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# PATENTS, FAMILY, AND SIZE. EVIDENCE FROM ITALIAN MANUFACTURING FIRMS


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# Patents, family, and size.
# Evidence from Italian manufacturing firms

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*Abstract.* This study explores whether the probability to patent differ between family and non-family firms, and whether any potential difference between firm-type is moderated by size. The analysis is based on a large archive of patenting activities (Orbis–PATSTAT dataset) carried out by around 3700 Italian manufacturing firms over the 2010–2017 period. The results from a probability model show that, on average, family firms patent less than non-family firms (the estimated average marginal effect is -0.0325). Firm size matters, as its average marginal effect is 0.0212, suggesting that the probability of patenting increases with size, no matter the firm ownership. The size effect differs, however, between family and non-family firms. It is demonstrated not only that family firms remain less likely to patent than non-family firms, but also that their disadvantages increase as they grow in size: in large firms, the probability of patenting is 0.22 for family firms and 0.39 for non-family firms. Importantly, the results hold when considering patent counts, citations and a number of additional sensitivity tests.

*JEL codes*: D22, L25, L60, O30
*Keywords*: family firms, patenting activities, firm size

## 1. Introduction

Research into the role of the family in influencing firm innovation is relatively recent, and has only increased in recent years (Calabrò et al., 2019; Röd, 2016). This interest has translated into a number of papers explaining why family and non-family firms differ in terms of innovation (for a review, see Carney et al., 2015). This huge body of literature provides evidence for and against family involvement in business (De Massis et al., 2013; Duran et al., 2016).

As observed by various scholars (among others, Chrisman and Patel, 2012; De Massis et al., 2014), these contrasting findings could be due to the fact that the sources of firm heterogeneity are not properly taken in account. This study investigates the circumstances under *which*, rather than *whether or not*, family firms (FFs) outperform or underperform compared to non-family firms (non-FFs). The underlying idea is that the interaction between ownership and some key contingency factors might play a crucial role in understanding whether and to what extent differences in FFs characteristics affect their innovative activities. One of these key factors is firm size, which has been ignored so far in the related literature (De Massis et al., 2013).

Although it has been well established that firm size affects innovative performance, the relationship is controversial. Some studies find a positive size-effect (Cohen, 1995; Cohen and Klepper, 1996a; Legge, 2000; Mintzberg, 1993; Whittington et al., 1999). The opposite is also demonstrated by several scholars (Acs and Audretsch, 1990, 1991; Cohen and Klepper, 1996b; Griliches, 1980; Lichtenberg and Siegel, 1991; Pavitt et al., 1987).

An intriguing aspect of this literature is that nothing is known about whether the ownership *per se* in the group of FFs drives innovation, or whether its effect is moderated by firm size. The research question is therefore: are there differences in the probability to patent between FFs and non-FFs, and do they vary according to firm size?

The analysis is carried out by using a large patenting dataset provided by the Bureau van Dijk, which has been linked to the European Patent Office's (EPO) PATSTAT dataset. The final sample comprises approximately 3700 Italian manufacturing firms, which are observed over the 2010–2017 period. Innovation is gauged by patents, because they are likely to be the most definite measure of innovation output (Wang, 2007) and they are less affected by personal views than measures used in surveys. Patents also reflect the quality of an innovation, as any patentable innovation is examined by experts who evaluate its novelty and utility. They also gauge the market value of an innovative project better than R&D input does.

Four specific results were noted. Firstly, the evidence confirms that ownership matters in determining the extensive margin of patenting. Other things being equal, we find that the probability of patenting is, on average, lower (-3.25%) for FFs than for their non-FF counterparts, thereby enriching the limited empirical evidence on the topic (Bannò, 2016; Chirico et al., 2020; Decker and Günther, 2017; Matzler et al. 2015; Tognazzo et al., 2013). Secondly, the probability of patenting increases with size, as its average marginal effect (AME) is significant and equal to 2.12%, confirming some prior research (Cohen, 1995; Cohen and Klepper, 1996a; Legge, 2000; Mintzberg, 1993; Whittington et al., 1999). Thirdly, firm size helps to better explain the conditions under which FFs outperform (underperform) compared to non-FFs. While FFs and non-FFs behave similarly when they are very small (with sales less than 2 million euros), after this threshold, the evidence suggests that FFs patent probability gap increases with size. For instance, the probability of patenting in large firms is 0.22 for FFs and 0.39 for non-FFs.

These points comprise the main contribution of the paper, because, to the best of our knowledge, no analysis has yet been carried out in this area of research in the family business innovation literature.

Importantly, when patent counts (intensive margins) are used as an outcome variable instead of the probability to patent (extensive margin), the analysis leads to the same conclusions. The same applies when using the number of patent citations as a proxy of patent quality: the greater the size the lower the quality of an FF's patents compared to non-FFs. Finally, it is worth mentioning that the results were not affected by the use of an alternative proxy for firm size or different measures of family ownership (thresholds other than 50% or a continuous variable).

