083

Source:
UK Innovation Survey, 1994-2021 and Business Structure Database, 1997-2021: Secure Access. UK Data Service.
Number of observations 24286 and 13876 unique firms after controlling for missing values in all variables.

Table 4. Logistic regression for Brittelstand firms. Dependent variables: collaboration with external partners

Dependent variable	Geography of collaboration								Collaboration partners											
Specification	(1)	p-value	(2)	p-value	(3)	p-value	(4)	p-value	(5)	p-value	(6)	p-value	(7)	p-value	(8)	p-value	(9)	p-value	(10)	p-value
Geography of collaboration	regional		country		Europe		World		Group		Supplier		Customer		Competitor		University		Government	
Brittelstand (H1)	**1.121 (.11)**		**0.842 (.08)**	<0.01	**0.866 (.11)**	<0.01	**0.531 (.10)**	<0.01	**1.450 (1.00)**		**0.204 (.16)**		**0.241 (.17)**	<0.05	**0.539 (.11)**		**0.348 (.05)**	<0.05	**0.785 (1.52)**	
Firm age	0.973 (.03)		0.989 (.04)		0.981 (.04)		0.979 (.03)		1.028 (.13)		0.862 (.11)		0.760 (.11)		1.103 (.10)		1.384 (.44)		1.119 (.41)	
Process innovation internal	2.103 (.07)	<0.01	2.374 (0.07)	<0.01	1.850 (.08)	<0.01	1.754 (0.07)	<0.05	2.940 (0.90)	<0.01	2.275 (0.80)	<0.05	1.911 (0.71)	<0.01	1.680 (0.48)	<0.01	2.301 (0.91)	<0.05	3.485 (1.60)	<0.01
Small-size firm	1.184 (.08)	<0.01	0.920 (.26)		0.837 (.17)		0.795 (.11)	<0.01	0.701 (.18)		0.717 (.15)		1.074 (.20)		0.773 (.19)		0.544 (.14)		0.414 (.15)	
Medium-size firm	1.149 (.06)	<0.01	0.997 (.07)		0.757 (.05)	<0.05	0.682 (.06)	<0.05	0.480 (.15)		0.574 (.17)	<0.01	0.757 (.10)	<0.05	0.575 (.23)		0.361 (.13)		0.304 (.15)	
Training	1.501 (.11)	<0.01	1.512 (.11)	<0.01	1.432 (.12)	<0.05	1.043 (.20)		0.955 (.19)		0.347 (.18)	<0.05	0.312 (.17)	<0.05	2.136 (.47)		2.059 (.44)		0.963 (.16)	
Design	1.455 (.09)	<0.05	1.380 (.09)	<0.05	1.374 (.07)	<0.01	1.531 (.09)	<0.05	1.805 (.12)	<0.01	1.514 (.13)	<0.01	1.616 (.15)	<0.01	1.688 (.10)	<0.01	0.817 (0.36)		1.255 (.11)	
Scientist	1.001 (.07)	<0.05	1.006 (.05)	<0.01	1.011 (.09)	<0.05	1.015 (.09)	<0.01	1.006 (.32)		1.004 (.30)		1.010 (.28)	<0.01	1.004 (.29)	<0.01	1.014 (.20)	<0.01	1.022	<0.05
In-house R&D expenditure	1.086 (.01)	<0.05	1.168 (.02)	<0.05	1.153 (.03)	<0.01	1.194 (.02)	<0.01	1.143 (.04)	<0.01	1.159 (.03)	<0.01	1.097 (.05)	<0.01	1.294 (.04)	<0.01	1.272 (.03)	<0.01	1.057 (.09)	
Foreign	0.758 (.07)		1.432 (.04)	<0.01	4.369 (.11)	<0.01	4.076 (.15)	<0.01	7.211 (.54)	<0.01	3.267 (.59)	<0.01	10.971 (1.12)	<0.05	2.631 (0.30)	<0.05	3.241 (0.29)	<0.01	2.261 (.47)	
Industry controls (2 digit SIC)	Yes		Yes		Yes		Yes		Yes		Yes		Yes		Yes		Yes		Yes	
Year controls	Yes		Yes		Yes		Yes		Yes		Yes		Yes		Yes		Yes		Yes	
City-regions controls	Yes		Yes		Yes		Yes		Yes		Yes		Yes		Yes		Yes		Yes	
Constant	0.08 (.00)	<0.01	0.17 (.01)	<0.01	0.12 (.01)	<0.01	0.09 (.01)	<0.01	0.08 (.01)	<0.01	0.22 (.01)	<0.01	0.12*** (.01)		0.10 (.01)	<0.01	0.05 (.01)	<0.01	0.07 (.01)	<0.01
Chi2	2581.2		4815.2		3658.2		3412.3		265.3		473.2		714.6		267.5		269.1		352.1	
Log-likelihood	-5964.		-6017.1		-3589.		-3141.		-319.3		-654.1		-907.3		-324.7		-198.7		-174.2	

