

R&D COLLABORATION BREADTH AND FAMILY-FIRM INNOVATION EFFICIENCY: THE ROLE OF FAMILY MANAGEMENT AND GENERATIONAL STAGE

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Abstract. This paper examines the relationship between R&D collaboration breadth and innovation efficiency within family firms. Based on the socioemotional wealth approach and recognising that family firms constitute a rather heterogeneous group, we study family firms' differences in the way of addressing the R&D collaboration breadth-innovation efficiency link, taking into account family management and the generational stage. Using a panel dataset of 424 manufacturing family firms during the 2007–2016 period, we find significant differences across family firms in the translation of gains from R&D collaboration breadth into innovation efficiency. Specifically, our findings reveal that family firms with higher levels of family management and in first generational stage weaken the R&D collaboration breadth – innovation efficiency link.

Keywords: innovation efficiency, R&D collaboration breadth, family management, generational stage, socioemotional wealth.

JEL Classification: M10, O32, O36.

Introduction

In today's rapidly changing and innovative business environments, R&D collaboration breadth and innovation efficiency have become vital strategic imperatives for the competitiveness or even the survival of firms (Feng et al., 2022; Lyu et al., 2020; Serrano-Bedia et al., 2019). Although existing evidence suggests that the link between R&D collaboration breadth and innovation efficiency is relatively established in the literature (Hernandez-Vivanco et al., 2018; Stefan & Bengtsson, 2017; Un & Asakawa, 2015), it does not necessarily hold true in the family firm sphere (Arzubiaga et al., 2019; Manzaneque et al., 2018). This is particularly striking considering that family firms, which, defined as firms predominantly dominated by a family with a focus on keeping family control over generations (Zellweger, 2017), stand

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for two-thirds of all firms in the world and generate the overwhelming majority of jobs and GDP in most economies worldwide (Family Firm Institute, 2018). Moreover, existing research suggests that family firms' distinctive characteristics, idiosyncratic behaviour, vision towards continuity and transgenerational outlook make them a unique organizational setting (Brinkerink et al., 2017) for examining R&D collaboration breadth and its influence on innovation efficiency.

Although some efforts have been made to improve the understanding of family firms' distinctive behaviour regarding such innovation strategies (Pellegrini & Lazzarotti, 2019; Serrano-Bedia et al., 2019), the subject is still scarce and contentious, as most studies so far have merely focused on comparing family and non-family firms (Alberti et al., 2014; De Massis et al., 2015), thus rejecting heterogeneity in family firms (Calabrò et al., 2019; Chrisman et al., 2015). Some scholars note that family firms draw on a larger amount of external partners to get access to resources and knowledge for innovation than non-family firms, because of their greater ability to manage collaborative R&D projects, due to unique family features, such as long-term orientation and strong social capital (Bigliardi & Galati, 2018; De Massis et al., 2015; Llach & Nordqvist, 2010). Other scholars highlight that family firms have a lower diversified partner set than non-family firms (Alberti et al., 2014; Lazzarotti et al., 2017), because of the lower family firms' readiness to be involved in R&D collaborative projects, due to family-specific attributes, such as limited cognitive diversity, craving for control and power, propensity for conservatism and parsimony or risk aversion. Thereby, in the light of these mixed results, a more in-depth exploration of family firms' differences in the way of addressing R&D collaboration breadth to achieve innovation efficiency is urgently required (Gjergji et al., 2019). Furthermore, it seems particularly relevant to achieve a better comprehension of how family-specific characteristics influence and shape the link between R&D collaborations and innovation efficiency (Bigliardi & Galati, 2018; Casado-Belmonte et al., 2021).

Based on these gaps identified in extant literature, the objective of this study is to analyse the moderating role of two family-specific characteristics, namely family management and the generational stage, which may have a critical role in determining family firms' heterogeneous behaviour in relation to the R&D collaboration breadth – innovation efficiency link. In doing so, we use socioemotional wealth (SEW), defined as the non-financial dimensions of firms that meet families' affective needs, such as, for example, the family identity or the capacity to exert family influence (Gómez-Mejía et al., 2007), as the main theoretical approach to elaborate our reasoning. Given that family firms' willingness to safeguard SEW varies according to the generational stage in which firms are, and according to the level of family management (Arzubiaga et al., 2019; Fang et al., 2018), we argue that these variations will be reflected in important family firms' differences towards R&D collaboration breadth and consequently, in the manner in which the latter is translated into innovation efficiency. To check the proposed moderated relationships, we use a panel dataset of 424 manufacturing family firms for the 2007–2016 period.

