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FIRM OWNERSHIP AND GREEN PATENTS. DOES FAMILY INVOLVEMENT IN BUSINESS MATTER?

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Firm ownership and green patents.

Does family involvement in business matter? •

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Abstract This paper investigates how family and non-family firms differ in terms of their capability to introduce environmental innovation, which is measured by green patents. The analysis is carried out using a large patenting data set related to the inventions produced by about 4200 Italian manufacturing firms over the period 2009–2017. The results show that family firms are less likely than non-family firms to implement innovations in green technologies. Moreover, the role played by the stock of knowledge and the environmental management system certification differs across firm type.

JEL codes: O31; C23; G34.
Keywords: eco-innovation; green patent; family firms.

1. Introduction

While a wide literature has investigated the determinants of eco-innovation (Barbieri et al., 2016; De Jesús Pacheco et al., 2016; Del Río et al., 2016; Hojnik and Ruzzier, 2016), little is known about the behaviour of family firms. This study contributes to the debate by determining how family and non-family firms differ in terms of introducing green technology, which is gauged by green patents.

Gaining a deeper understanding of the association between family ownership and eco-innovations is relevant for at least two reasons. Firstly, family firms are the prevalent organizational form in many countries (IFERA, 2013). Secondly, the European Commission has shown increasing

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concern about the impact of economic activity on the natural system (https://ec.europa.eu/environment/ecoap/frontpage_en). Therefore, from an economic and social perspective, the conditional effect of the most prevalent form of business ownership on the eco-innovation levels has become a key issue for both research and policy and may prove helpful in optimizing innovation- and sustainability-related policies (Bammens and Hunermund, 2018).

Along this line of reasoning, the research on the role of family in influencing firm environmental performance has increased over the last decade. However, the current understanding of the effect of family ownership on green innovation is very limited. This is because, on the one hand, mainstream innovation researchers have largely overlooked family variables in their studies (Calabrò et al., 2018) and, on the other hand, comparative research on family *versus* non-family firms' environmental performance has produced competing arguments and mixed results.

The theoretical arguments suggest that family firms differ from non-family firms in terms of environmental behaviour, but they present conflicting viewpoints. The risk aversion of family firms induced by a more general long-term orientation (Gómez-Mejía et al., 2007; Le Breton-Miller and Miller, 2006; Lumpkin et al., 2010) could have a negative influence on their environmental innovation activities. The conservation of wealth for future family generations (Zellweger et al., 2012) and of the family name and reputation (Dyer and Whetten, 2006; Lumpkin et al., 2010) makes risky behaviour less likely in these firms. Nonetheless, the socioemotional wealth (SEW) approach (Gómez-Mejía et al., 2007) highlights specific characteristics of family businesses as being able either to foster or to hinder green innovation (Cruz et al., 2014; Kellermanns et al., 2012; Kim et al., 2017; Samara et al., 2018).

Contradictory results have also emerged from the empirical research. Some scholars have found that family-owned firms are more environmentally responsible than their non-family counterparts (Berrone et al., 2010; Block and Wagner, 2014; Marques et al., 2014), while others have raised some doubts (Cruz et al., 2014; Kellermanns et al., 2012).

This ambivalence in results makes it difficult to produce an integrative picture of the state of the art. The relationship between family involvement and green behaviour is more complex and multidimensional than predicted, considering that (a) eco-innovations differ with respect to other innovations and (b) the innovation phenomenon differs for family and non-family firms. As highlighted by Hojnik and Ruzzier (2016), green innovations use more complex and diversified knowledge and skills and require a greater propensity to take risk, a greater facility to access external sources of funding and more intensive external relationships than other kinds of innovation. Additionally, the eco-innovation efforts of family firms are limited by a number of distinctive traits, such as a conservative posture (Habbershon et al., 2003), organizational rigidity (Kets de Vries, 1993), high risk aversion (König et al., 2013; Munoz-Bullon and Sanchez-Bueno, 2011), willingness to keep control of the firm (Gòmez-Mejìa et al., 2007), a limited propensity to use investment capital to fund innovation projects (Block et al., 2013), and little ability to cooperate with external partners for innovation (Nieto et al., 2015).

With respect to the related literature, this paper feeds the debate by comparing the introduction of green technologies in family and non-family firms. In this way, it addresses the call for additional investigations into the innovation dynamics in family firms (De Massis et al., 2015; Duran et al., 2016) by contributing to filling the gap in the literature on green innovation in family firms claimed by Calabrò et al. (2018). Throughout the paper, green technology is gauged by patents, which are best suited to identifying specifically 'environmental' innovation (Haščič and Migotto, 2015; Oltra et al., 2010). As patents are used as a measure of innovation output, we follow – among many others – Brunnermeier and Cohen (2003), Laurens et al. (2017), Montobbio and Solito (2018), Nameroff et al. (2004) and Wagner (2007). To the best of our knowledge, no study in the family business innovation literature has estimated the propensity to introduce a green patent to date.