Note: Results are reported in odd ratios. Standard errors are robust for heteroscedasticity in parenthesis. Industry (1 digit SIC) and year fixed effects are suppressed to save space. Estimation method: logistic regression. Note: reference category for legal status is Company (limited liability company). industry (mining), region (North East of England). Robust standard errors are in parenthesis.

Source: UK Innovation Survey, 1994-2021 and Business Structure Database, 1997-2021: Secure Access. UK Data Service.

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Number of observations 24286 and 13876 unique firms after controlling for missing values in all variables.

Table 5. Mixed-effect GLM estimation of product innovation. Dependent variable – share of new to market products

Specification	(1)		(2)		(3)		(4)		(5)		(6)		(7)		(8)	
Region of collaboration	Regional	p-value	National	p-value	Europe	p-value	World	p-value	Regional	p-value	National	p-value	Europe	p-value	World	p-value
Small	0.54 (.08)	<0.01	0.56 (.08)	<0.01	0.57 (.07)	<0.01	0.56 (.07)	<0.01	0.55 (.08)	<0.01	0.59 (.08)	<0.01	0.59 (.07)	<0.01	0.51 (.08)	<0.01
Medium	0.38 (.00)	<0.01	0.38 (.03)	<0.05	0.40 (.00)	<0.01	0.39 (.08)	<0.01	0.38 (.00)	<0.01	0.38 (.03)	<0.05	0.40 (.00)	<0.01	0.39 (.08)	<0.01
Training	0.33 (.00)	<0.01	0.34 (.00)	<0.01	0.37 (.00)	<0.01	0.38 (.00)	<0.01	0.33 (.00)	<0.01	0.34 (.00)	<0.01	0.37 (.00)	<0.01	0.38 (.00)	<0.01
Design	0.74 (.00)	<0.01	0.73 (.00)	<0.01	0.71 (.00)	<0.01	0.69 (.00)	<0.01	0.74 (.00)	<0.01	0.70 (.00)	<0.01	0.70 (.00)	<0.01	0.65 (.00)	<0.01
Entrepreneurial climate	0.09 (.05)		0.08 (.05)		0.09 (.06)		0.10 (.07)		0.09 (.05)		0.05 (.05)		0.08 (.06)		0.10 (.07)	
Process innovation external	0.68 (.00)	<0.01	0.64 (.00)	<0.01	0.68 (.00)	<0.01	0.71 (.00)	<0.01	0.68 (.00)	<0.01	0.64 (.00)	<0.01	0.68 (.00)	<0.01	0.71 (.00)	<0.01
Process innovation internal	0.25 (.00)	<0.01	0.25 (.00)	<0.01	0.26 (.00)	<0.01	0.27 (.00)	<0.01	0.25(.00)	<0.01	0.25 (.00)	<0.01	0.26 (.00)	<0.01	0.27 (.00)	<0.01
In-house R&D expenditure	0.23 (.00)	<0.01	0.22 (.00)	<0.01	0.22 (.01)	<0.01	0.25 (.01)	<0.01	0.25 (.02)	<0.01	0.20 (.01)	<0.01	0.22 (.01)	<0.01	0.25 (.01)	<0.01
External R&D	0.18 (.00)	<0.01	0.19 (.00)	<0.01	0.19 (.02)	<0.01	0.20 (.02)	<0.01	0.18 (.00)	<0.01	0.19 (.00)	<0.01	0.19 (.02)	<0.01	0.20 (.02)	<0.01
Scientists	0.005 (.00)	<0.01	0.005 (.00)	<0.01	0.006 (.00)	<0.01	0.006 (.00)	<0.01	0.005 (.00)	<0.01	0.005 (.00)	<0.01	0.006 (.00)	<0.01	0.007 (.00)	<0.01