This study adds to the literature in several ways. First, it enriches the lively debate on family firm innovation by revealing that the influence of R&D collaboration breadth on innovation efficiency varies across family firms because of the divergence in family's SEW goals and priorities. In so doing, this study offers new empirical evidence to the ongoing and prominent

debated on the heterogeneity of family firms (Daspit et al., 2021), and responds to the need for further research on this topic (Alayo et al., 2022; Muñoz-Bullón et al., 2018). In this sense, by introducing family management on the one hand, and the firm generational stage on the other hand, as moderating factors in the R&D collaboration breadth – innovation efficiency linkage, we provide very valuable insights on how family-specific characteristics distinctively influence and shape innovation decision-making within family firms. Finally, this study provides interesting practical and managerial implications.

1. Theoretical background and hypotheses

R&D collaboration breadth, or the number of distinct external partners (i.e., competitors, universities, suppliers, customers) with which a firm collaborates simultaneously (Faems et al., 2010), is a powerful strategy that enables firms to build competitive advantages and increase value by exchanging and sharing their resources with those of other entities along the supply chain (Godlewska et al., 2022; Van Beers & Zand, 2014). The study of R&D collaboration breadth has gained considerable relevance in today's complex landscape, where family firms are increasingly looking to create interactive innovation networks with different types of partners to address issues related to shortening innovation cycles, decreasing R&D costs, enhancing firm outcomes, and ultimately creating value for all stakeholders (Ferrerás-Méndez et al., 2015; Martínez-Alonso et al., 2022a; Martínez-Romero et al., 2020). Accordingly, R&D collaboration breadth is crucial for firms' long-term survival (Lyu et al., 2020; Stuart, 2000), and specifically, it is essential for family firms to survive across generations (Bigliardi & Galati, 2018; Feranita et al., 2017).

The central purpose of establishing R&D collaboration breadth is geared towards achieving better innovation performance (Nieto & Santamaría, 2007; Pereira & Leitão, 2016), in order to ensure the continuous launch of improved and new products on the market, while minimizing the cost of innovation processes (Arzubiaga et al., 2019). In this regard, previous studies have shown that R&D collaborations with a multiplicity of diverse partners lead to cumulative learning effects with positive implications for firms' innovation efficiency (Becker & Dietz, 2004; Jiang et al., 2010; Van Beers & Zand, 2014). Furthermore, the effective usage and integration of external ideas and innovations from the combination of various channels can significantly help firms to achieve the synergies and the necessary complementarities to ensure more efficient innovation processes (Cui et al., 2015; Lyu et al., 2020).

Nevertheless, to date, there is a dearth of available knowledge on how the impact of R&D collaboration breadth on innovation efficiency varies across family firms and, in essence, how family management and the generational stage may moderate such link. In family firms, the interplay of family and firm systems and the wish to maintain the firm control in family hands across generations give rise to idiosyncratic goals, behaviours, and resources that directly affect their strategic choices (Memili et al., 2015; Nordqvist & Zellweger, 2010), and particularly those choices related to innovation, such as R&D collaborations (Ardito et al., 2019; Feranita et al., 2017).

According to resource-based view and stewardship scholars, R&D collaboration breadth can be an important tool allowing family firms to achieve and maintain competitive advan-

tages for innovation efficiency (Bigliardi & Galati, 2018; Martínez-Alonso et al., 2022a). In this regard, family firms seem to be able to manage promising R&D collaboration projects because of their long-term vision and higher level of social capital (De Massis et al., 2015; Llach & Nordqvist, 2010). Other scholars also suggest that the imprint of tradition for innovation, i.e., the integration of practices, beliefs and the know-how belonging to past generations (De Massis et al., 2016), endow family firms with unique managerial and entrepreneurial competences, which can benefit the attainment of greater innovation efficiency from more fruitful collaborative R&D relationships (Del Vecchio et al., 2019; Erdogan et al., 2020).