The paper is organised as follows. Section 2 presents the theoretical framework. Data, variables, and the empirical strategy are described in Section 3, and the results are presented in Section 4. Section 5 discusses the results and draws some concluding remarks.

## 2. Theoretical background and hypothesis development

This section presents a conceptual framework for the moderating role of firm size in explaining the relationship between family ownership and innovation.

Prior research on family business innovation highlights how FFs show different behaviour in terms of innovation compared to non-family counterparts (exhaustive reviews have been written by Carney et al., 2015; De Massis et al., 2013; Duran et al., 2016; Röd, 2016). While most studies have focused on R&D investments (Aiello et al., 2020; Block, 2012; Brinkerink and Bammens, 2018; Chen and Hsu, 2009; Gomez-Mejia et al., 2007; Kotlar et al., 2014), a few have considered the propensity to patent (Bannò, 2016; Chirico et al., 2020; Decker and Günther, 2017; Tognazzo et al., 2013). Despite the numerous studies, there is no consensus about whether family ownership is good or bad for innovation (Calabrò et al., 2019; De Massis et al., 2013; Duran et al., 2016).

It has been argued that the contrasting findings could be due to specific factors of firm heterogeneity which are not properly taken in account (Chrisman and Patel, 2012; De Massis et al., 2014; Daspit et al., 2021). In other words, the interaction between ownership and some key contingency aspects might play a crucial role in providing a better understanding of whether and to what extent differences in FFs characteristics affect their innovative activities. Some scholars have focused on the degrees of ownership and generational stage (Decker and Gunther, 2017) and others on the role of age (Bianchini et al., 2018) or the background characteristics of executives. No one has considered the role of size, even though the business dimension is a representative indicator of the heterogeneity in family organisations. For instance, Miller et al. (2013) demonstrated that firm size and owner concentration are good predictors of how having a family CEO affects Italian firm performance (expressed as the return on assets). Bauweraerts et al. (2021) confirmed this result for Belgian firms. However, size also acts as a contingency factor in determining the effect of FFs on innovation (De Massis et al., 2013). Werner et al. (2018) provided some evidence showing that smaller German FFs are more likely to introduce product/process innovation than their non-family counterparts.

Departing from these insights, we formulate a research hypothesis according to which the innovative gap – expressed as the attitude to patenting – between FFs and non-FFs varies with firm size. In so doing, we refer to the agency cost and socioemotional theories as well as decision-making processes.

It is well known that some unique traits of FFs act as a restraint or *stimulus* for innovation compared to non-FFs. On one hand, the dominance of non-economic goals (Gómez-Mejía et al., 2007) means that innovation in FFs is limited because they are risk averse and use less external finance in order to avoid ownership dispersion (Chirico et al., 2020; Naldi et al., 2007). Another concern relates to tacit knowledge. FFs can leverage tacit knowledge and exploit personal links with external stakeholders to innovate more easily than non-FFs (Arregle et al., 2007; Patel and Fiet, 2011). Patenting activities make the knowledge public, however, thereby destroying the capital of soft information, which is a key asset for FF survival and generational succession (Chirico et al., 2020; Cabrera-Suárez et al., 2001; Sirmon et al., 2008).

On the other hand, innovation is positively related to informal decision making and flexibility in processes which are prevalent in FFs (Daily and Dollinger, 1992). The alignment of interests and minimal information asymmetry between owners and managers (Chrisman et al., 2004; Jensen and Meckling, 1976) also enables fast coordination and efficient management (Werner et al., 2018), thus affecting innovation.

An intriguing issue is whether the above considerations hold when considering firm size. In other words, the potential advantages may be eroded or even reversed when a business increases in size.

As companies grow bigger, any firm process increases in complexity, and greater formalisation is needed to coordinate and take advantage of emerging market opportunities. There is thus usually a need for new skills that are difficult to find in a restricted family circle, as the pool of qualified family managers is limited (Lubatkin et al., 2005). Conversely, recruitment in non-FFs is from a very large pool of potential candidates that can inject fresh energy and resources that will boost innovation (Nordqvist and Melin, 2010). Notably, even when family executives perform poorly, they are hard to remove because of their significant ownership or their influence over other family owners (Miller et al., 2013; Morck and Yeung, 2003).

Another aspect to be considered arises from the organisation of decision-making processes. Larger firms usually coordinate innovation activities with the help of formal management systems, while FFs rely mainly on less formalised processes that can turn into disadvantages compared to non-FFs. The costs of a limited organisational structure may be higher than the benefits of an FF's closer connections with stakeholders, or of the tacit knowledge that family members usually possess.

Size is important when considering finance for innovation. Micro and small firms face a number of financial constraints, whatever their ownership, however, the picture changes as size increases because more finance is required to innovate. In such a case, the search for additional finance is limited by an FF's lower propensity to make use of risky capital to fund innovation projects (Block et al., 2013) in order to avoid loss of control (e.g. Gómez-Mejía et al., 2007).

