Inter-firm R&D collaborations and green innovation value: The role of family firms' involvement and the moderating effects of proximity dimensions

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ABSTRACT

The present paper investigates the relationship between the involvement of family firms in R&D collaborations aimed at developing green solutions and the value of resulting innovations. To dig into this relationship, the moderating effects of two proximity dimensions (i.e., geographical distance and technological relatedness) are also assessed. Analyses are based on a sample of 156 joint patents classified into the "Alternative energy production" field, as defined by the International Patent Classification Green Inventory, and successfully filed at the United States Patent and Trademark Office in the period 1997-2010 by publicly listed companies. According to our conjectures, results reveal a positive relationship between the involvement of family firms and green innovation value. Moreover, our findings show that this relationship is hindered when partners are geographically distant or technologically proximate. Eventually, we contribute to the literature on green innovation by unveiling under which conditions inter-firm R&D collaborations lead to more valuable innovations.

Keywords: family firm; green innovation; Inter-firm R&D collaborations; proximity dimensions; alternative energy; joint patents

1 INTRODUCTION

Discussion about the relevance of inter-firm R&D collaborations has been translated into the context of green innovations – i.e., innovations aimed at reaching economic prosperity and environmental benefits simultaneously (OECD, 2012; Schiedering *et al*., 2012). Indeed, as emerged in a recent literature review (Hojnik and Ruzzier, 2016), green innovations require more complex and diversified knowledge and skills. Therefore, since a single company often does not internally possess all those required resources (Horbach *et al*., 2013), firms conducting green innovation activities should place more emphasis on external knowledge sourced by partnering with external actors (Hojnik and Ruzzier, 2016). Accordingly, green innovators have resulted to establish more intensive external R&D relationships than innovators in non-green sectors (De Marchi and Grandinetti, 2013; Zhao *et al*., 2018). This phenomenon is further exacerbated by the fact that environmental issues do not usually represent core competencies for most firms, and returns of green innovations are more uncertain and riskier (De Marchi, 2012). Thereby, firms attempt to collaborate to mitigate the corresponding higher hazard of failure (Cainelli *et al*., 2015).

That said, it must be recognized that collaborating partners are not all equal, and an investigation of the different types of partners involved in joint innovation activities may contribute to explain differences across the value of resulting green innovations (Melander, 2017). Notwithstanding, very few studies have offered empirical evidence regarding the relationship between partners' types and green innovation performance (Dangelico and Pontradolfo, 2015; De Marchi and Grandinetti, 2013). In detail, to the best of our knowledge, no research has evaluated if the involvement of family firms may impact the value of green innovations resulting from inter-firm R&D collaborations. This is a relevant gap, considering that family firm decisions reflect broad criteria that go beyond financial objectives, as the case of socioemotional goals (Feldman *et al*., 2016; Souder *et al*., 2017), which may drive their behaviors towards proactive environmental (innovation) strategies (Berrone *et al*., 2010; Craig and Dibrell, 2006). In addition, family firms show unique characteristics regarding their innovative attitudes (Peruffo and Perri, 2017), particularly in collaborative R&D processes (Bigliardi and Galati, 2017; Feranita *et al*., 2017). For instance, distinctive traits of family firms in terms of social, patient, and survivability capital might place them in a more favorable position in the context of alliances than their non-family counterparts (Gomez-Mejia *et al*. 2007; Sirmon and Hitt, 2003), especially to develop innovations not only aimed at attaining economic returns, as green innovations. Thus, by integrating the streams of research on green innovation, collaborative innovation, and family business, we aim to answer the following research question: *Does the involvement of family firms in inter-firm R&D collaborations aimed at developing green solutions affect the value of resulting innovations?*

Several studies have also pointed out that proximity dimensions are crucial to elucidate the innovative outcomes of inter-firm R&D collaborations because they alter the effectiveness with which knowledge, problem-solving approaches, and objectives are shared among partners (Boschma, 2005; Oerlemans *et al*. 2001; Heringa *et al*., 2014). Proximity dimensions mainly refer to the geographical, technological, and organizational distance/relatedness between partners (Knoben and Oerlemans, 2006). Two of these proximity dimensions are particularly relevant in both the green innovation and family business contexts, namely (i) geographical distance, which points at the spatial distance that separates partners and (ii) technological relatedness, which accounts for the extent of similarity between partners in terms of technological knowledge.