The analysis focuses on the manufacturing sector in Italy. The data are from the Orbis data set provided by the Bureau van Dijk, which has recently been linked to the European Patent Office's

(EPO) PATSTAT data set. In addition, green patents are identified using the WIPO Green Inventory. The final data set comprises 4226 firms, which are observed over the 2009–2017 period.

Here, it is noteworthy that Italy represents a suitable research setting. Indeed, not only is this country the third-largest national economy in the euro-zone but also family firms account for a large share of its economy: according to European Family Businesses, family firms constitute about 75% of all the active firms in Italy (http://www.europeanfamilybusinesses.eu/). Further, the green economy is acquiring growing relevance in the country: the Green Italy 2018 report (Fondazione Symbola-Unioncamere, 2018) indicated that 30.7% of manufacturing companies made green investments during the period 2014–2017 or planned to do so by the end of 2018.

The results show that family firms are less likely than other firms to implement innovations in green technologies. Moreover, we find a robust positive association between the past capital of knowledge accumulated regarding green technology and the propensity to introduce a green patent for both family and non-family firms. Past knowledge of non-green technologies plays a positive role in the sample of family firms. The same applies to the environmental management system (EMS) certification.

The work is organized as follows. Section 2 present a brief literature review. The data, variables and econometric model are described in Section 3, while the results are presented and discussed in Section 4. Section 5 concludes.

2. Family businesses and eco-innovation: literature review

A wide literature has investigated the determinants of eco-innovation (see Barbieri et al., 2016; De Jesús Pacheco et al., 2016; Del Río et al., 2016; Hojnik and Ruzzier, 2016 for recent overviews). However, an issue that has been overlooked in these studies is related to the effect of family ownership on green innovation, and comparative research on family *versus* non-family firms' environmental performance has produced competing arguments and mixed results.

Theoretical arguments suggest that family firms differ from non-family firms regarding environmental behaviour, but they present conflicting viewpoints. The risk aversion of family firms, induced by the family being the owner and the more general long-term orientation of family firms, makes risky behaviour less likely in these firms (Gómez-Mejía et al., 2007; Le Breton-Miller and Miller, 2006; Lumpkin et al., 2010) and, hence, could have an important negative influence on their environmental innovation activities.

At the same time, arguments grounded in the theoretical views of socioemotional wealth (SEW) (Gómez-Mejía et al., 2007) show that family owners are concerned about a variety of non-financial aspects of firm ownership that can influence corporate social responsibility – which comprises ecological concerns – such as desires to obtain a high social status in a local community (Block, 2010) and to fulfil needs related to organizational and family identification (Le Breton-Miller et al., 2011; Zellweger et al., 2010). Recent works, however, have indicated that SEW can be considered as a double-edged sword that can reveal either its bright or its dark side (Cruz et al., 2014; Kellermanns et al., 2012; Kim et al., 2017; Samara et al., 2018). For example, Kim et al. (2017) argued that family firms value their reputation and role in a community more than non-family firms and thus behave more responsibly. This is the bright side of SEW. At the same time, due to their concern with preserving the business's financial stability and a sense of financial responsibility for preserving family wealth across generations, family firms are less likely to invest in the protection of the environment because the investments are meant to be a net cost. This is the dark side of SEW. Therefore, from a theoretical point of view, there are specific characteristics of family businesses that can either foster or hinder green innovation.

Research has also produced mixed results from the empirical point of view. The empirical analyses may be classified into two groups. The first group refers to the literature on the innovative behaviour of family firms and then on family firms' risk awareness. The second group focuses on the influence of family ownership on corporate social responsibility (CSR) and then on family firms' aim to achieve socioeconomic wealth. In this literature, the environment constitutes a dimension of CSR.

Regarding the empirical studies about the innovation behaviour of family firms, the prior knowledge is that family firms pursue inherently uncertain activities less than non-family firms and therefore invest fewer resources in R&D and innovation (Block, 2012; Duran et al., 2016). This also concerns innovation with environmentally highly beneficial products, (technological) processes and organization-related changes.