Contrary to this positive view, certain studies have found that R&D collaboration breadth may not be a panacea for family firms insofar as it implies significant risks for their family control (Gómez-Mejía et al., 2007; Memili et al., 2015), as it would force them, for example, to provide confidential information to different potential partners (e.g., universities), or to cede part of products' technological paths to such partners (Kotlar et al., 2013). R&D collaboration breadth also demands high levels of commitment and the contribution of own resources and expertise to the network (Lazarrotti et al., 2017), something that in most cases family firms are not ready or willing to assume. This is because family firms tackle R&D collaborations with the SEW preservation as the main point of reference (Bigliardi & Galati, 2018; Veider & Matzler, 2016). SEW refers to the non-financial aspects and affective needs pursued by family firms, such as the capacity to exercise family influence over the firm, or the emotional attachment among firm members (see Berrone et al., 2012, for a review). SEW allows to explain differences among family firms' R&D collaboration breadth, as the ultimate objective of preserving such SEW results in a conservative approach, characterized by risk aversion and linkages with less diversified sets of innovation partners (Classen et al., 2012).

By focusing primarily on comparisons between family and non-family firms (Lazarrotti et al., 2017; Nieto et al., 2015), most studies up to now have overlooked the idea that family firms strongly differ in the manner in which they conduct R&D collaboration agreements to achieve innovation performance. Given that not all family firms share the same set of SEW goals and priorities when developing collaborative innovation (Lazarrotti & Pellegrini, 2015) and thus, do not equally translate the benefits derived from such networks into innovation efficiency, we explore under what conditions family management and the generational stage might influence the R&D collaboration breadth – innovation efficiency relationship.

1.1. Moderating role of family management

Family management, defined as the participation of family members in the firm's TMT (Martínez-Alonso et al., 2020), is a common SEW source for a family (Block et al., 2013) because it has a more immediate and direct impact on shaping and defining the firm's innovation strategy (Li & Daspit, 2016). As the number of family managers increases, decisions and actions around R&D collaboration breadth are likely to be more influenced by a greater concern for SEW preservation (Arzubiaga et al., 2019). In other words, an increased presence of an owning family in the TMT will lead to prioritising SEW aspects, such as craving for control and power (Bigliardi & Galati, 2018; Gjergji et al., 2019), arguably counterproductive for turning R&D collaboration breadth into innovation efficiency.

Improving innovation efficiency via R&D collaboration breadth is not without its difficulties (Aiello et al., 2021) and would therefore push family firms to recruit non-family managers, characterized by greater skills than family managers (Casillas et al., 2010) to adequately manage these complex networks. The recruitment of these non-family managers can increase the levels of professionalization and technical expertise of family firms' TMTs (Pellegrini & Lazzarotti, 2019), which is crucial for establishing relationships with diverse set of partners to develop and implement R&D collaborative projects (Feranita et al., 2017). Nevertheless, family managers are usually hesitant to allow non-family managers to take control of the strategic decisions (Kotlar et al., 2013), as this implies ceding discretionary power on the R&D collaboration strategies to outsiders. As a result, family firms' TMTs typically suffer from limited cognitive diversity (Bigliardi & Galati, 2018) that, in turn, undermines certain technical competencies (e.g., absorptive capacity) that are essential ingredients for effectively managing the complexity of diverse innovation networks (Classen et al., 2012).

Moreover, family firms' desire to safeguard SEW leads to scenarios where family managers are appointed on the basis of nepotism and altruism, rather than meritocracy considerations (Ashwin et al., 2015; Llach & Nordqvist, 2010). In other words, if nepotism is the assumed rule, unqualified family relatives will be appointed to key management posts (Schepers et al., 2014), thus limiting the family firm TMT's ability to cope with choices and activities associated with R&D collaboration breadth.

Furthermore, the fact that different potential partners gain power over future products' technological paths (De Massis et al., 2015), may be perceived by family managers as a loss of the family's capacity to exert unfettered authority and a hazard to the foundation of SEW authority (Gómez-Mejía et al., 2010). The reluctance to loss family control and authority in R&D collaborations, in turn, minimises the broadmindedness and knowledge that family managers possess of other entities, a key aspect for improved efficiency in innovation processes (Kraiczyn et al., 2014).

Hence, we expect that a high level of family management will act as a major barrier to the achievement of innovation efficiency from R&D collaboration breadth, due to the greater family managers' preference for maintaining SEW. Accordingly, we propose that:

Hypothesis 1. Family management negatively moderates the R&D collaboration breadth-innovation efficiency relationship.