Indeed, on the one hand, prior research recognizes that family firms differ from non-family ones in their ability to exploit resources that are geographically bounded and establish R&D relationships with localized organizations since they often present embeddedness within the cultural and socio-economic local context in which they arose and grew (Cappuyns, 2004; Sciascia *et al*., 2012). That is, territorial ties are very relevant, and they may strongly affect goals and strategies of family firms, also with regard to (collaborative) innovation. Therefore, the relationship between the involvement of family partners and the development of valuable innovations is likely to be contingent upon the geographic origin of the collaborating partners. This contingent effect is also of interest in the green innovation realm (Hansen, 2014). Notably, geographical distance between partnering firms may influence the development of this type of innovation given the geographically dispersed nature of environmental (technological) knowledge (Albino *et al*., 2014; Verdolini and Galeotti, 2011; Wagner, 2007). Yet, it is unclear whether and how the influence of family firms' involvement in green collaborative innovation projects is mitigated/augmented by the fact that partners come from distant geographic areas. On the other hand, family firms tend to maintain the focus on continuity rather than discontinuity, thus making them less able to divert their attention from current technological trajectories to innovate (König *et al*., 2013; Souder *et al*., 2017). Hence, when inter-firm R&D collaborations involve family firms, it is likely that differences between the technological stocks of the collaborating partners may ultimately affect the value of the generated innovations. This issue might turn more complex due to the non-path-dependent nature of green innovations since they "require firms to deal with different techno-economic problems which entail different kind of knowledge and knowledge interactions" (Ghisetti *et al*., 2015:1082; Nemet, 2012). Therefore, it seems to be also crucial to unveil the moderating effect of technological relatedness on the relationship between family firms' involvement and green innovation value. Eventually, the foregoing discussion leads to our second research question: *Do proximity dimensions (geographical distance and technological relatedness) moderate the relationship between the involvement of family firms in inter-firm R&D collaborations aimed at developing green solutions and the value of resulting innovations?*

To answer our research questions, we develop hypotheses and test them based on a sample of 156 dyadic joint patents classified into the "Alternative energy production" field and successfully filed at the United States Patent and Trademark Office (USPTO) in the period 1997-2010 by publicly listed companies. Results reveal a positive relationship between the involvement of family firms in inter-firm R&D collaborations and green innovation value. This relationship is hindered when partners are geographically distant or technologically related. Such findings let us unveil under which conditions collaborations foster the development of valuable green innovations.

The paper proceeds as follows. Next section develops the hypotheses. Afterward, the methodology and results are presented. Finally, we discuss main findings, implications, and future research directions.

2 THEORY AND HYPOTHESES

2.1 Family firms' involvement and green innovation value

The willingness and the ability to engage in collaborative innovation are different between family and non-family firms, such that inter-firm R&D collaborations may generate more value when a family firm is involved in because of the uniqueness deriving from the overlap between family and business (Bigliardi and Galati, 2017; Perri and Peruffo, 2017). This uniqueness is denoted by the dimensions of socioemotional wealth leading to the generation of higher social, patient, and survivability capital (Sirmon and Hitt, 2003). The former reflects the structural (networks and their configurations), cognitive (shared language and narratives), and relational (trust, norms, and obligations) capital family firms build to establish more effective relationships with third-party organizations while maintaining legitimacy with important stakeholders (e.g., customers and the local community). Patient capital represents instead family firms' more creative and long-term strategies (Kang, 2000), which put them in a better position to devote the proper time to cultivating knowledge transfer and problem-solving sharing processes with collaborating partners while limiting opportunistic behaviors (Arregle *et al*., 2007). The integration of these dimensions is the survivability capital. Since scholars have demonstrated that green innovations strongly benefit when they result from cooperative relationships (e.g., Hojnik and Ruzzier, 2016; De Marchi, 2012), the uniqueness of family firms respect to the establishment of effective partnerships is likely to improve the value of green innovations generated by inter-firm R&D collaborations involving this type of companies.

Furthermore, such uniqueness has been proven to enhance family firms' performance in specific areas of innovation (Peruffo and Perri, 2017). This may be the case of green innovation even though it exists a constant trade-off between their risk aversion and environmental, long-term orientation. That is, on the one side, family firms may opt for conservative, path-dependent innovation strategies (König *et al*., 2013) that may result in a suboptimal contribution to joint green innovation efforts, at least in their initial stages (Doluca *et al*., 2018). This is dependent upon the strong emotional ties to existing assets and the risk aversion against diversification and paradigmatic shifts (Souder *et al*., 2017), as the sustainability transition. On the other side, family firms are pushed to adopt or develop environmentally responsible innovations (Dangelico, 2017) since they are closely connected and more responsive to the growing environmental concerns of the local community (Zellweger and Nason, 2008; Huang *et al*., 2009, 2016), as result of their inclination to listen to family stakeholders (i.e., the social capital). On the same vein, Laguir *et al*. (2016) found that family firms are more involved in innovating to solve social or environmental issues than their non-family counterparts, supporting the stewardship perspective. This demonstrates that family firms present a better ability to turn competencies linked to the natural environment into innovative outcomes, as also confirmed by the fact that they better comply with environmental policies (Craig and Dibrell, 2006). Additionally, due to their long-term orientation (i.e., the patient capital), family firms are more likely to be socially responsible and adopt proactive environmental strategies to benefit future generations (Cennamo *et al*., 2012; Berrone *et al*., 2010; Yu *et al*., 2015), in turn improving their environmental performance (Block and Wagner, 2014). With this regard, Delmas and Gergaud (2014) showed that ties to future generations are associated with the adoption of sustainable certifications, which can be conductive to more valuable green innovations. Similarly, although the initial transition towards green innovation activities is perceived too risky and expensive by family firms, Doluca *et al*. (2018) found that their long-term orientation is mainly responsible for the ultimate impetus towards more environmentally-friendly oriented behaviors, which may be reflected into green innovations of higher value.