The hypothesis, based on these arguments, is that size affects the context in which firms operate, thus affecting their patent activities. The level of complexity, the number of people to be managed, and the amount of resources available increase with size. Small FFs represent a context wherein the advantages and disadvantages possessed by an FF compared to a non-FF offset each other, with potentially neutral implications for innovation. Conversely, increasing size amplifies the disadvantages and reduces the advantages of family-owned firms, thereby widening the innovative gap with non-FFs.

We thus recognise the relevance of firm size in predicting the effect of family ownership on probability to patent, and expect that FFs perform similarly to non-FFs when they are small, and underperform when they are large.

## 3. Empirical setting

This section presents the data (§ 3.1) and describes the econometric strategy implemented in the analysis (§ 3.2).

### *3.1 Data*

The sample used in this study was obtained from the Orbis Europe (Bureau van Dijk) database and comprised an initial panel of about 26,000 firms which had applied for at least one patent with the European Patent Office (EPO) between 1981 and 2017.[1] A homogeneous population of potentially innovative firms for which patenting is (or has been) a relevant tool to protect innovation has thus been considered.

The patents are from the Orbis Europe dataset by Bureau van Dijk, which was connected to PATSTAT released by the EPO. The Orbis–PATSTAT dataset makes available a unique firm identifier, which allows firm-level patents and the balance sheet data contained in Bureau van Dijk's Orbis Europe archive to be matched (Bureau van Dijk's Orbis Europe archive also provides information on the ownership structure of the firms).[2]

Innovation output is measured by patents, and, in order to limit potential bias due to lowest-quality patents (such as non-successful applications), the sample comprises the patents granted by EPO. A caveat to this choice is that it excludes patent applications made in the most recent years of the period under scrutiny, thereby leading to the potential underestimation of firm innovation activities (Francis et al. 2021; Hall et al. 2001). Indeed, if applications are made towards the end of the period, then a sample formed by granted patents will exclude them because of the time lag involved in the examination process at any patent office. To limit this truncation bias we include patents applied for until 2017 and granted by 2021. In other words, we follow patents up to 2021, that is when they were granted (in our sample it takes about three years for a patent to be granted by the EPO).[3]

[1] This study is based on patent applications filed at the EPO rather than at the National Patent Office. Given that national filings are likely to have lower average quality (Boeing and Mueller, 2016; Deng, 2007) and have lower costs associated with the European patenting route, the measure adopted in this study could be biased in favour of large companies compared to small and medium enterprises.

[2] Only priority patents were included, while equivalent patent filings were excluded. A priority patent is the first patent filing made by applicants to protect the invention in a given country, and the equivalent patents are the subsequent filings made in other patent offices where protection is sought.

[3] For a discussion of the advantages and disadvantages of using patents as a measure of technological change, see Archibugi and Pianta (1996) and Aiello et al. (2021a). Here, it is worth summarising a few points. 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. Notably, patents are commensurable as they are based on an

After merging the financial data of firms with patents, the final unbalanced panel data includes about 26,000 observations obtained from Italian manufacturing firms over the period 2010–2017. The sample comprises 3715 firms, 88% of which were observed every year over the period 2010-17 (this proportion increases to 95% for firms which had been in the sample for at least three years). Table 1 refers to 2017, and shows the sample distribution among FFs (1749 out of 3715 companies) and non-FFs (1966 companies). Firms with at least one patent between 2010 and 2017 comprise 57.44% of the sample; among these, 42.41% are FFs and 57.59% are non-FFs. As far as size is concerned, FFs are concentrated in the group of small and medium enterprises, while non-family companies are mostly medium and large.[4] Here, it is worth mentioning that in this discussion of the sample, firms are grouped following the classification proposed by Eurostat (2017) (high technology, medium-high technology, medium-low technology, and low technology) which takes into account the technological intensity of each manufacturing sector. Firm location is defined at the level of macro-regions (NUTS 1).[5] The sample presents a high concentration of firms in the medium–high-tech companies (49.04%), located mainly in the north of Italy (83.53%), which is the most industrialised area in the country, and old companies (67.36%). The data reveal that the distribution of FFs and non-FFs does not substantially differ when considering geography and industry composition.

objective standard; that is, the type of invention that can be patented is clearly defined, meaning that patents are probably the most definite measure of innovation (Wang, 2007). Indeed, compared with other innovation measures, usually gauged through surveys, patents are less exposed to personal views. They also reflect the quality of an innovation, as any patentable innovation is examined by experts who evaluate its novelty and utility. By contrast, reliable information on the quality of an innovation can rarely be gathered from other sources, especially if they are based on subjective judgements. Moreover, and differently from R&D expenditures, patents measure the outputs of the inventive process, thereby gauging the market value of an R&D project better than investments. Finally, patent data are quantitative and widely available. For these reasons, their use as a measure of the output of the inventive process has become widespread in the literature (Griliches, 1990; Hall et al., 1986).

[4] Firm size is measured in terms of annual turnover, which allows the sample to be split on the basis of the threshold values reported in the Commission Recommendation 96/280/EC (updated in 2003/361/EC of May 6, 2003).