The studies that have investigated the relationship between family firms and environment and social responsibility have produced contradictory results. Some papers have shown that family-owned firms can be concerned with the long-term reputation of the business and with preserving a healthy and prosperous environment in which the firm will continue to thrive (e.g. Berrone et al., 2010; Block and Wagner, 2014; Marques et al., 2014), while others have raised some doubts about whether family enterprises are more environmentally responsible than their non-family counterparts (Cruz et al., 2014; Kellermanns et al., 2012). Calza et al. (2016) provided a clearer result by hypothesizing that ownership concentration, as is the case for family firms, negatively determines proactive environmental firm behaviour. Finally, Doluca et al. (2018) offered a more complex overview of the differences regarding the development of firms' environmental behaviour. They used four waves of the German Sustainability Barometer survey (2001, 2006, 2011 and 2016) and found that family firms are less likely than other firms to implement environment-related activities and innovations in early diffusion phases but catch up with non-family firms later. They also discovered that family firms' environmental behaviour is less volatile and more stable over time than that of non-family firms. In summary, competing arguments and conflicting results are associated with the comparison of family and non-family firms' environmental performance.

A clearer picture may emerge from considering the specificities of eco-innovations compared with innovations tout court and evaluating whether specific family firm attributes facilitate or hinder eco-innovation. The existing literature on eco-innovations has shown that these innovations have different determinants from other innovations. For example, eco-innovations are, on average, more complex than non-green innovations (De Marchi, 2012) and are, on average, characterized by higher

levels of novelty, uncertainty and variety than other innovations (Cainelli et al., 2015). The more an innovation is novel, the more the uncertainty and risk associated with it increase. Moreover, environmental innovations require more heterogeneous sources of knowledge with respect to other innovations (Horbach et al., 2013). Empirical analyses support this view: environmentally innovative firms cooperate on innovation with external partners to a greater extent than other innovative firms (Cainelli et al., 2015; De Marchi, 2012; De Marchi and Grandinetti, 2013; Fabrizi et al., 2018), and the breadth of the firm's knowledge sourcing has a positive effect on environmental innovation (Ghisetti et al., 2015). Finally, compared with non-environmental innovations, the existence of financial barriers and the structured organization working on innovation are important distinctive drivers of eco-technologies (De Marchi, 2012; Del Río et al., 2013; Ghisetti et al., 2017). Given these specificities, environmental innovators are likely to have a greater need for human (high-skilled employees and managers) and financial resources to be able to respond to such inputs than non-environmental innovators.

In summary, the main results in this literature are that the propensity to take risk, capability to cooperate with external partners, facility to access external sources of funding and availability of human resources are very important for eco-innovations compared with other traditional and more established innovation fields. Family firms show unique characteristics regarding their innovative attitudes. In particular, family firms mobilize human and financial resources in a suboptimal fashion, which should lead to weak performance in terms of eco-innovations. The desire to provide careers for family members (Schulze et al., 2001) makes it difficult to recruit, reward and monitor their managers effectively (Lubatkin et al., 2005). The final result is a shortage of qualified talents, that is, the managers who are charged with deciding on innovation processes. With regard to resource constraints, because of the fear of losing decision-making control, family firms are not particularly inclined to access capital markets or to allow the entry of other investors (Block et al., 2013; Kets de Vries, 1993). This limits the possibility of financing innovation activities by reducing the firm's ability to exploit the existing information. Indeed, assimilating technological knowledge from outside

requires ‘absorptive capacity’, which is largely determined by past knowledge (Cohen and Levinthal, 1990).

Moreover, eco-innovations need complex and flexible structures, while family firms are less flexible and more conservative organizations (Zahra et al., 2004). This is a circumstance that could potentially inhibit their predisposition towards the adoption of green innovation. Similarly, considering the use of external sources of innovation, the pre-existing evidence indicates that family firms are not particularly in favour of collaborative relationships (Nieto et al., 2015) due to their strong concerns about the potential loss of control (Gòmez-Mejìa et al., 2007). Finally, since investing in green technologies represents a higher risk, it is plausible that family firms, which are notably risk averse (König et al., 2013; Munoz-Bullon and Sanchez-Bueno, 2011), might be opposed to green innovation.

The synthesis of all these argumentations is that family firms are less likely than other firms to implement innovations in green technologies.

3. Empirical setting

This section describes the data and the variables used throughout the paper (§ 3.1) and presents the econometric model implemented in the analysis (§ 3.2).

3.1 Data

The study is based on a panel data set built by combining multiple data sources on administrative patent data, firm-specific factors and environmental management systems (ISO 14001).

The sample is obtained from an initial panel of 26000 firms in the Amadeus (Bureau van Dijk) database comprising the applicants for at least 1 patent at the EPO between 1981 and 2017. This allows us to consider a homogeneous population of potentially innovative firms for which patenting is (or has been) a relevant tool to protect inventions and innovations.

The patents are from the Orbis data set provided by Bureau van Dijk, which has recently been linked to the European Patent Office's (EPO) PATSTAT data set. The main advantage of using the Orbis–PATSTAT data set relates to the availability of a unique firm identifier, which allows the matching between firm-level patents and balance sheet data contained in Bureau van Dijk's Amadeus archive. Importantly, Bureau van Dijk's Amadeus provides information on the ownership structure of the firms.