In summary, considering that family firms possess some distinctive traits that may make them ideal potential partner, and that these unique traits are also conductive to environmentally-friendly practices, we claim that:

> **Hypothesis 1 (H1).** *The involvement of family firms in inter-firm R&D collaborations aimed at developing green solutions is positively related to the value of resulting innovations.*

2.2 The moderating role of geographical distance

The relevance of geographical distance in the context of green innovations is noticeable because the knowledge and practices underlying this type of innovations are geographically dispersed (Albino *et al*., 2014; Verdolini and Galeotti, 2011; Wagner, 2007). This hints that geographically scattered R&D partners may better develop valuable green innovations. However, the cognitive, cultural, and managerial barriers (Asakawa, 2001) that emerge in cross-border R&D relationships cannot be underestimated, especially when family firms are involved. Notably, the social, patient, and survivability capital characterizing family firms are more evident when these collaborate with companies in their home country given the embeddedness within the same cultural and socio-economic local context (Cappuyns, 2004; Sciascia *et al*., 2012). Such embeddedness leads family firms to develop strong and trustworthy relational ties with local partners (Corbetta and Salvato, 2012), as well as to generate environmental knowledge that is sticky and, in turn, hard to transfer to geographically distant firms (e.g., Jaffe, 1999). Accordingly, being geographically proximate encourages the transfer of knowledge for sustainable development between R&D partners (Pavlovich and Akoorie, 2010). Therefore, we contend that cognitive, cultural, and managerial barriers are likely to weaken the benefits that family firms' involvement in inter-firm R&D collaborations has on green innovation value.

More in detail, geographical distance limits partners' ability to interact repeatedly and, hence, develop, learn, and adjust over time the idiosyncratic languages needed for sharing and retaining fine-grained and tacit information (Uzzi, 1997), as environmental knowledge (Ghisetti *et al*., 2015). The resulting cognitive barrier is exacerbated by differences in cultures and values, which further undermine the ability to establish effective interactions (Gibson and Gibbs, 2006) and pursue common environmental objectives (Cramer, 1998). These issues are more pronounced when a collaboration involves family firms because, due to the local embeddedness, they are less willing/able to interact with firms not adopting similar communication modes and not sharing same values and cultural traditions. As a result, the positive effect to green innovation value deriving form family firms' social capital is lessened. From a managerial perspective, being geographically distant does not let partners build common modus operandi for an effective knowledge-intensive R&D cooperation. Thereby, family firms are more focused on reconciling organizational routines than devoting the adequate attention to innovation activities (Fernhaber and Li, 2013; Ocasio, 1997), which are however necessary for the development of valuable green innovations. In turn, the development of trust-based, long-term R&D relationships is hampered. This favors opportunistic behaviors, so reducing the relevance of the family firms' survivability capital that, instead, stimulates actual collaborative green innovation activities (Delmas and Gergaud, 2014). In line with this reasoning, we hypothesize that:

Hypothesis 2 (H2). *Geographical distance negatively moderates the positive relationship between the involvement of family firms in inter-firm R&D collaborations aimed at developing green solutions and the value of resulting innovations.*

2.3 The moderating role of technological relatedness

Green innovations often denote solutions covering multiple applications and satisfying multiple needs, thus requiring firms to cope with different techno-economic issues (Ghisetti *et al*., 2015) that entail a systemic combination of diverse technological areas, also originating in different industries (Horbach *et al*., 2013; OECD, 2012; Nement, 2012). Therefore, family firms may take advantage from the cross-fertilization of diverse technological domains enabled by technologically distant partners (Sampson, 2007). This augments recombinant opportunities, which limits the hazards to fall into competency traps and more likely boosts pioneering activities aimed at exploring new external resources, relations, and opportunities coming from the R&D collaboration (Capaldo and Messeni Petruzzelli, 2014; Knoben and Oerlemans, 2006). As a result, family firms can more easily divert from current core competencies and better contribute to innovation activities that require a combination of multiple technological areas (Carnes and Ireland, 2013), as green innovation ones. In turn, the ability of family firms to meet environmental policies and the growing environmental concerns of the local community in the long-run may grow. This means that socioemotional goals may be more easily pursued, further benefiting the overall innovation performance of green collaboration projects involving these companies. This is not the case of R&D partnerships with technologically proximate companies that would likely augment family firms' path-dependency and, in turn, reduce the possibilities to cope with the diverse techno-economic issues characterizing green innovations.

Together with cross-fertilization opportunities, technologically diversified partners may share the risks and costs underlying green innovations by providing family firms with the (distant) environmental technological knowledge they have probably not developed due to their myopic loss aversion (Chrisman and Patel, 2012). Thereby, the premises for more effective long-term relations are enhanced (i.e., the patient capital), likely triggering environmental research activities earlier in time. Conversely, an R&D collaboration with partners in the same technological area may reduce opportunities for knowledge sharing because of fear of knowledge leakage, being the competition between similar partners more relevant. Therefore, the overall survivability capital of family firms, useful to increase green innovation value, is expected to be hindered by technologically proximate partners while improved by technologically distant ones.