1.2. Moderating role of generational stage

The generational stage, which applies to the generation that controls and also manages the firm (Cruz & Nordqvist, 2012; Diéguez-Soto et al., 2022), represents an important source of heterogeneity in family firms' innovation decision-making (Eddleston et al., 2019). While family firms in first generational stage are run by the founder, family firms in second and later generational stages are managed by successive generations, distinguished by a more professional leadership style and a less "paternalistic" approach (Alayo et al., 2022). Research indicates that the significance that family firms give to SEW goals is closely related to the generation in charge of the firm (Stockmans et al., 2010) and varies throughout the different generational stages (Fang et al., 2018). Specifically, SEW preservation is probably more salient

for family firms in first generational stage because family firm founders are typically distinguished for having stronger personal attachment, self-identification and commitment to the firm (Fang et al., 2018; Le Breton-Miller & Miller, 2013). Family firms are thus expected to approach the link between R&D collaboration breadth and innovation efficiency differently according to their generational stage.

In the first generational stage, the founder's entrepreneurial spirit may struggle with the aim of maintaining family control (Gómez-Mejía et al., 2007). As a result, family firm founders might be reluctant to engage in certain innovation activities, because they may imply, for example, ceding a critical part of the innovation process to be run by external partners (e.g., suppliers), which will be detrimental to SEW (De Massis et al., 2015). Accordingly, family firm founders will tend to avoid innovation strategies, such as R&D collaboration breadth, which may ultimately erode the family's control over the business. Conversely, in second and later generational stages, family firm descendants are expected to place less emphasis on preserving family control, preferring instead the goal of passing on a healthy and successful business to next generations (Muñoz-Bullón et al., 2018). Consequently, this greater preference for continuing the family legacy may lead family firm descendants to be more open-minded about innovation activities (Sánchez-Marín et al., 2020). Thus, subsequent generations will be more willing to collaborate on R&D with different types of partners to achieve enhanced innovation efficiency.

Moreover, family firms in first generational stage are likely to have a high identification with the firm (Sciascia et al., 2014), and therefore, family firm founders will avoid situations, such as allowing partners to take control of innovation processes, as it may involve, for example, losing the association of the family name with the products of their businesses (Kotlar et al., 2013). In addition, the strong emotional attachment of family firm founders is expected to be reflected in lower complacency towards external partners (Muñoz-Bullón et al., 2018), thus reducing any aspiration to engage in R&D collaboration agreements. Contrary, in second and later generational stages, the identification and the emotional attachment of family firm descendants are likely to diminish (Le Breton-Miller & Miller, 2013). Differences in needs, goals, and commitments of family members from multiple family branches raise the risk of conflict and nepotism (Kellermanns et al., 2012), requiring more formal governance mechanisms and control systems (Voordeckers et al., 2007), which are excel to better managing R&D collaboration breadth and therefore, to obtaining improved innovation efficiency.

Thereby, we argue that family firms in first generational stage are more likely to preserve SEW and avoid engaging in complex and uncertain innovation strategies, thus negatively influencing the link between R&D collaboration breadth and innovation efficiency. Accordingly, we formulate that:

Hypothesis 2. The generational stage negatively moderates the R&D collaboration breadth-innovation efficiency relationship.

The proposed relationships are depicted in Figure 1.

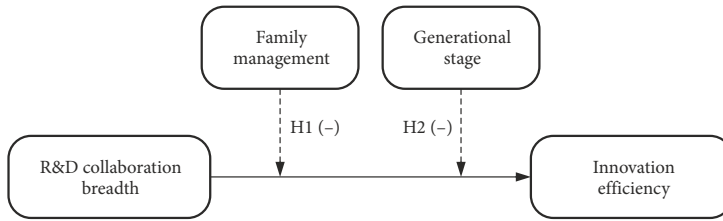


Figure 1. Theoretical model

2. Empirical study

2.1. Data and sample

The dataset utilised is the Survey on Business Strategies (ESEE). This is a longitudinal survey administered on a yearly basis, comprising all manufacturing sectors in Spain according to NACE Rev. 2. The data are collected by the SEPI Foundation and the Spanish Ministry of Industry, Trade and Tourism. The sample provides an accurate and representative image of the Spanish manufacturing industry and the sampling procedure is stratified according to firm size. That is, all businesses over 200 employees are surveyed, while businesses comprising between 10 and 200 employees are selected by random sampling. Firms leaving the sample for any cause are substituted with new firms, following the previously described sampling procedure. The ESEE contains a broad array of information related to firms' operations, including their products, services, technological activities, accounting data, and so on. All the ESEE information is controlled for quality and consistency.