We count the number of patents granted per firm per year, including only priority patents and excluding equivalent patent filings. The fact that the focus is on granted patents implies that the sample is not likely to include the lowest-quality patents (such as non-successful applications). In addition, green patents in Orbis are identified using the WIPO Green Inventory, which includes all the IPC classes that are associated with environment-friendly technologies in the fields of alternative energy production, transportation, energy conservation, waste management, agriculture/forestry, administrative regulatory and nuclear power generation.

After merging firms' financial data and patent portfolio from the Amadeus database, the final panel comprises about 30000 observations obtained from about 4200 Italian manufacturing firms observed from 2009 to 2017. The final step is to identify the ISO 14001 certified firms, and the source is the ACCREDIA (the Italian Accreditation Body) Register, updated to 2017.

Table 1 shows the sample distribution between family firms (2157 out of 4226 companies) and non-family firms (2069 companies). Firms with at least 1 green patent represent 4.71% of the sample; among these, 1.63% are family firms and 3.08% non-family firms. In terms of industry composition, the highest concentration of firms is in the medium-high-tech (48.06%) and medium-low-tech (28.92%) manufacturing sectors. As far as the geographical distribution is concerned, it emerges that the firms are mainly in the north of Italy (83.68%). Again, the data reveal that the proportions of family and non-family firms do not differ significantly when considering the geographical distribution and the industry composition.

Table 1. Distribution of the sample

Total firms			Family firms		Non-family firms	
	N.	%	N.	%	N.	%
Firms with at least one green patent	199	4.71%	69	1.63%	130	3.08%
Sectors						
High Tech	381	9.02%	146	3.45%	235	5.56%
Medium High Tech	2031	48.06%	983	23.26%	1048	24.80%
Medium Low Tech	1222	28.92%	705	16.68%	517	12.23%
Low Tech	592	14.01%	323	7.64%	269	6.37%
Territorial area						
North-East	1645	38.93%	840	19.88%	805	19.05%
North- West	1891	44.75%	919	21.75%	972	23.00%
Centre	514	12.16%	300	7.10%	214	5.06%
South	176	4.16%	98	2.32%	78	1.85%
Firm-year observations	4226	100.00%	2157	51.04%	2069	48.96%

Authors' elaboration on data from Amadeus/Orbis (Bureau van Dijk)

3.2 Variables and methodology

To test whether and to what extent green patenting differs between family and non-family firms, a panel random-effect probit model is applied. As the aim is to estimate the probability of introducing a green innovation, the dependent variable is the dummy variable *Green Patent*, which takes the value one when a firm has at least one green patent and zero otherwise.

While patents have some drawbacks as indicators of technological activity (not all inventions are patented, and the incentives to patent differ according to the sector and market), they present a number of advantages over alternative measures of innovation.[1] For this reason, their use as a measure of the output of the inventive process has become standard in the literature (Griliches, 1990; Hall et al., 1986). In particular, they are best suited to identifying specifically 'environmental' innovation

[1] Notably, they are commensurable because patents are based on an objective standard (the type of invention that can be patented is well defined); they measure the outputs of the inventive process (in contrast to data on R&D expenditures, which only measure the input); and the data are quantitative and widely available. For a discussion on the advantages and disadvantages of using patents as a measure of technological change, see Archibugi and Pianta (1996).

(Haščič and Migotto, 2015; Oltra et al., 2010), since the data can be disaggregated into specific technological fields, which are a key feature in studying 'environmental' innovation. In other words, patent classification systems are 'technological' by nature (unlike commodity and industry classifications) and allow for a rich characterization of relevant technologies by describing the engineering features of an invention and its applications at a fine level of detail (Haščič and Migotto, 2015). All this implies that the use of patents in environmental fields of activity is very common (Brunnermeier and Cohen, 2003; Laurens et al., 2017; Montobbio and Solito, 2018; Nameroff et al., 2004; Wagner, 2007).

The independent variables are chosen for the analysis on the basis of the prior empirical literature, provided that they are available in the database (Corrocher and Solito, 2017; Horbach, 2008; Kesidou and Demirel, 2012; Laurens et al., 2017; Montobbio and Solito, 2018; Wagner, 2008).

The key explanatory variable is the family dummy. There is no agreement on the definition of a family business (for a recent review, see Hernàndez-Linares et al., 2018). In this study, firms are classified as family firms when individuals or families record direct ownership of over 50%.

Recently, a conspicuous stream of literature has highlighted the importance of firm-level factors as key determinants of green patenting. Some of them are common to all innovations – such as the past stock of knowledge (Laurens et al., 2017; Montobbio and Solito, 2018) – and others are specific to eco-innovations – such as the presence of environmental management systems (Dangelico et al., 2016; Montobbio and Solito, 2018; Wagner, 2007).