All in all, considering the beneficial effects of technological diversity on green innovations and the opportunities technologically distant partners may provide to family firms in terms of risk reduction and recombinant opportunities, we can argue that the stronger the technological relatedness, the less positive the relation between the involvement of family firms in inter-firm R&D collaborations and green innovation value. Stated more formally:

> **Hypothesis 3 (H3).** *Technological relatedness negatively moderates the positive relationship between the involvement of family firms in inter-firm R&D collaborations aimed at developing green solutions and the value of resulting innovations.*

The hypothesized relationships are illustrated in Figure 1.

<Insert Figure 1 about here>

3 METHODOLOGY

3.1 Sample and data

To test the proposed hypotheses, we relied on a sample of 156 dyadic joint patents classified into the "Alternative energy production" field, according to the classification proposed by the IPC Green Inventory (WIPO, 2012), and successfully filed by publicly listed companies at the USPTO in the period 1997-2010.

The "Alternative energy production" field was chosen because it is one of the most relevant fields in green innovation studies. Indeed, greening the energy sector by developing valuable innovations is pivotal to improve both economic and environmental performance. Therefore, the discussion about augmenting the value of alternative energy innovations has become of foremost importance among scholars and policymakers (OECD, 2012; Albino *et al*., 2014). This field is also characterized by firms operating in diverse countries and industrial domains (Verdolini and Galeotti, 2011; WIPO, 2012), which makes this setting suitable to examine proximity dimensions from a geographical and technological perspective. Moreover, the alternative energy field presents a heavily patenting activity since patenting represents the main solution to signal and capture the value of respective innovations (Lane, 2013). This can justify our choice to adopt patents as a proxy for alternative energy innovations. This is also consistent with the more general literature on green innovation, which has widely accepted patents as a measure of the outcomes of green innovation processes (Oltra *et al*., 2010). Relatedly, by collecting (alternative energy) patents jointly owned by multiple firms, it is possible to assess whether a patented (green) innovation is the result of an inter-organizational collaboration. Indeed, previous studies have largely demonstrated that if more organizations share the property right of the same patent, they have collaborated in the related innovation project (e.g., Hagedoorn, 2003; Messeni Petruzzelli, 2011).

The USPTO was selected as the data source because more and more alternative energy patents are being registered in this patent office, and such trend is due to the contribution of organizations from all over the world (Albino *et al*., 2014), thus making the USPTO the database that suffers the country bias less than the others (Kim and Lee, 2015). We limited the time period of our investigation (1997-2010) because, on the one hand, the year 1997 is characterized by the establishment of new policies and incentives towards alternative energy production. For instance, in 1997, the Kyoto Protocol was first ratified, the European Commission set a new action plan for the adoption of alternative energy sources (European Commission, 1997), and the US Congress launched a national Renewable Portfolio Standard for the first time, which is a mandate that requires electricity providers to supply to their customers a minimum amount of power from renewable sources (Sullivan *et al*., 2009). On the other side, the operationalization of the dependent variable required to count the citations received by the sample patents in the seven years after patent applications (see the sub-section "Dependent variable"). Thereby, we could not consider patents applied after 2010 since no complete information about forward citations of these patents exists.

Regarding the data collection process, we retrieved all the patents registered in the USPTO whose IPC classes pertain to the "Alternative energy production" filed, as defined by the IPC Green Inventory (WIPO, 2012). Then, we collected bibliographic information of all the retrieved patents such as inventors' and assignees' names, technological classes, filing and issue years, citations, etc. Afterward, we restricted the sample to the patents registered by two publicly listed firms. The reasons are twofold. First, the dyad is considered the best unit of analysis for disentangling the effects of collaboration characteristics (e.g., family firms' involvement) on the innovation performance of the collaborations (Hoang and Rothaermel, 2005). Second, publicly listed firms dominate the energy systems in terms of decisions about investments in new greener technological solutions and generation capacity (Arango and Larsen, 2010; Thomas, 2006). Finally, data regarding patent owners (e.g., family ownership, size, age, and financials) were gathered from Orbis, Thomson One, and/or company reports.

3.2 Variables

Dependent variable. Green innovation value (*Value*) was computed by counting the number of citations received by a joint patent in the seven years after its application. The use of forward citations is a robust, established mean to measure the value of an innovation. Indeed, highly cited patents, more than others, have promoted the development of further innovations. In other words, they have been considered as valuable pieces of technological knowledge, such that subsequent innovators have built upon them for the generation of novel innovations (e.g., Capaldo *et al*., 2017; Harhoff *et al*., 2003; Singh, 2008; Trajtenberg, 1990). Additionally, forward citations have been widely correlated with the social and economic value of the respective patents (e.g., Fischer and Leidinger, 2014; Harhoff *et al*., 1999), hence making us more confident about the suitability of this measure. A defined time-window was needed because "directly comparing patent citations across patents from different years would be inappropriate" (Capaldo *et al*., 2017:515; Nootebom *et al*., 2007). Notably, older patents have had more time to be cited, and a common time span to observe the citation rate of the sample patents allows controlling for this issue. The choice of a seven years time-window was more conservative than the common five years (Nootebom *et al*., 2007), especially in our setting, where the drop of patent citations manifest later in time (Nemet, 2012).