[5] Detailed sectoral and geographical distributions of the sample employed when performing the econometric analysis (i.e., NUTS-2 regions and NACE 2-digit code, respectively) are given in Tables A2 and A3 in the appendix.

## Table 1. Distribution of the sample of firms

| | | | | FFs | | Non-family firms | |
|---|---|---|---|---|---|---|---|
| | | N. | % | N. | % | N. | % |
| Firms | | 3,715 | 100% | 1,749 | 47.08% | 1,966 | 52.92% |
| Firms with at least one patent | | 2,134 | 57.44% | 905 | 42.41% | 1,229 | 57.59% |
| *Firm size** | | | | | | | |
| | Micro (≤ €2 m) | 575 | 15.91% | 430 | 25.12% | 145 | 7.63% |
| | Small (≤ €10 m) | 1,050 | 29.06% | 707 | 41.30% | 343 | 18.04% |
| | Medium (≤ €50 m) | 1,298 | 35.93% | 506 | 29.56% | 792 | 41.66% |
| | Large (> €50) | 690 | 19.10% | 69 | 4.03% | 621 | 32.67% |
| *Sectors* | | | | | | | |
| | High Tech | 343 | 9.23% | 114 | 6.52% | 229 | 11.65% |
| | Medium–high tech | 1,822 | 49.04% | 804 | 45.97% | 1,018 | 51.78% |
| | Medium–low tech | 1,037 | 27.91% | 562 | 32.13% | 475 | 24.16% |
| | Low tech | 513 | 13.81% | 269 | 15.38% | 244 | 12.41% |
| *Territorial area* | | | | | | | |
| | Northeast | 1,463 | 39.38% | 672 | 38.42% | 791 | 40.23% |
| | Northwest | 1,640 | 44.15% | 745 | 42.60% | 895 | 45.52% |
| | Centre | 459 | 12.36% | 246 | 14.07% | 213 | 10.83% |
| | South | 153 | 4.12% | 86 | 4.92% | 67 | 3.41% |
| *Firm age** | | | | | | | |
| | Young (< 6 ) | 151 | 4.14% | 58 | 2.57% | 93 | 6.73% |
| | Mature (6–20) | 1,038 | 28.49% | 478 | 21.14% | 560 | 40.52% |
| | Old (> 20) | 2,454 | 67.36% | 1725 | 76.29% | 729 | 52.75% |

**Note**: * Due to missing data on size and age in some years, the number of firms differs from the entire sample.
**Source**: Authors' elaboration of data from Orbis Europe (Bureau van Dijk).

### *3.2 Empirical strategy and variables*

To test whether and to what extent patenting differs between FFs and non-FFs, a panel random-effect probit model is applied, thereby allowing time-invariant predictors to be included in the regression.[6] In order to estimate the probability of filing a patent application,[7] the dependent variable is the dummy variable *Patents*, which takes a value of one when a firm has at least one patent, and zero otherwise.

The model specification is as follows:

$$p_{i,t} = \Pr\left(Patents_{i,t} = 1 | \boldsymbol{X_{it}}, \boldsymbol{\beta}, \boldsymbol{\delta}, \boldsymbol{\theta}, \alpha_i\right) =$$

$$=\Phi(\alpha_i + \beta_0 + \beta_1 Family_i + \beta_2 Size_{i,t} + \beta_3 Family_i * Size_{i,t} + \beta_4 Stock\ of\ patents_{i,t} + \beta_5 Age_{i,t} + \sum_j \boldsymbol{\delta}_j \boldsymbol{D}_{ji} + \sum_t \theta_t T_t)$$

where $p_{it}$ is the probability that the dependent variable *Patents* is equal to 1 for firm *i* in the year *t*, $\Phi(\cdot)$ is the cumulative standard normal distribution function, *Family, Size, Stock of Patents* and *Age* are the explanatory variables presumed to affect $p_{it}$; $\boldsymbol{\beta}$ are the coefficients to be estimated. Vector $\boldsymbol{D}_i$ includes additional control variables, that is sector and regional dummies, and $\boldsymbol{T}$ refers to year dummies.

The key explanatory variables are the *Family* dummy and firm *Size*. As there is no agreement on the definition of a family business (Hernàndez-Linares et al., 2018), firms are classified as FFs when individuals or families record the direct ownership of over 50%.[8] Some robustness checks are performed with two additional ownership thresholds (40% and 60%) and with a continuous measure of ownership. Here, firm *Size* is measured by the logarithm of turnover, which is replaced in the sensitivity analysis by the number of employees.

Regressions include several controls to correctly estimate the factors that are correlated with current patent probability. One of these is the stock of patents, which we use as a proxy for a firm's overall capacity to learn through patenting. As in Aiello et al. (2021a), it is meant to gauge the role of past knowledge accumulation, and is calculated by applying the perpetual inventory method to firm patents over the period 1981–2017 with a knowledge depreciation rate equal to 10%.[9]

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[6] It may be possible to estimate fixed effects with a Probit including firm-specific dummy variables, however, the estimates would not be consistent. See Cameron and Trivedi (2005) for an exhaustive discussion on nonlinear panel data models.