To test the role of the past knowledge accumulation, the analysis includes two variables. The first is the stock of green patents (*K_G*), which is meant to be a proxy for a firm's learning capacity in the field of green technology. The second variable is the stock of non-green patents (*K_NG*), based on all technological fields except green technologies. It is a proxy for a firm's overall capacity to learn through patenting. The firm's past experience or its surrounding knowledge pool is distinguished into green and non-green technologies to control for potential overlapping between the two categories. To compute the firm patent stocks, we refer to the period 1981–2017 and use the

perpetual inventory method, with a knowledge depreciation rate (δ) = 10%. The two stocks of firm patenting are measured as:

$$K\_T_{it} = PAT\_T_{it} + (1 - \delta)K\_T_{it-1}$$

where *PAT* denotes patents and *T* refers to *G* and *NG*, respectively (where *G* stands for green and *NG* for non-green).

As mentioned above, independently of the existence of family involvement in business, firms' environmental behaviour has been studied with respect to environment-related activities and best practices, such as environmental management systems (EMSs). EMSs are a specific management process implemented voluntarily by private firms and based on the improvement of the environmental performance at the firm level. Several studies have hypothesized that EMSs can promote eco-innovations (among others, Dangelico et al., 2016; Montobbio and Solito, 2018; Wagner, 2007). Theoretical arguments suggest that family firms differ from non-family firms regarding the role of EMS certification, which merits separate and comparative analyses. Reputational and image-related reasons promote family firms' behaviour regarding the adoption of EMS certification. However, given that family firms are smaller than their non-family counterparts (Block and Wagner, 2014; Zahra et al., 2004), the lack of human and financial resources that are potentially needed for certification hinders its adoption. These arguments are taken into account by the environmental management system certification, which is gauged through the International Organization for Standardization's ISO14001 standard.[2]

Finally, the model specification includes several controls to estimate correctly the factors that are correlated with green patent propensity. The first controlling variable is *Size*, which aims to take into account the firm size effect. It is measured as the number of employees (in log). Another control is *Profit Margin*, which is a profitability indicator that takes into consideration the role of a firm's

[2] ISO 14001 is the most widespread international standard that supports organizations in the implementation and maintenance of their environmental management system (EMS), defining a list of requirements to improve their environmental performance (source: ACCREDIA).

financial performance in patenting. Moreover, the regressions include variables capturing factors related to (a) the firm location (four dummies considering whether a firm is based in the *North-West*, *North-East*, *Centre* and *South*, respectively); (b) the industry specialization (four industry dummies signalling whether the firm belongs to high-tech manufacturing, medium-high-tech manufacturing, medium-low-tech manufacturing and low-tech manufacturing); and (c) the firm age, measured as the number of years since the company was established. Finally, year dummies are added to capture period trend effects.[3] Table 2 provides a description of all the variables used in the analysis, while the descriptive statistics of the main variables are presented in Appendix A.

[3] The variables on the stock of patents, environmental certification dummy, size and profit margin are included with a one-year lag to take into account the likelihood that these factors will affect the propensity to patent in green technologies with a period lag.

Table 2 Description of variables

Variable	Description
Dependent variables	
$Green\_Pat_{it}$	Dummy indicating whether firm *i* is engaged in green patent at time t, with t = 2009, ….., 2017
Explanatory variables	
$Family_{it}$	Dummy taking the value 1 if a firm is over 50% owned by individuals or families, and 0 otherwise
K_G_{it-1}	Stock of Green patent calculated with perpetual inventory method
K_NG_{it-1}	Stock of Non-Green patent calculated with perpetual inventory method
D_EMS_{it-1}	Dummy equal to 1 if firm has an environmental management system certification (measured according to the International Organization for Standardization's ISO14001 standard) and 0 otherwise
Sector:	
$High\ Tech_{it}$	Dummy equal to 1 if the firm belongs to a High Tech Manufacturing and 0 otherwise.
$Medium\ High\ Tech_{it}$	Dummy equal to 1 if the firm belongs to a Medium High Tech Manufacturing and 0 otherwise
$Medium\ Low\ Tech_{it}$	Dummy equal to 1 if the firm belongs to a Medium Tech Manufacturing and 0 otherwise
$Low\ Tech_{it}$	Dummy equal to 1 if the firm belongs to a Low Tech Manufacturing and 0 otherwise
Territorial dummies:	
$North\ east_{it}$	Dummy equal to 1 if firms is located in the North East of Italy and 0 otherwise
$North\ west_{it}$	Dummy equal to 1 if firms is located in the North West of Italy and 0 otherwise
$Centre_{it}$	Dummy equal to 1 if firms is located in the Centre of Italy and 0 otherwise
$South_{it}$	Dummy equal to 1 if firms is located in the South of Italy and 0 otherwise
Age_{it}	Number of years since the company was established
$Size_{it-1}$	Number of employees (in log)
$Profit\_margin_{it-1}$	Profit before tax/Operating revenue (%)

4. Results

The results for the probit model, that is, the coefficients and average marginal effects, are reported in table 3 and table 4. Model 1 in table 3 displays the regression estimates of the model without controlling for sector, geographical and time effects. In model 2, the year dummies are included, whereas model 3 also controls for sector membership. Model 4 is the full specification, as it adds the geographical controls to model 3. Table 4 refers to the results obtained after estimating the full model specification for the samples of family (model 5) and non-family (model 6) firms.