Given the wide range of information, several previous studies have employed the ESEE as a primary data source (e.g., Martínez-Alonso et al., 2022b; Un & Asakawa, 2015). The ESEE is particularly relevant to our research because of the following aspects. First, the ESEE approach in the manufacturing industry seems appropriate for investigating the impact of R&D collaborations on innovation efficiency, as four out of ten Spanish firms involved in innovation activities pertain to this industry (Confederación Española de Organizaciones Empresariales [CEOE], 2018), and the products of such firms are typically made up of components provided from other actors (Almirall & Casadesus-Masanell, 2010). Second, although business families are active in a broad spectrum of industries, family firms are found to be a predominant organisational form in manufacturing industries (Kotlar et al., 2014). Third, the ESEE enables the use of longitudinal designs, which is crucial for examining the suggested hypotheses in this study.

Taking into account the objectives of our study, we chose a sample entirely composed of family firms. The ESEE employs a dummy variable to distinguish between family and non-family firms. The ESEE establishes that firms are categorized as family firms when they are self-identified as being part of a family group. This self-identification method is extensively accepted and commonly applied in prior studies (e.g., Gjergji et al., 2020; Martínez-Romero et al., 2022; Sánchez-Marín et al., 2020). After eliminating firms with missing values in the main variables, an unbalanced panel dataset of 424 family firms and 1,851 firm-year observations was obtained. Table 1 shows a detailed picture of the sampled firms according to the sub-industry to which they belong.

Table 1. Distribution of the sampled firms by sub-industry and technological intensity^a

	N	%
<i>High technology</i>	656	35.44
Chemical and pharmaceutical products	205	11.08
Agricultural and industrial machinery	178	9.62
Computer, electronic and optical products	40	2.16
Electrical machinery and material	79	4.27
Motor vehicles	109	5.89
Other transport equipment	45	2.43
<i>Medium and Low technology</i>	1,195	64.56
Meat industry	124	6.70
Foodstuffs and snuff	225	12.16
Drinks	62	3.35
Textiles and clothing	144	7.78
Leather and footwear	43	2.32
Timber industry	29	1.57
Paper Industry	24	1.30
Graphics	23	1.24
Rubber and plastic	101	5.46
Non-metallic mineral products	122	6.59
Ferrous and non-ferrous metals	45	2.43
Metal products	140	7.56
Furniture industry	85	4.59
Other manufacturing	28	1.51
Total (observations)	1,851	100.00

Notes: ^aHigh-, medium- and low-technology industries have been classified according to the Spanish National Statistics Institute criteria.

2.2. Variable operationalization

2.2.1. Innovation efficiency

We follow Martínez-Alonso et al. (2022b) and use the ratio between number of product innovations and firms' R&D expenditure as a proxy for innovation efficiency. According to our measure, innovation efficiency increases when a higher number of new products is obtained with an equal amount of R&D, or when the same number of new products is produced with a lower quantity of R&D.

2.2.2. R&D collaboration breadth

As in previous research (e.g., Laursen & Salter, 2006), we define R&D collaboration breadth as the number of external partners that firms rely upon to enhance their innovation processes. In the ESEE database, firms annually specify whether they have been involved or not in R&D collaborations with (1) competitors, (2) universities and/or technological institutes,

(3) suppliers, and (4) customers. These four items are initially coded as dummy variables, with 1 being the use of the type of partner and 0 being non-use. We then measure R&D collaboration breadth as the sum of these four dummy variables, ranging from 0 (the firm does not collaborate with any partner) to 4 (the firm collaborates with all the indicated partners in the innovation process).

2.2.3. Family management

Consistent with Manzanque et al. (2020), we measure family management by counting the number of family owners and owners' relatives holding posts in the TMT of the family firm. Given that this is a direct measure of family influence on firms' decision-making, extant research often utilizes it as an objective indicator of family management (e.g., Muñoz-Bullón et al., 2020).

2.2.4. Generational stage

We follow Sánchez-Marín et al. (2020) and use a proxy of the family generation in charge of the business according to firm age. Particularly, we use a cut-off point of 25 years to catch generational effects (Gersick et al., 1997). Hence, we build a dummy variable that takes the value 1 if the family firm is in the first generational stage (less than 25 years old) and 0 if the family firm is in second or later generational stage (over 25 years old).