Exporter	0.65 (.05)	<0.01	0.61 (.05)	<0.01	0.61 (.08)	<0.01	0.52 (.02)	<0.01	0.68 (.04)	<0.01	0.63 (.06)	<0.01	0.61 (.08)	<0.01	0.52 (.02)	<0.01
Foreign	-0.07 (.05)		-0.08 (.07)		-0.07 (.08)		-0.07 (.09)		-0.07 (.05)		-0.08 (.07)		-0.08 (.09)		-0.09 (.06)	
Firm age	-0.07 (.01)	<0.01	-0.08 (.02)	<0.01	-0.07 (.02)	<0.01	-0.07 (.02)	<0.01	-0.07 (.01)	<0.01	-0.08 (.02)	<0.01	-0.07 (.02)	<0.01	-0.08 (.02)	<0.01
Brittelstand	**0.03 (0.03)**		**0.05 (0.04)**		**0.08 (0.06)**		**0.08 (0.05)**		**0.04 (.03)**		**0.05 (.03)**		**0.06 (.05)**		**0.07 (.05)**	
Customers	0.44*** (.07)		0.84** (.06)		0.49*** (.12)		0.55*** (.05)		0.39*** (.02)		0.76** (.04)		0.48*** (.05)		0.45*** (.05)	
Brittelstand x Customers (H2)									**0.70 (.16)**	<0.01	**0.75 (.26)**	<0.01	**0.43 (.50)**		**0.81 (.53)**	
Controls for collaboration partner	Yes		Yes		Yes		Yes		Yes		Yes		Yes		Yes	
Constant	-1.93 (.05)	<0.05	-1.98 (.04)	<0.05	-1.90 (.05)	<0.05	-1.89 (.04)	<0.01	-1.91 (.04)	<0.01	-1.97 (.05)	<0.01	-1.90 (.05)	<0.05	-1.88 (.05)	<0.01
variance (year)	1.20 (1.1)		1.09 (.25)		1.20 (.92)		1.21 (.24)		1.20 (.90)		1.17 (.79)		1.20 (.79)		1.22 (.67)	
variance (year / region)	0.07	<0.01	0.08	<0.01	0.08	<0.01	0.09	<0.01	0.07	<0.01	0.08	<0.01	0.08	<0.01	0.09	<0.01

	(.02)		(.03)		(.02)		(.02)		(.02)		(.03)		(.02)		(.02)	
LR test vs. logistic model: chi2	712.12		758.96		800.09		803.75		731.01		736.45		811.01		803.04	
Overall model chi2	1922.85		1925.31		1915.10		1908.09		1925.49		1953.43		1916.28		1911.51	
log likelihood	-5129.41		-5210.10		-5138.8		-5139.3		-5125.1		-5120.6		-5138.3		-5136.9	

Note: standard errors are robust for heteroscedasticity in parenthesis. Reference category for firm size=large firm (250+ FTEs); Reference category for firm ownership status: public corporation. Industry (1 digit SIC) and year fixed effects are suppressed to save space. Estimation method: Mixed-effects GLM: Product innovation regression/ LR test vs. logistic model supports use of Multi-level mixed-effects generalized linear model. Controls for collaboration include binary variables for external stakeholders' controls: enterprise group, suppliers, customers, competitors, universities, government. Collaboration with consultants is a reference category.
Source: UK Innovation Survey, 1994-2021 and Business Structure Database, 1997-2021: Secure Access. UK Data Service.
Number of observations 24286 observations and 13876 unique firms after controlling for missing values in all variables.