The most important finding is that the variable family shows a negative and significant coefficient, indicating that family firms are less likely than other firms to implement innovations in green technologies. Family firms are 0.2% less likely to have green patents than non-family firms (table 3). This evidence is robust after controlling for the effects of industry, firm location and other firm-level factors. It is also consistent with the hypothesis according to which eco-innovations are complex and characterized by higher levels of novelty, uncertainty and variety (De Jesús Pacheco et al., 2016; Del Río et al., 2016; Hojnik and Ruzzier, 2016) and therefore require high-skilled employees and managers, the propensity to take risk, the capability to cooperate with external partners and the facility to access external sources of funding, which are less available in family than in non-family firms (Cainelli et al., 2015; De Marchi, 2012; Fabrizi et al., 2018; Ghisetti et al., 2015; Horbach et al., 2013). Finally, it is well known that family firms are characterized by specific traits regarding their innovative attitudes that should lead to weaker eco-innovation performance when compared with their non-family counterparts. These refer to family firms' organizational rigidity (Kets de Vries, 1993), high risk aversion (König et al., 2013; Munoz-Bullon and Sanchez-Bueno, 2011) and low ability to cooperate with external partners for innovation (Nieto et al., 2015), thereby signalling particular aversion to green innovation. Moreover, the willingness to keep control of the firm (Gòmez-Mejìa et al., 2007) hinders family firms from recruiting their managers effectively (Lubatkin et al., 2005) and limits their propensity to use investment capital to fund innovation projects (Block et al., 2013), which are necessary attributes for going green.

As green innovation in family firms is an unexplored research path (Calabrò et al., 2108), there is no study on the influence exerted by family ownership on the propensity to introduce a green patent; hence, no comparison with the pre-existing literature is possible. To the best of our knowledge, only Ardito et al. (2019) analysed family firm involvement in the development of green patents, but they examined the topic from a different point of view, the collaboration among firms being the main focus of their analysis.[4]

With respect to the role played by the knowledge accumulated in green fields, we find positive effects on the propensity to patent in green technologies. This result is in line with the existing empirical literature (for example, Laurens et al., 2017). The stock of knowledge in non-green technologies does not significantly affect the production of green patents. From this, a conclusion can be drawn: past investment in green knowledge 'pays' more than investment in other types of knowledge activity for current green patents.

Furthermore, to investigate whether the accumulation of knowledge has different impacts according to the firm type, we split the sample by considering family and non-family firms separately (table 4). We find that past investment in technology – irrespective of the type – could be beneficial for producing green inventions for family but not for non-family firms. For the latter, only green stock has a significant effect on the probability of introducing green patents.[5]

As far as the role of EMS certification is concerned, we find that having environmental management certification is positively and highly significantly correlated with the probability of introducing green innovation. In brief, EMS certification is effective in spurring patented innovation at the firm level (table 3). In terms of the magnitude effect, firms with EMS certification have a 0.6% higher probability of registering a green patent than non-certified firms. This result is similar to the

[4] Ardito et al. (2019) analysed the relationship between the involvement of family firms in R&D collaborations and the value of the resulting innovations and found a positive relationship between them in a sample of 156 joint patents classified as belonging to the 'alternative energy production' field.

[5] Here, it is interesting to highlight that the regressions do not include any innovation input, such as the investments in R&D. This is because of data unavailability in the Amadeus archives. However, the effect of past R&D efforts made by firms to produce technology is gauged by the stock of patenting.

findings of other studies in German and US settings (Chang and Sam, 2015; Wagner, 2007) and in line with the results found by Montobbio and Solito (2018) for a sample of European firms.[6] Our results stand in contrast to Wagner's (2007) finding for a sample of German firms that there is no significant association between environmental management and green patents. Interestingly, when we consider family and non-family firms separately, the coefficient is significantly positive for non-family firms (table 4), indicating that the implementation of environmental management systems can spur green innovation for non-family firms only.