2.2.5. Control variables

We also incorporate some control variables into the analysis. We use firm size, innovation subsidies, financial slack, technology committee and the sub-industries in which firms operate. Therefore, first, we calculate firm size utilising the natural log of total assets. Second, we operationalize innovation subsidies as a dummy variable that is equal to 1 if the business reports to have obtained innovation subsidies and 0 otherwise. Third, we measure financial slack as the ratio of current assets to current liabilities. Fourth, we operationalize technology committee as a dummy variable that takes the value of 1 if the business has a technology or R&D committee and 0 otherwise. Finally, since literature suggests that innovation regimes vary dramatically across manufacturing sub-industries (Coad & Rao, 2008), possibly leading to different degrees of propensity regarding innovation efficiency (Martínez-Alonso et al., 2022b), we add twenty dummy variables representative of each manufacturing sub-industry to control for industry effects. Table 2 presents the means, standard deviations and correlations for all the variables. The inter-correlations between the explanatory variables are moderate, suggesting that multicollinearity is not a serious concern in this study.

2.3. Econometric tool: Random-effect Tobit models

To exploit the potential of the longitudinal character of our dataset, we use panel data models. Specifically, we use random-effect Tobit models for hypothesis testing. The utilization of Tobit models is due to the dependent variable, i.e., innovation efficiency, is left-censored (it is free of negative scores and many observations are 0). In this situation, Tobit models represent the best statistical method to avoid biased and inconsistent parameter estimates (Muñoz-Bullón et al., 2018). On the other hand, we opted for random-effect models because

Table 2. Means, standard deviations and correlations

	Mean	SD	1	2	3	4	5	6	7
1. Innovation efficiency ^a	0.04	0.43	1.00						
2. Firm size	17.11	1.46	-0.12***	1.00					
3. Innovation subsidies	0.29	0.45	-0.03	0.29***	1.00				
4. Financial slack	2.50	2.44	-0.01	-0.14***	-0.11***	1.00			
5. Technology committee	0.63	0.48	0.05*	0.21***	0.24***	-0.07***	1.00		
6. R&D collaboration breadth	1.59	1.14	-0.05	0.28***	0.39***	-0.06**	0.31***	1.00	
7. Family management	1.06	1.18	0.03	-0.16***	-0.01	0.06**	-0.03*	-0.04	1.00
8. Generational stage	0.26	0.44	0.07***	-0.20***	-0.02	-0.06**	-0.08***	-0.05*	-0.06**

Notes: ^aInnovation efficiency was rescaled by a factor of 1,000. *** $p < 0.01$; ** $p < 0.05$; * $p < 0.10$.

the time invariant character of certain control variables, such as industry effects, precludes us from using fixed-effect models (Ashwin et al., 2015). Furthermore, a lag of one year is used between the dependent variable and the remaining variables to minimize possible endogeneity problems and facilitate casual inference.

3. Results

3.1. Hypotheses testing

To examine the proposed hypotheses, we developed and tested a set of models. In order to mitigate potential multicollinearity issues that arise in moderating analyses and to obtain estimates that are easier to interpret, we mean-centred our interaction variables (Aiken & West, 1991).

Table 3 reports the random-effect Tobit regression results. Regarding hypothesis 1, we proposed a weakening moderating effect of family management on the R&D collaboration breadth-innovation efficiency relationship. In Model 1, we found that the interaction term between R&D collaboration breadth and family management is negative and statistically significant on innovation efficiency ($\beta = -0.057$, $p < 0.01$). This implies that high levels of family management are not rewarding for the link between R&D collaboration breadth and innovation efficiency. Thus, hypothesis 1 is fully supported (a more nuanced picture of this effect is provided in Figure 2).

Regarding hypothesis 2, we postulated that the generational stage weakens the R&D collaboration breadth-innovation efficiency link. In Model 2, we found that the interaction term between R&D collaboration breadth and generational stage is negative and statistically significant ($\beta = -0.120$, $p < 0.01$). The abovementioned effect on innovation efficiency is shown in

Figure 3. These results indicate that the relationship between R&D collaboration breadth and innovation efficiency is weaker for family firms in first generational stage. Thus, hypothesis 2 is strongly supported.