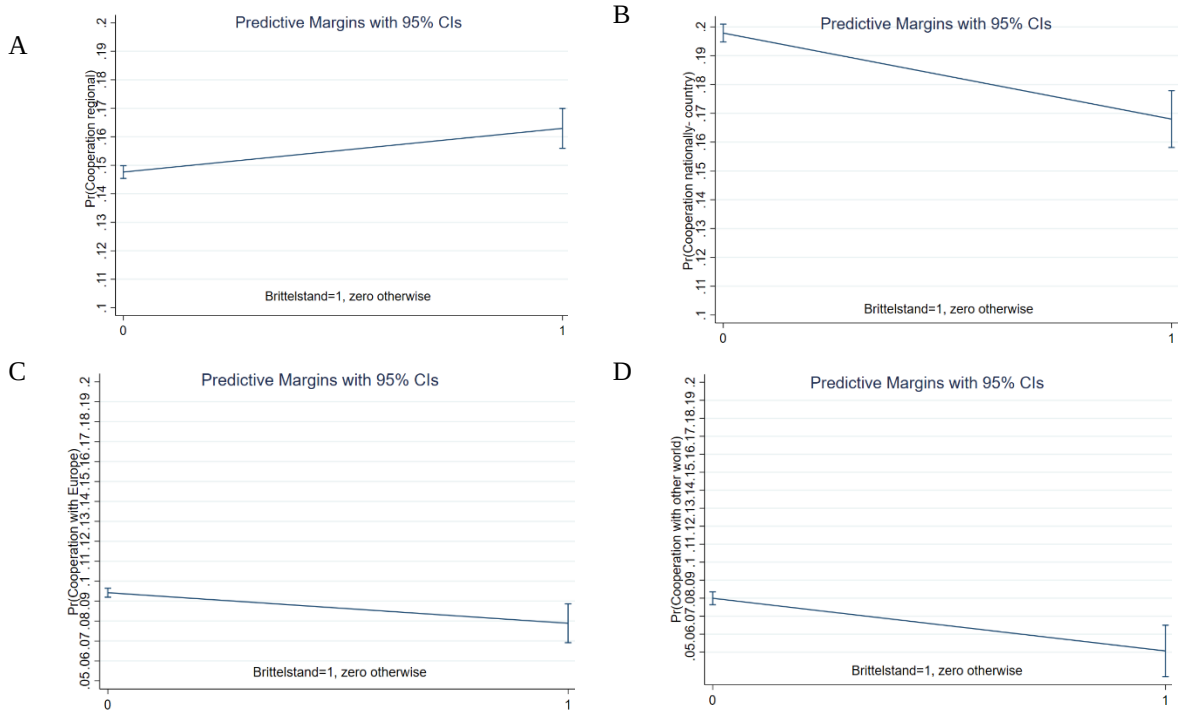

Figure 1. Predictive margins of collaboration with regional (A), national (B), European (C) and other world (D) partners for innovation between the Brittelstand and non-Brittelstand firms.