Independent and moderating variables. The independent variable (*FamilyInvolvement*) is a dummy variable that captures whether, at least, one of the two assignees of a given patent is a family firm. That is, whether a family firm is involved in the R&D collaboration established to develop the patent. In case of a family firm's involvement, the variable assumes the value of one, zero otherwise. We considered a company as being family-firm if a family or a member of the founding family is a company shareholder with at least 20% of the company's ownership rights, as indicated by Thomson One (ownership module). Indeed, the 20% threshold is considered a sufficient percentage to ensure that a family has some control over the company, and so socioemotional goals may actually affect a firm's decisions (e.g. Faccio and Lang, 2002; Maury, 2006; Morck and Yeung, 2004; Munari *et al*., 2010).

The first moderating variable (*GeoDistance*) was computed as the spatial distance, in thousands of kilometers, between the assignees' location sites. When we noted that the inventors' addresses reported in the patent documents were different from its headquarter location, we focused on the inventors' addresses. This allowed us to avoid assigning patents to the company headquarter regardless of the fact that some company subsidiaries may have been involved in the innovation process (Capaldo and Messeni Petruzzelli, 2014; Singh, 2008).

Finally, following previous studies (e.g., Messeni Petruzzelli, 2011; Sampson, 2007), we operationalized technological relatedness (*TechRelatedness*) by measuring the extent to which co-assignees had patented with the USPTO in the same technology classes. Specifically, we employed the following index:

$$TechRelatedness = \frac{f_i\, f'_j}{\sqrt{(f_i f'_i)(f_j f'_j)}},$$

where f_i and f_j are multidimensional vectors assessing the distribution of all the patents filed by assignee i and assignee j, respectively, across all IPC classes assigned to the sample patents during the five years preceding the filing date of the joint patent under investigation. Apexes indicate transposed vectors. *TechRelatedness* presents values between zero and one, where the higher its value the higher the co-assignees' technological relatedness.

Control variables. Control variables were included to improve the reliability of the analysis. Specifically, for each joint patent, we controlled for (i) the number of patent claims (*Claims*) (Tong and Frame, 1994), (ii) the number of backward citations (*Cited*) (Harhoff *et al*., 2003), (iii) the number of citations to non-patent documents (Narin *et al*., 1997) - i.e., the scientific knowledge underlying the patent (*Scientific*) - (iv) the time elapsed, in years, between the application and issue dates (*GrantingLag*) (Nemet, 2012), (v) the patent scope (*Scope*), as measured by the number of different three-digit US classes assigned to a patent (Lerner, 1994), and (vi) the number of inventors involved in the innovation process (*TeamSize*) (Singh, 2008). We also controlled for a number of elements characterizing each joint patent's assignees. First, we included a dummy variable having a value of one if the co-assignees are in the same industrial group (*Group*) (Grimpe and Sofka, 2009). Second, as a measure of organizational proximity, we counted the number of patents the co-assignees have developed together in the five years prior to the application of the patent under investigation (*OrgProximity*) (Messeni Petruzzelli, 2011). Third, as a measure of firm size (Ghisetti *et al*., 2015), we included variables reflecting the revenues of the first (*Assignee1revenues*) and second (*Assignee2revenues*) assignee. Fourth, the difference between the ages of the co-assignees (*AgeDifference*) was considered. Sixth, to account for sector differences, we added a dummy variable taking the value of one if the co-assignees have the same SIC code (*SameSIC*) (Ghisetti *et al*., 2015). Finally, to further control for time-period effects, we distinguished patents applied before the 2002 Earth Summit from those applied afterward through a dummy variable (*dummy97-02*).

4 RESULTS

Table 1 presents descriptive statistics and pairwise correlations. Correlation values are below the threshold of 0.70, so limiting multicollinearity concerns. Since our dependent variable is an over-dispersed (i.e., the standard deviation is higher than the mean) non-negative integer count variable, we run a negative binomial regression to test the hypotheses (Wooldridge, 2012). Table 2 shows the results. Specifically, Model 1 is the baseline model including control variables only. Models 2 adds the independent variable, thus testing H1. Model 3 tests H2, in that it also includes *GeoDistance* and its interaction term with *FamilyInvolvement.* Instead, Model 4 tests H3, in that it adds to Model 2 *TechRelatedness* and its interaction term with *FamilyInvolvement.* Model 5 incorporates all the variables and interaction terms.

<Insert Table 1 about here>

Model 1 suggests that green innovation value increases with the number of a patent's backward citations (β=0.021, $p<0.05$), whereas it decreases as the granting lag (β=-0.248, $p<0.01$), the difference between the age of co-assignees (β=-0.013, $p<0.05$), and the revenues of the first assignee (β=-0.000, $p<0.05$) grow. According to Model 2, H1 is supported since the coefficient estimate of *FamilyInvolvement* is positive and significant (β=0.544, $p<0.05$). Model 3 confirms H2, being the interaction term *FamilyInvolvement* x *GeoDistance* negative and significant (β=-0.652, $p<0.05$). Likewise, Model 4 supports H3 since the interaction term *FamilyInvolvement* x *TechRelatedness* is negative and significant (β=-2.648, $p<0.05$). Model 5 corroborates the results obtained in the partial models.