Whit regard the control variables, we find that age does not exert any significant impact, while firm size influences green innovation negatively for family firms and positively for non-family firms. In addition, the profit margin has a negative and significant influence on green innovation for non-family firms. Moreover, we find that the sector does not exert any significant impact. Finally, family firms located in the north-west of the country have a lower probability of registering a green patent than family firms in other geographical areas (table 4, model 6).

[6] In Montobbio and Solito's (2018) study, EMS certification tended to show a positive correlation with green patents, although it could not be considered to be statistically different from zero. These results could have been affected by the small number of green patents and the small number of green innovators detected in the sample, as the authors themselves admitted.

Table 3 - Probit random effects, estimation results

Variables	Model 1 Coefficients - All	Model 1 AME - All	Model 2 Coefficients - All	Model 2 AME - All	Model 3 Coefficients - All	Model 3 AME - All	Model 4 Coefficients - All	Model 4 AME - All
Dummy for Family Firms	-0.1324*	-0.0023*	-0.1320*	-0.0023*	-0.1257*	-0.0022*	-0.1359*	-0.0024*
	(0.0753)	(0.0013)	(0.0756)	(0.0013)	(0.0759)	(0.0013)	(0.0764)	(0.0013)
K_NG (t-1)	0.0015	0.0000	0.0016	0.0000	0.0016	0.0000	0.0017	0.0000
	(0.0014)	(0.0000)	(0.0014)	(0.0000)	(0.0014)	(0.0000)	(0.0014)	(0.0000)
K_G (t-1)	0.3099***	0.0056***	0.3039***	0.0054***	0.3031***	0.0054***	0.3012***	0.0054***
	(0.0326)	(0.0007)	(0.0331)	(0.0007)	(0.0331)	(0.0007)	(0.0331)	(0.0007)
D_EMS (t-1)	0.3099***	0.0068***	0.2917***	0.0063***	0.2949***	0.0064***	0.2901***	0.0062***
	(0.0847)	(0.0023)	(0.0851)	(0.0022)	(0.0854)	(0.0022)	(0.0860)	(0.0022)
Size (t-1)	0.0641***	0.0012**	0.0682***	0.0012**	0.0645***	0.0012*	0.0637***	0.0011*
	(0.0244)	(0.0004)	(0.0246)	(0.0004)	(0.0247)	(0.0004)	(0.0247)	(0.0004)
Profit margin (t-1)	-0.0033	-0.0001	-0.0039	-0.0001	-0.0040*	-0.0001*	-0.0038	-0.0001
	(0.0024)	(0.0000)	(0.0024)	(0.0000)	(0.0024)	(0.0000)	(0.0024)	(0.0000)
Age	-0.0013	-0.0000	-0.0019	-0.0000	-0.0016	-0.0000	-0.0013	-0.0000
	(0.0020)	(0.0000)	(0.0020)	(0.0000)	(0.0020)	(0.0000)	(0.0020)	(0.0000)
High tech					0.1096	0.0021	0.0789	0.0015
					(0.1432)	(0.0030)	(0.1443)	(0.0029)
Medium high tech					0.1795*	0.0032*	0.1921*	0.0034*
					(0.1065)	(0.0019)	(0.1068)	(0.0019)
Medium low tech					0.0543	0.0010	0.0582	0.0011
					(0.1159)	(0.0022)	(0.1160)	(0.0022)
Centre							0.0118	0.0002
							(0.1668)	(0.0030)
North west							-0.1638	-0.0029
							(0.1535)	(0.0028)
North east							-0.2072	-0.0036
							(0.1550)	(0.0026)
Constant	-3.1173***		-3.0375***		-3.1470***		-3.0048***	
	(0.1457)		(0.1601)		(0.1870)		(0.2275)	
Year dummies	No		Yes		Yes		Yes	
Observations	29,544	29,544	29,544	29,544	29,544	29,544	29,544	29,544
log likelihood	-1328		-1319		-1316		-1314	
Wald chi2	250.9		265.8		270.3		274.2	
p-value	0		0		0		0	