Last, a complete model (Model 3), which simultaneously includes both interaction terms, confirms the obtained results.

Table 3. Random-effect Tobit regression results for hypotheses 1 and 2

Dependent variable: Innovation efficiency ^a						
	Model 1		Model 2		Model 3	
	Coeff.	SE	Coeff.	SE	Coeff.	SE
1. Firm size _{t-1}	-0.053**	0.027	-0.052**	0.027	-0.050**	0.027
2. Innovation subsidies _{t-1}	0.085**	0.063	0.070*	0.063	0.074*	0.063
3. Financial slack _{t-1}	-0.012	0.013	-0.010	0.013	-0.010	0.013
4. Technology committee _{t-1}	0.196***	0.066	0.193***	0.066	0.192***	0.066
5. Industry dummies _{t-1}	yes		yes		yes	
6. R&D collaboration breadth _{t-1}	0.077**	0.033	0.053**	0.031	0.135***	0.039
7. Family management _{t-1}	0.128***	0.039	0.032*	0.024	0.141***	0.039
8. Generational stage _{t-1}	0.197***	0.073	0.376***	0.103	0.411***	0.103
9. R&D collaboration breadth _{t-1} * family management _{t-1}	-0.057***	0.018			-0.065***	0.019
10. R&D collaboration breadth _{t-1} * generational stage _{t-1}			-0.120***	0.049	-0.146**	0.049
11. Intercept	0.112	0.469	0.135	0.472	0.011	0.469
12. Wald chi-square	50.46***		46.80***		58.91***	
13. Log likelihood	-1079.138		-1080.878		-1074.742	
14. Likelihood ratio test	110.13***		113.97***		108.00***	

Notes: ^aInnovation efficiency was rescaled by a factor of 1,000. ***p < 0.01; **p < 0.05; *p < 0.10.

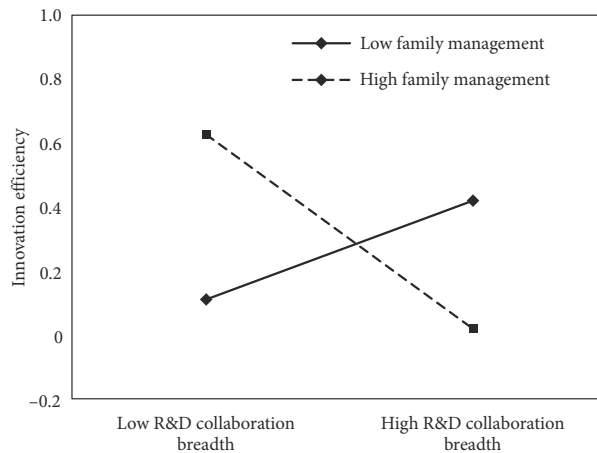


Figure 2. Moderating influence of family management on the R&D collaboration breadth-innovation efficiency relationship

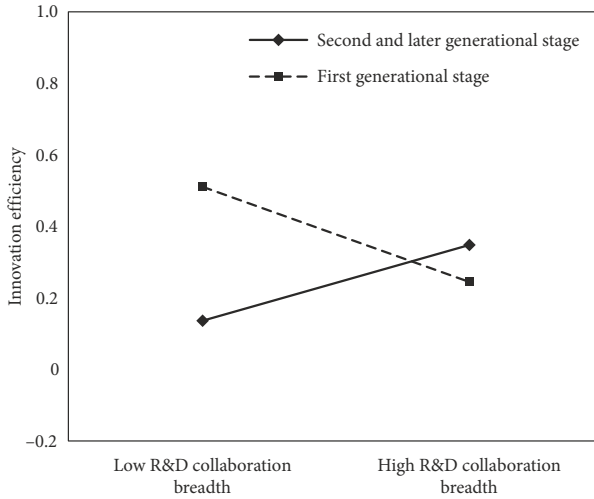


Figure 3. Moderating influence of the generational stage on the R&D collaboration breadth-innovation efficiency relationship

4. Robustness checks

To ensure the robustness of these results, we performed additional estimates. They are available upon authors' request. First, we repeated the main regression analysis by considering an alternative measure of R&D collaboration breadth. This variable is set to 0 if the firm does not engage in R&D collaborations with any partner, to 1 if the firm collaborates with one partner, or to 2 when the collaboration is made with at least two partners. Hypotheses 1 and 2 are supported with the same level of significance, which further confirms our results in Table 3.