[7] Here, it is useful to say that we model the probability to patent because we are not able to distinguish between the propensity to patent, leading from inventions to patents, and research productivity, leading from research to inventions. Indeed, it is worth noting that both dimensions could determine a given number of patents, and were found to be affected by the design of policy tools, such as education, and policies on intellectual property and science and technologies (De Rassenfosse and de la Potterie, 2009).

[8] In the related literate, a threshold of at least 50% of the company's shares is commonly used for privately-held companies (e.g., Arregle et al., 2012; Arzubiaga et al., 2018; Broekaert et al., 2016; Classen et al., 2014; Memili et al 2015b; Meroño-Cerdán et al., 2018; Miller et al., 2013; Vandekerkhof et al., 2018). This common practice seems to be appropriate for our setting because the structure of firm ownership in Italy is characterised by a limited number of shareholders with very large block holdings, thereby implying that a 50% stake is enough to achieve control of the company (Miller et al., 2013). Some robustness checks, however, are performed considering the thresholds of 40% and 60% and a continuous variable of family ownership.

[9] The intangible nature of a stock of knowledge makes it difficult to determine the depreciation rate of knowledge. Some scholars use a rate of 15% (Aiello and Cardamone 2012; Goto and Suzuki 1989; Griliches and Mairesse 1983; Hall et al., 2005; Laurens et al., 2017), while others consider 10% (Bitzer and Stephan 2007; Montobbio and Solito, 2018; Zawalińska et al., 2018). While we applied a rate of 10%, a sensitivity analysis has been conducted using 15%. The results are robust, and available upon request.

Regressions also include variables capturing factors related to industry specialisation.[10] In such a case, firms are classified at the two-digit level of the statistical classification of economic activities developed by the EU since 1970, and known as NACE (Nomenclature statistique des Activités économiques dans la Communauté Européenne). It collects a large range of data according to economic activity in the fields of economic statistics (e.g. production, employment, national accounts) and in other statistical domains. The firm location is also at the two-digit level of the Nomenclature of Territorial Units for Statistics (NUTS2, corresponding to the regions).[11] Finally, firm age is measured as the number of years since the company was established, and the year dummies are added to control for time effects.[12] When performing robustness checks, the probability to patent as an outcome variable is replaced by the number of patent applications, and the by the number of citations that each patent received within five years from the first publications.

The summary statistics of the key variables used in this study are presented in Table 2. It emerges that patenting firms represent 17% of the sample, while the average number of patents per firm is 0.37 and the average number of citations is 1.17. FFs account for 47% of the sample. Firm sales are, on average, about 9 million euros, while the stock of patents is about 2 patents (in Table 2 the latter two variables appear in log). The firms are 27 years old on average. Finally, the explanatory variables are weakly correlated (Appendix Table A4).

**Table 2 Descriptive statistics**

| Variable | Obs | Mean | Std.Dev. | Min | Max |
|---|---|---|---|---|---|
| Patent (dummy) | 24,850 | 0.17 | 0.38 | 0.00 | 1.00 |
| Number of patent applications | 24,850 | 0.37 | 1.70 | 0.00 | 55.00 |
| Number of citations | 4,216 | 1.17 | 4.31 | 0.00 | 197 |
| Family firms | 24,850 | 0.47 | 0.50 | 0.00 | 1.00 |
| Size (Sales) (in log) | 24,850 | 9.07 | 2.17 | -0.04 | 17.08 |
| Stock of patents | 24,850 | 0.65 | 0.64 | 0.00 | 5.24 |
| Age | 24,850 | 27.255 | 16.50 | 1.00 | 120.00 |

**Source**: Authors' elaboration of data from Orbis Europe (Bureau van Dijk).

## 4. Results

### *4.1 Size moderates the ownership effect on the probability to patent*

Table 3 shows the results obtained through the Probit random effects. Columns 1 and 2 report the estimates (coefficients and AME) when the model is estimated with the *Family* dummy variable only (Model 1). The opposite holds for Model 2 (Columns 3 and 4) in which *Size* replaces *Family*. The next two columns are related to the model with *Size* and the *Family* dummy variables (Columns 5 and

[10] A typical argument in the neo-Schumpeterian literature is that the characteristics of a particular sector or industry with which a firm is affiliated may affect its innovation activity. Different sectors have different technology and innovation opportunities, and are thus characterised by different technological regimes (Malerba and Orsenigo, 1993).

[11] The Nomenclature of Territorial Units for Statistics (NUTS) is a geographical nomenclature subdividing the economic territory of the European Union into regions at three different levels (NUTS 1, 2 and 3 respectively, moving from larger to smaller territorial units).

[12] The variables of the stock of patents and size are included with a one-year lag to take into account the likelihood that these factors will affect the probability to patent in technologies with a period lag.

6 – Model 3), while the regression results obtained with the interaction between family and firm size are displayed in Columns 7 and 8 (Model 4). Every model specification includes a set of controls.