Standard errors in parentheses *** p<0.01, ** p<0.05, * p<0.1

Table 4 - Family and Nonfamily firms: Probit random effects, estimation results

	Model 5		Model 6	
Variables	Coefficients - Family	AME - Family	Coefficients - Non-family	AME - Non-family
K_NG (t-1)	0.0394**	0.0005**	0.0009	0.0000
	(0.0179)	(0.0002)	(0.0014)	(0.0000)
K_G (t-1)	0.2235***	0.0027**	0.2927***	0.0069***
	(0.0854)	(0.0011)	(0.0384)	(0.0010)
D_EMS (t-1)	0.3117	0.0051	0.2645***	0.0070**
	(0.1906)	(0.0040)	(0.0980)	(0.0029)
Size (t-1)	-0.0862*	-0.0010*	0.1275***	0.0030***
	(0.0472)	(0.0006)	(0.0306)	(0.0008)
Profit margin (t-1)	0.0001	0.0000	-0.0049*	-0.0001*
	(0.0048)	(0.0001)	(0.0028)	(0.0001)
Age	-0.0006	-0.0000	-0.0000	-0.0000
	(0.0040)	(0.0000)	(0.0024)	(0.0001)
High tech	0.1246	0.0017	-0.0111	-0.0003
	(0.2438)	(0.0037)	(0.1839)	(0.0042)
Medium high tech	0.1725	0.0022	0.1776	0.0041
	(0.1657)	(0.0021)	(0.1413)	(0.0033)
Medium low tech	0.1475	0.0019	-0.0036	-0.0001
	(0.1735)	(0.0024)	(0.1584)	(0.0037)
Centre	-0.1261	-0.0014	0.1479	0.0038
	(0.2278)	(0.0024)	(0.2486)	(0.0071)
North west	-0.4527**	-0.0053*	0.0486	0.0011
	(0.2189)	(0.0027)	(0.2276)	(0.0053)
North east	-0.2549	-0.0031	-0.1408	-0.0032
	(0.2122)	(0.0027)	(0.2322)	(0.0051)
Constant	-2.6011***		-3.4493***	
	(0.3190)		(0.3176)	
Year dummies	Yes		Yes	
Observations	14,983	14,983	14,561	14,561
Number of BVD_id	2,157		2,069	
log likelihood	-457.1		-836.1	
Wald chi2	62.48		205	
p-value	1.56e-06		0	

Standard errors in parentheses *** p<0.01, ** p<0.05, * p<0.1

5. Concluding remarks

Although the literature on family business innovation has increased over the last decade, the role played by family involvement in green innovation is unexplored. This paper contributes to the existing research on the driving forces of eco-innovation by analysing how family and non-family firms differ in terms of introducing innovation in green fields. It uses a large patenting data set related to inventions produced by about 4200 Italian firms in the manufacturing sector over the 2009–2017 period. In so doing, it is the first work to address the issue of whether the involvement of family firms may affect the propensity to undertake green innovations.

The results show that family firms are less likely than non-family firms to implement innovations in green technologies. Moreover, we find that past investment in both green and non-green technology could be beneficial for producing green inventions in family firms. For non-family firms, only green stock plays a significant role in the probability of introducing green patents. Finally, the implementation of environmental management systems spurs green innovation only in the case of non-family firms.

It is well known that green innovation plays a key role in the smart and sustainable growth of a country. Here, the findings suggest that family firms are less likely than non-family firms to implement innovations in green technologies. An explanation is grounded in the divergence between the characteristics required to produce green innovation and the characteristics of family businesses. The literature investigating the determinants of eco-innovation has highlighted the fact that eco-innovations need complex and flexible structures, requiring the availability of qualified human resources (high-skilled employees and managers). Additionally, research in green fields is riskier than for other innovations and thus necessitates a high propensity to take risk and the capability to cooperate with external partners. However, family firms are notably risk averse, have difficulty in recruiting managers and other human resources effectively, are characterized by less flexible and more conservative organizations and, ultimately, are less inclined to engage in collaborative relationships.

These considerations suggest some strategic decisions to be adopted to increase family firms' capability to pursue green targets. For instance, family firms should deal with their low risk propensity. To this end, they should adopt procedures aimed at evaluating risky investments to understand better the opportunities to be gained from green riskier investments. Furthermore, firms should share the risk with other firms through collaborative innovation. In addition, family firms should promote a better managerial culture and a more flexible organization to be able to manage the complexity of environmental innovations. In this respect, they should recruit the necessary talented professional managers and specialized skills necessary to go green from outside the family circle.

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Appendix A - Descriptive statistics of the main variables

Variable	Obs	Mean	Std. Dev.	Min	Max
Firms with at least one green patent	29.544	0,01	0,10	0	1
Dummy for family firms	29.544	0,51	0,50	0	1
K_G	29.544	0,07	0,56	0	16,89
K_NG	29.544	2,31	13,14	0	717,66
D_EMS	29.544	0,13	0,33	0	1
Size (in logs)	28.203	3,99	1,47	0	10,42
Profit margin	28.455	4,15	11,07	-99,61	97,89
Age	29.544	27,88	16,30	1	120
High tech	29.544	0,09	0,28	0	1
Medium high tech	29.544	0,48	0,50	0	1
Medium low tech	29.544	0,29	0,45	0	1
Low tech	29.544	0,14	0,35	0	1
North east	29.544	0,39	0,49	0	1
North west	29.544	0,45	0,50	0	1
Centre	29.544	0,12	0,32	0	1
South	29.544	0,04	0,19	0	1

Authors elaboration on data from Amadeus/Orbis (Bureau van Dijk) and Accredia