<Insert Table 2 about here>

To dig into the moderating effects, we decomposed interaction terms and conducted a simple slope analysis. We considered two levels of each moderating variable - low (one standard deviation below the mean) and high (one standard deviation above the mean) - and estimated the effect of the independent variable on *Value* for both levels. Figure 2 depicts the relationship between *FamilyInvolvement* and *Value* for both levels of *GeoDistance*, revealing that green innovation value is higher when *GeoDistance* is at the low level, thus confirming its negative moderating effect. Similarly, Figure 3 shows that green innovation value is higher when *TechRelatedness* is at the low level, which further supports H3.

<Insert Figure 2 and Figure 3 about here>

To improve the reliability of the analysis some auxiliary checks were conducted. First, we adopted a restricted time-window to count forward citations in the operationalization of our dependent variable, i.e., five years (Nootebom *et al.*, 2007). In this case, H3 is marginally significant, albeit in the expected sign. Second, *TechRelatedness* was computed by assessing the similarity of the patent stock respect to the ten (instead of five) years prior to the development of the joint patent under analysis. This check confirms all the hypotheses. Finally, we restricted the sample by removing patents owned by two family firms. All hypotheses remained supported with the remaining 146 observations.

5 DISCUSSION AND CONCLUSIONS

5.1 Main findings

Based on a sample of 156 dyadic joint patents classified into the "Alternative energy production" field and registered in the USPTO by publicly listed firms, this paper analyzes the relationship between the involvement of family firms in inter-firm R&D collaborations aimed at developing green solutions and the value of resulting innovations. Our findings reveal that family firms' involvement has a positive influence on the development of valuable green innovations. This is ascribed to theories arguing that investment decisions of family firms involve socioemotional wealth, besides economic considerations (Souder *et al*., 2015). Indeed, goals related to socioemotional wealth allow family firms to develop unique traits (i.e., the social, patient, and survivability capital), which put them in a better position to establish more effective R&D partnership interactions (Perri and Peruffo, 2017; Sirmon and Hitt, 2003) and, hence, develop green innovations of a higher value. Moreover, socioemotional goals lead family firms to devote more attention on environmental issues (Berrone *et al*., 2010; Yu *et al*., 2015), further suggesting a positive relationship between family firms' involvement and green innovation value.

Additionally, the moderating effects of two proximity dimensions (i.e., geographical distance and technological relatedness) on this relationship has been assessed. Geographical distance has been found to weaken the impact of family firms' involvement on green innovation value. Although green innovations may benefit from the interaction of partners scattered across nations, it should be recognized that cross-border R&D relations are more complex due to cognitive, cultural, and managerial barriers, which are particularly harmful in the context of family business. Notably, family firms are locally embedded (Cappuyns, 2004; Sciascia *et al*., 2012); therefore, the advantages generated by the structural, patient, and survivability capital are lessened when family firms interact with geographically distant organizations, ultimately limiting the potential to develop valuable green innovations. Likewise, technological relatedness has proven to have a negative moderating effect. In fact, as opposed to collaborating with technologically distant partners, engaging in cooperative innovation activities with partners that share the same technological knowledge likely hinders the possibilities of family firms to establish trustworthy partnerships and recombine knowledge of diverse technological domains, as required for the development of valuable green innovations. These findings offer several theoretical and practical implications.

5.2 Implications

From a theoretical standpoint, research on the determinants of green innovations has mainly focused on environmental-level factors (e.g., public policy, stakeholder impacts, and market demands). Instead, we have narrowed the attention on network-level variables, which are also critical drivers of green business strategies and innovation performance (Dangelico, 2017). More in detail, it has been widely debated the need to rely on inter-organizational R&D collaborations to develop green innovations of a higher value. Despite this, very few studies have delved into the collaborations leading to more relevant green innovations (Dangelico and Pontrandolfo, 2015; Zhao *et al*., 2018). Therefore, by unveiling that family firms' involvement affects green innovation value, we may contend that our understanding on this issue has been moved one step further. Indeed, this paper represents one of the few attempts to analyze how an inter-firm R&D collaboration should be composed, in terms of partners' types, to achieve better green innovation performance. Specifically, to the best of our knowledge, the role of family firms' involvement has never been examined nonetheless the newly set of studies that lies at the intersection of family business and green innovation theory. While these studies have mostly discussed the factors favoring the adoption of green innovations by family firms as a result of socioemotional goals (e.g., Huang *et al*., 2016), we have redirected the attention towards the influence family firms exert in inter-firm R&D

collaborations for their development. That is, we have expanded the use of socio-emotional wealth as a theoretical lens to articulate its linkage to collaborative relationships aimed at creating valuable green innovations. Overall, this helps to refine the current discussion on the uniqueness of family business in the context of environmental sustainability (e.g., Berrone *et al*., 2010). Furthermore, the recent study by Hansen (2014) highlights that proximity dimensions cannot be underestimated in the analysis of collaborative green innovation projects. We have embraced and added to this, undervalued, line of inquiry by revealing their moderating effects on the influence family firms' involvement has on green innovation value.