Before discussing the evidence related to the key research questions, it is useful to note here that in all estimations firm *Age* has a negative effect on the probability of patenting. This is in line with the literature, which found an inverse relationship between age and innovative output (Hansen, 1992), a high propensity for young firms to introduce radical innovation (Acemoglu and Cao, 2015), and a low level of innovation by aged firms because of their incumbent inflexibility (Hill and Rothaermel, 2003). Furthermore, the stock of patents has a positive and significant effect, suggesting that past investments are beneficial for introducing patented innovation.

The variables of interest are *Family* and *Size*. The first valuable finding is that in the baseline model the variable *Family* has a negative and significant coefficient (the AME is –0.054, Column 2), indicating that FFs are less likely than other firms to implement patented innovations. Importantly, the sign and statistical significance hold after controlling for the effects of industry, time, firm location, and other firm-level factors (i.e., in the full model specification, the AME of *Family* is – 0.0325).

The second finding involves the role of *Size*. First of all, and in line with the Schumpeterian assumption, in a basic model we find that, on average, firm *Size* has a positive and significant effect on patenting (Columns 3-4 of Table 3). When both *Family* and *Size* enter into regressions, the family ownership effect remains highly significant and the firm effect is positive and significant (i.e. the AME is 0.0212 in column 8). This might be driven by the fact that large organisations have more resources to adopt new innovations (Kitchell, 1995). In fact, patenting entails several direct and indirect costs related to developing, attaining, and maintaining patent protection.

At this stage of the discussion, it is of interest to verify whether and to what extent the effect of firm size differs between FFs and non-FFs, and whether the results vary with different values of *Size*. Indeed, there could be potential channels through which *Family* and *Size* interact. Therefore, in the following, we refer to the probit estimates without (Column 5) and with the interaction between *Family* and *Size* (Column 7). In discussing the coefficients of interactions in probit models, we follow Ai and Norton (2003), Karaca-Mandic et al. (2012), and Mize (2019), and convey our results in a meaningful way by providing graphical interpretations. The probability of patenting is thus plotted against *Size*, distinguishing between family and non-family firms (Figure 1).

Figure 1a plots the predicted probability of patenting at different values of *Size* for FFs and non-FFs with no interaction; that is, it refers to the estimates reported in Column 5 of Table 3. Whatever the *Size*, non-FFs (blue line) register a significantly higher probability of patenting than FFs (red line). The two curves are quasi-parallel, as suggested by the marginal effect (ME) values calculated at three levels of *Size*. Importantly, the curves of the probability of patenting in Figure 1.b are very different, suggesting that the interaction between family and size addresses the issue related to potential model *mis*-specification bias (Mize, 2019). The results also confirm that the interaction effect cannot be evaluated simply by looking at the sign, magnitude, or statistical significance of the coefficient of the interaction term when the model is nonlinear.

It is worth noting that when *Size* is very low, the curve of FFs is higher than that of non-FFs. As *Size* is higher than 5, the probability that FFs will patent is always lower than that of non-FFs, however, the relevance of the between-group difference depends on *Size*: it gains statistical significance after a certain threshold, which is about 1 million euros. In brief, ownership does not affect the probability of patenting only in very small firms, but it is crucial as firm size increases.

Except for micro businesses, Figure 1.b clearly shows a very different slope of the two curves, thereby signalling that FFs tend to have a lower probability of patenting than non-FFs. In other words, the innovative gap increases with *Size*. Some numerical examples can help explain this. Let us fix size equal to 1: a one-unit increase in *Size* determines the same increase of the probability of patenting (0.008 for FFs and 0.006 for non-FFs, although their difference is not significant). When *Size* increases, for instance from 10 to 11, the probability of patenting increases by 0.015 for FFs and 0.031

for non-FFs. At size = 15, the probability increases by 0.019 and 0.041 for FFs and non-FFs respectively.