Source: UK Innovation Survey, 1994-2021 and Business Structure Database, 1997-2021: Secure Access. UK Data Service

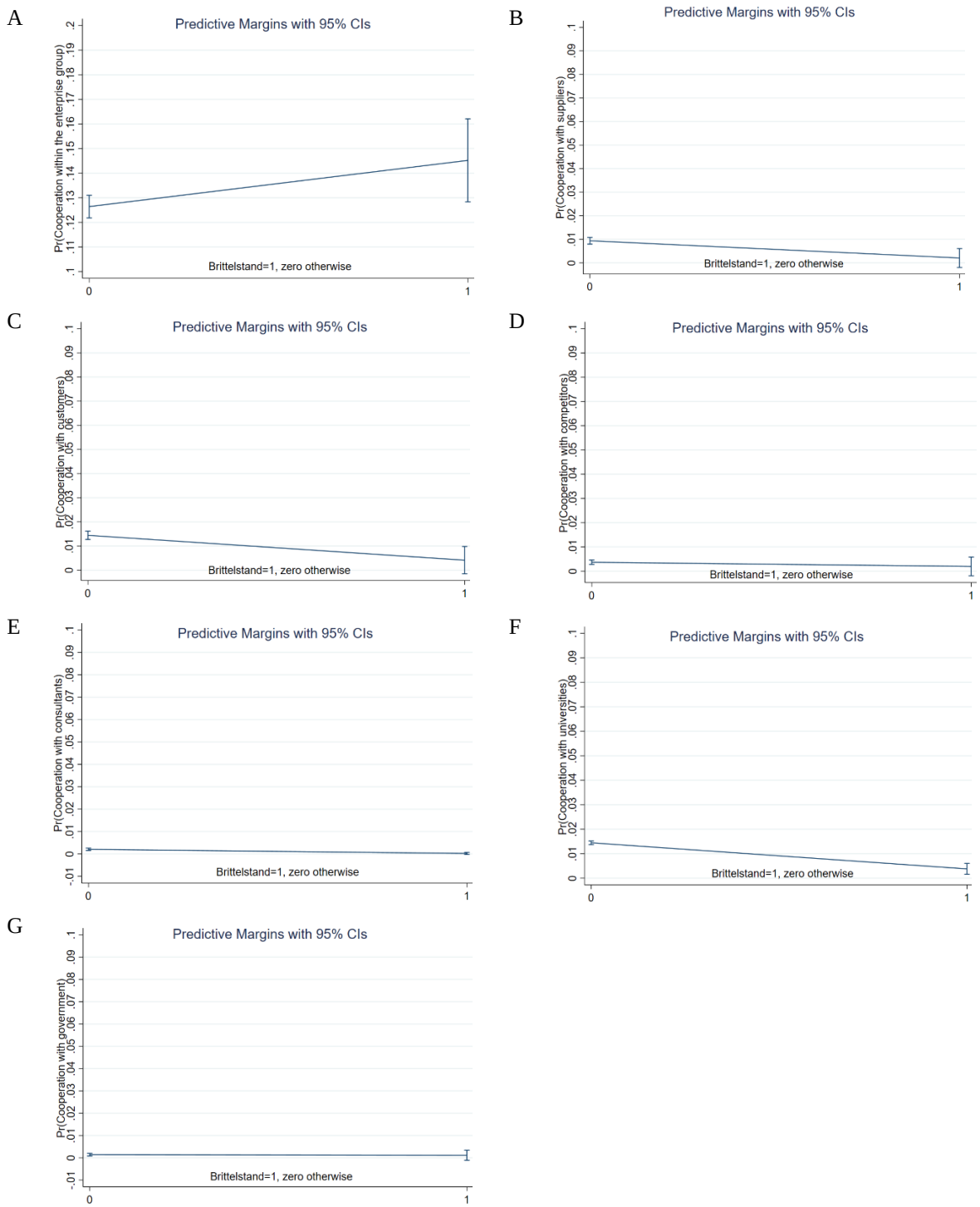

Figure 2: Predictive margins of collaboration with enterprise group (A), suppliers (B), customers (C) competitors (D), consultants (E), universities (F) and government (G) for innovation between the Brittelstand and non-Brittelstand firms.

Source: UK Innovation Survey, 1994-2021 and Business Structure Database, 1997-2021: Secure Access. UK Data Service