From a practical standpoint, our results have implications for business strategy and policy decisions since we provide more detailed directions to managers and policymakers respect to the peculiarities of inter-firm R&D collaborations aimed at developing (valuable) green innovations. That is, we highlight that family firms possess some unique traits that let them simultaneously establish effective partnership relationships and commit to greener innovation activities. This can guide managers in the process of partner selection by pushing them to establish inter-firm R&D collaborations involving family firms. Moreover, we may further refine this suggestion by arguing that the involvement of family firms is less beneficial when such companies collaborate with geographically distant or technologically related partners. In other words, managers are advised that more valuable green innovations result from the collaboration of family firms with companies that are located within the same geographical area, and that let them reduce the risks towards green innovation activities by promoting knowledge recombination across technological boundaries. Eventually, considering that partner selection is challenging, this study equips managers with theories and supporting evidence that may help to simplify this process when collaborative green innovation projects will be pursued. From a policy perspective, to boost the development of valuable green innovations policymakers should design research actions to stimulate inter-firm green innovation projects that include family firms. These initiatives should also favor the collaboration of these companies with partners geographically proximate, yet with differences in terms of technological knowledge.

5.3 Limitations and future research directions

Of course, this article has some limitations that can, however, lend useful hints for future research. Firstly, although the use of patents is very-well established in green innovation studies, it mainly reflects technological innovations. Therefore, our results leave out discussion about organizational or service green innovations, which deserve more attention and are probably characterized by dynamics not considered in this research. Second, the sample under investigation may be enlarged by considering non-publicly listed companies and/or firms operating in other green sectors (e.g., waste management). Indeed, the alternative energy sector is predominant in the literature on green innovations, and publicly listed companies lead the sustainability transition; notwithstanding, some peculiarities underlying other sectors or firms may improve our understanding of the phenomenon under investigation. Third, while we still underline the relevance of proximity dimensions in our study, additional contingent effects may be considered. These include environmental variables (e.g., policy measures, market dynamics, and stakeholder pressures) that may alter the role socioemotional goals play in family firms' green collaborative innovation activities. Likewise, other partners' characteristics from a governance (e.g., gender diversity) or strategic (e.g., strategic orientations) perspective can further unveil when collaborations promote the development of valuable green innovations.

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TABLES

TABLE 1 Descriptive statistics and pairwise correlations

	Mean	S.D.	Min	Max	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
1-Value	2.712	5.615	0	32	1															
2-FamilyInvolvement	.410	.493	0	1	0.234*	1														
3-GrantingLag	3.795	1.4667	1	8	-0.185*	0.001	1													
4-Scientific	2.526	4.187	0	39	-0.021	0.101	0.234*	1												
5-Claims	12.462	8.627	1	47	0.165*	0.058	-0.006	-0.014	1											
6-Cited	9.276	12.236	0	96	0.215*	0.133	-0.058	-0.009	0.118	1										
7-Scope	1.814	1.082	1	7	0.042	-0.086	-0.134	0.057	-0.159*	-0.022	1									
8-TeamSize	4.667	2.416	1	13	0.088	-0.004	-0.052	0.123	-0.064	0.016	0.270*	1								
9-Group	.853	.356	0	1	0.021	0.053	-0.058	0.009	-0.205*	-0.176*	0.146	0.175*	1							
10-OrgProximity	26.051	82.041	0	368	-0.124	-0.205*	-0.089	-0.126	-0.174*	-0.084	-0.100	-0.024	0.114	1						
11-Assignee1revenues	18975.95	39525.76	.01250	154630.30	-0.175*	-0.298*	-0.066	-0.108	-0.064	-0.130	-0.103	-0.071	-0.350*	0.599*	1					
12-AgeDifference	23.038	24.770	0	99	-0.092	-0.172*	-0.059	-0.119	-0.048	-0.006	0.050	-0.106	0.258*	-0.017	-0.181*	1				
13-Assignee2revenues	11046.87	23542.08	.11570	121294.30	-0.013	-0.211*	-0.063	-0.015	0.009	0.209*	-0.082	-0.198*	-0.415*	0.308*	0.212*	-0.133	1			
14SameSIC	.147	.356	0	1	-0.163*	-0.120*	0.046	-0.156	-0.090	-0.109	-0.163*	-0.130	0.122	0.658*	0.494*	-0.060	0.207*	1		
15-GeoDistance	.636	1.907	0	10.668	-0.016	-0.133	0.051	0.150	0.252*	0.087	-0.036	0.060	0.130	-0.099	-0.152	0.134	-0.120	-0.063	1	
16-TechRelatedness	.255	.295	0	1	-0.172*	-0.053	0.042	0.013	-0.075	-0.143	-0.092	-0.148	0.010	0.611*	0.352*	-0.134	0.158*	0.668*	-0.064	1
17-dummy97-02	.218	.414	0	1	0.191*	0.002	-0.149	-0.063	0.160*	-0.114	0.062	0.267*	0.220*	-0.149	-0.224*	0.026	-0.212*	-0.132	0.025	-0.169*