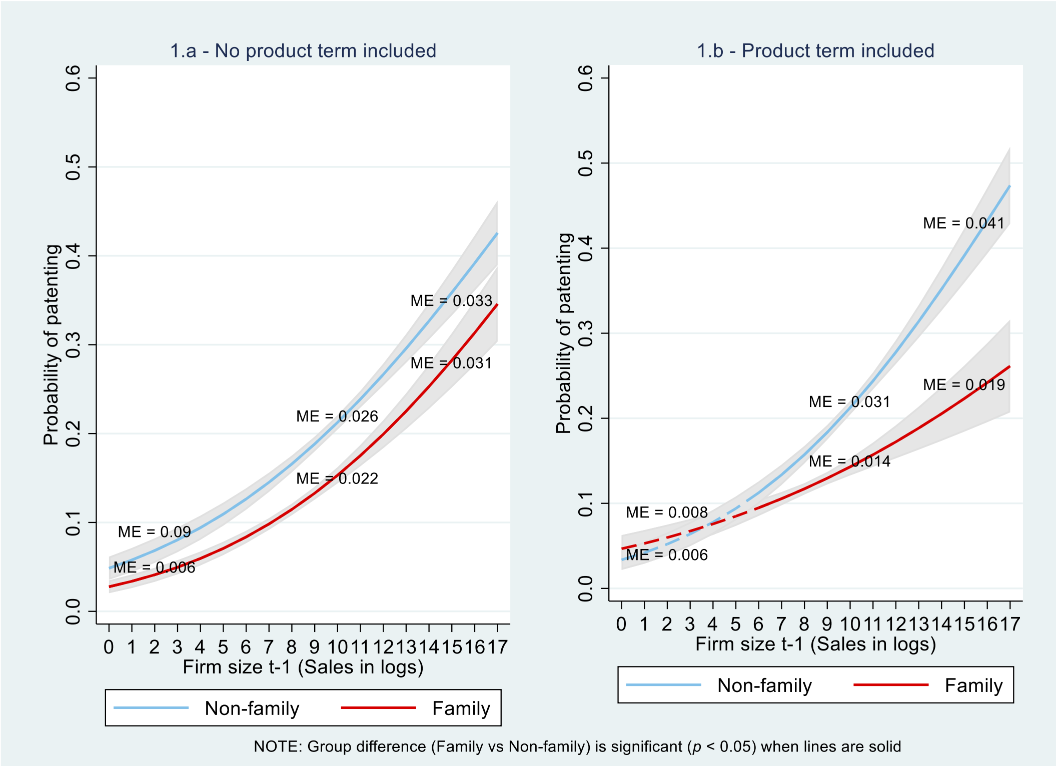
The result of these dynamics is that at any level of *Size*, *ceteris paribus*, the probability of patenting exhibits very different values: for instance, with size = 15, that is, in the case of large firms, the probability of patenting is 0.22 for FFs and 0.39 for non-FFs. In brief, the evidence is that the larger the size, the greater the expected difference between the probability of FFs and non-FFs patenting.

**Table 3 Family ownership and the probability of patenting. Results from a panel probit random effects model**

| | Model 1 | | Model 2 | | Model 3 | | Model 4 | |
|---|---|---|---|---|---|---|---|---|
| | (1) | (2) | (3) | (4) | (5) | (6) | (7) | (8) |
| | Coefficients | AME | Coefficients | AME | Coefficients | AME | Coefficients | AME |
| Family firms$_{it}$ | -0.252*** | -0.0548*** | | | -0.1273*** | -0.0277*** | 0.3277*** | -0.0325*** |
| | (0.0256) | (0.0055) | | | (0.027) | (0.0059) | (0.1225) | (0.0058) |
| Firm size$_{it-1}$ (in logs) | | | 0.1101*** | 0.024*** | 0.0981*** | 0.0214*** | 0.1175*** | 0.0212*** |
| | | | (0.0069) | (0.0015) | (0.0073) | (0.0016) | (0.009) | (0.0016) |
| Family firms$_{it}$*Firm Size $_{it-1}$ | | | | | | | -0.0504*** | |
| | | | | | | | (0.0132) | |
| Stock of patents $_{it-1}$ (in logs) | 0.485*** | 0.1058*** | 0.4287*** | 0.0936*** | 0.4236*** | 0.0923*** | 0.4188*** | 0.0911*** |
| | (0.0213) | (0.0049) | (0.022) | (0.005) | (0.0221) | (0.005) | (0.0222) | (0.005) |
| Firm age$_{it}$ | -0.0014* | -0.0003* | -0.0055*** | -0.0012*** | -0.005*** | -0.0011*** | -0.0047*** | -0.001*** |
| | (0.0008) | (0.0002) | (0.0008) | (0.0002) | (0.0008) | (0.0002) | (0.0008) | (0.0002) |
| Sectors dummies (NACE 2) | YES | YES | YES | YES | YES | YES | YES | YES |
| Regions dummies (NUTS 2) | YES | YES | YES | YES | YES | YES | YES | YES |
| Years dummies | YES | YES | YES | YES | YES | YES | YES | YES |
| Constant | -1.2542*** | | -2.2852*** | | -2.1375*** | | -2.345*** | |
| | (0.0927) | | (0.1105) | | (0.1142) | | (0.1279) | |
| Observations | 25473 | 25473 | 24850 | 24850 | 24850 | 24850 | 24850 | 24850 |
| Log likelihood | -10.388.751 | | -10091.56 | | -10.080.355 | | -10.073.127 | |
| Wald chi2 | 978.01 | | 1205.07 | | 1245.05 | | 1265.65 | |
| p-value | 0.000 | | 0.000 | | 0.000 | | 0.000 | |

Standard errors in parentheses; *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$. The dependent variable is the dummy *Patents*. Columns 1 and 2 report the estimates (coefficients and AME) when the model is estimated with the *Family* dummy variable only; Columns 3 and 4 display the estimates when the model is estimated replacing the variable *Family* with *Size*; Columns 5 and 6 refer to the model with *Size* and *Family*; Columns 7 and 8 add the product term *Family**Size*.