Second, we also created alternative measures for our moderating variables. For family management, we built a dummy variable operationalized as 1 if one or more family members occupy posts in the TMT, and 0 otherwise. Regarding generational stage, we classified firms into three categories according to the 25-year cut-off point: first generational stage, second generational stage, and third and later generational stage. Three dummy variables were constructed accordingly. For both moderators, our hypotheses 1 and 2 are supported with the same level of significance, thus our results are reinforced.

Conclusions and future research

Scholars are immersed in a lively and heated debate about the family-specific characteristics that can provide a better understanding of the distinctive manners in which family firms conduct collaboration agreements to achieve improved innovation performance. Contributing to this debate, and in view of the fact that family firms are heterogeneous entities regarding innovation, we aim to elucidate the conditions under which family management and the generational stage influence family firms' R&D collaboration breadth to obtain innovation efficiency. To do so, we apply random-effect Tobit regression models on a panel dataset of 424 manufacturing family firms for the period 2007–2016.

Regarding our first hypothesis, we find that high levels of family management weaken the positive relationship between R&D collaboration breadth and innovation efficiency. This result is consistent with prior studies supporting that family management decreases efficiency levels in innovation processes, due to their common lack of professional skills and their focus on non-economic family goals. In other words, family managers fear losing control over innovation processes and also fear the technological and economic failure that may result from R&D collaborations, which would jeopardise their SEW.

Concerning our second hypothesis, the results corroborate that family firms in first generational stage reduce the beneficial influence of R&D collaboration breadth on innovation efficiency. This finding is in consonance with extant studies evidencing that family firms in second and later generational stages are more open-minded towards innovation. Successive generations are likely to be more committed to strategic change and innovation and attach less importance to family aspects, such as keeping autonomy on the innovation process or identification with the firms' products, as a result of a decreased preference for retaining SEW. In addition, family firms in second and later generational stages tend to be staffed by more experienced and educated family members, with the required technical skills and knowledge to achieve higher innovation efficiency from R&D collaborations.

Therefore, this study enriches the ongoing debate on family firm innovation by using the SEW approach to deepen in the heterogeneity of achieving higher innovation efficiency from R&D collaborations. Specifically, this study increases the understanding of the conditions under which, two salient family-specific characteristics, namely family management and the generational stage, shape the R&D collaboration breadth-innovation efficiency link within family firms. Taken together, our work advances existing knowledge and offers a more holistic view of the heterogeneous behaviour of family firms regarding innovation.

Our study also has practical implications. It is clear from our results that a high level of family management does not lead to greater innovation efficiency derived from R&D collaboration breadth. Therefore, family firms should professionalize their TMTs. In this regard, non-family managers are expected to increase the search breadth for new partners to collaborate with, enhance the use of more diverse outside knowledge and broaden cognitive diversity by incorporating fresh insights previously unknown to the family. Thus, family managers should move away from their need to "keep it all in the family" and should include properly skilled non-family managers in TMTs.

Moreover, as first-generation family firms weaken the R&D collaboration breadth-innovation efficiency link, family founders should try to foster innovative collaborations that promote innovation efficiency from the firm's inception. Family founders should be aware of the positive consequences of R&D collaborations on innovation efficiency since the firm's establishment. Consequently, family founders should adapt their management style, trying not to exclusively focus on control concerns, being less paternalistic and more professional.

At the institutional level, policy makers can contribute to enhance innovation efficiency from R&D collaborations by introducing a series of specific policies and initiatives, such as, for example, the protection of intellectual property rights, to support firm networking. In this way, they can also incentivise the protection of SEW or facilitate the access of family firm owners and managers to new knowledge on the topics of R&D collaborations and innovation efficiency by strengthening family business' professional networks.

Nevertheless, our study has some limitations. First, our findings rely on a sample of Spanish firms, so they cannot be generalised elsewhere. Second, the ESEE does not contain information on whether innovations are incremental or radical. Thus, future studies should consider not only the quantity of innovations, but also their typologies, to calculate a more accurate measure of innovation efficiency. Third, future research could contemplate other family managers' features, such as age difference, gender, seniority, or educational diversity. Finally, more emphasis should be given to the study of the link between R&D collaboration and innovation efficiency at the international level, which is an under-explored issue in the family firm field.

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Author contributions

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