n=156; *p<0.05

TABLE 2 Descriptive statistics and pairwise correlation

	Model 1	s.e.	Model 2	s.e.	Model 3	s.e.	Model 4	s.e.	Model 5	s.e.
FamilyInvolvement **(H1)**			0.544**	0.261	0.680**	0.289	1.062***	0.376	1.153**	0.384
FamilyInvolvement X GeoDistance **(H2)**					-0.652**	0.271			-0.568**	0.265
FamilyInvolvement X TechRelatedness **(H3)**							-2.648**	1.078	-2.564**	1.06
GrantingLag	-0.248***	0.075	-0.238***	0.069	-0.247***	0.067	-0.218***	0.065	-0.226***	0.065
Scientific	0.011	0.025	0.012	0.027	0.014	0.029	0.0326	0.028	0.0337	0.029
Claims	0.024	0.021	0.020	0.019	0.019	0.020	0.020	0.018	0.0196	0.019
Cited	0.021**	0.010	0.018*	0.009	0.018**	0.009	0.014*	0.008	0.014*	0.008
Scope	-0.031	0.130	0.006	0.120	-0.021	0.117	-0.008	0.119	-0.033	0.116
TeamSize	0.024	0.058	0.041	0.055	0.032	0.055	0.024	0.053	0.019	0.053
Group	0.507	0.573	0.577	0.544	0.670	0.565	0.695	0.615	0.784	0.629
OrgProximity	-0.003	0.004	-0.004	0.003	-0.004	0.003	-0.004	0.004	-0.004	0.004
AgeDifference	-0.013**	0.006	-0.008	0.006	-0.010*	0.006	-0.008	0.005	-0.009*	0.006
Assignee1revenues	-0.000**	0.000	-0.000*	0.000	-0.000**	0.000	0.000	0.000	-0.000*	0.000
Assignee2revenues	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
SameSIC	-0.285	0.699	-0.204	0.673	-0.173	0.673	-0.387	0.637	-0.358	0.648
GeoDistance					-0.001	0.059			-0.010	0.058
TechRelatedness							0.714	0.603	0.712	0.607
dummy97-2002	0.484*	0.292	0.485*	0.282	0.435	0.291	0.529*	0.269	0.475*	0.276
Constant	1.041	0.963	0.452	0.826	0.582	0.849	0.227	0.915	0.329	0.934
WaldChi2	62.04***		67.48***		73.57***		75.92***		85.86***	
LogPseudolikelihood	-292.82		-291.01		-289.55		-288.12		-286.94	

n=156; *p<0.10; **p<0.05; ***p<0.01

FIGURES

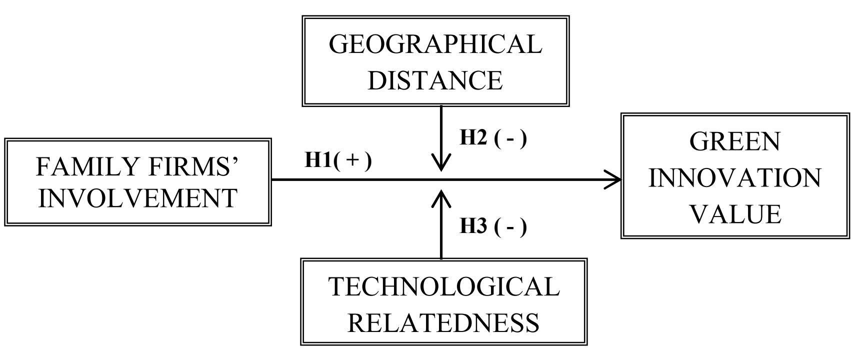

FIGURE 1 Hypothesized relationships

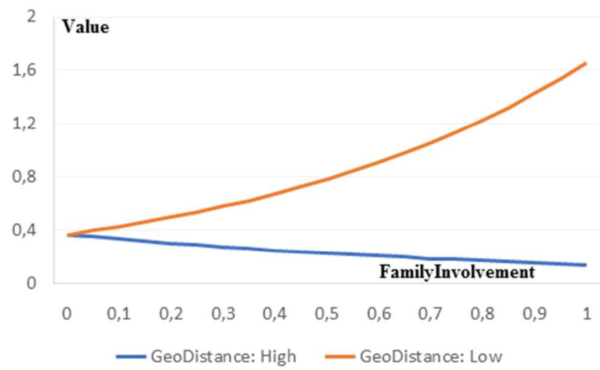

FIGURE 2 Moderating effect of GeoDistance

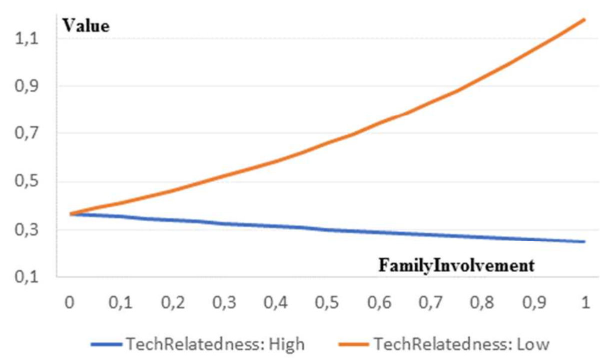

FIGURE 3 Moderating effect of TechRelatedness