**Figure 1. The predicted probability of patenting by firm ownership and size**




*4.2 Sensitivity analysis*

In this section we examine the robustness of the relationship between family ownership, size and the extensive margin of firm patenting (i) using different definitions of family firms, (ii) measuring firm size with the number of employees instead of sales, (iii) considering the number of patents as innovation output (intensive margin of patenting) and (iv) using the total number of forward citations per patent as a measure of the ''quality'' of innovation output. Tables 4 and 5 give the regression results.[13]

The first check comes from using alternative definitions of FF. We proceed by following two alternative approaches. Because there is no universally accepted conceptualisation of family business (Hernàndez-Linares et al., 2018), the first approach is to consider different thresholds of family ownership. Here we consider 40% and 60% instead of 50% as thresholds of family ownership. The results confirm the evidence so far discussed: AME is negative for FFs and positive for *Size* (Columns 2 and 4 of Table 4). Importantly, the magnitude of the effect is always -0.03 for FFs and 0.02 for *Size*. The analysis allows the same picture to be shown when using a more restrictive definition of FFs. For instance, Figure 1 refers to the estimates obtained when FF is not only family-owned but also with a CEO belonging to the family circle. The meaningful evidence is that the two curves behave similarly to the ones in Figure 1b, confirming that family involvement in business matters beyond a certain threshold of firm size. Indeed, micro-FFs with a family CEO perform similarly to non-FFs. Conversely, at any level of *Size* above about 1 million euros of sales, the extensive margin of patenting is significantly lower for FFs than for non-FFs.

The second approach is to re-run the regressions by referring to a continuous measure of family ownership instead of the dummy *Family*. Thus, we use the variable *Family Ownership* which is expressed as the percentage of shares owned by a family (that is, the number of shares held a family

[13] Compared to Table 3, the results displayed in Tables 4 and 5 refer only to the model with the product term between *Family* and *Size*. However, the robustness checks have also been performed for the other three models of Table 3, and the estimates are provided as online supplementary material.

divided the total shares) (on this, see Anderson et al. (2012)). While the estimates are in Table 4 (Columns 5-6), Figure 3 summarises the most relevant result, given the scope of the paper. Indeed, it provides a visual representation of how the probability of patenting changes for different values of *Family Ownership* and *Firm Size*.[14] The colouration changes from lighter to darker shades: the lightest grey shades of the contours refer to the lowest probability of patenting, while the darkest shade shows a greater probability. The vertical line represents the share of family ownership that allows control of the company (51%). It emerges that when firms are small (i.e., with about 1 million euros of sales), the probability of patenting is low, regardless of the ownership stake. This confirms that micro-FFs perform similarly to their non-FFs counterparts. When size increases, the probability of patenting decreases on average, as the ownership share held by the family increases. The highest predicted probability of patenting is observed for large firms with a family ownership less than 30%.

[14] Following Chirico et al. (2020) we augment the model including the quadratic term of family ownership. However, the likelihood-ratio test to determine whether adding Family Ownership$^2$ improves model fit yields evidence in favour of the model without the squared term. This conclusion is supported by the Bayesian information criterion (BIC) (Raftery, 1995). This does not seem to be unexpected evidence, as the non-linearity of the estimator we use still captures the non-linear effect of Family Ownership (non-linearity is, for instance, depicted in Figure 3). In any case, the results of the model with the squared term of Family Ownership$^2$ are provided as online supplementary material.

**Table 4. Probit random effects results on the probability of patenting for alternative measures of family ownership and when firm size is expressed as number of employees**

| | Ownership threshold | | | | Continuous measure of ownership | | Firm size as number of employees | |
|---|---|---|---|---|---|---|---|---|
| | 40% | | 60% | | | | | |
| | (1) | (2) | (3) | (4) | (5) | (6) | (7) | (8) |
| | Coefficients | AME | Coefficients | AME | Coefficients | AME | Coefficients | AME |
| Family firms$_{it}$ | 0.3291*** | -0.0321*** | 0.2998** | -0.0326*** | 0.0033** | -0.0004*** | 0.2234*** | -0.0246*** |
| | (0.1223) | (0.0058) | (0.1228) | (0.0059) | (0.0015) | (0.00007) | (0.0811) | (0.0064) |
| Firm size$_{it-1}$ (in logs) | 0.1186*** | 0.0212*** | 0.1157*** | 0.0212*** | 0.1174*** | 0.0210*** | 0.1987*** | 0.0364*** |
| | (0.0092) | (0.0016) | (0.0089) | (0.0016) | (0.0108) | (0.0017) | (0.0133) | (0.0023) |
| Family firms$_{it}$*Firm Size $_{it-1}$ | -0.0503*** | | -0.0475*** | | -0.0005*** | | -0.0788*** | |
| | (0.0131) | | (0.0133) | | (0.0002) | | (0.0198) | |
| Stock of patents $_{it-1}$ (in logs) | 0.4178*** | 0.0909*** | 0.4192*** | 0.0912*** | 0.3986*** | 0.0869*** | 0.3994*** | 0.0865*** |
| | (0.0222) | (0.005) | (0.0222) | (0.005) | (0.0243) | (0.0055) | (0.0238) | (0.0054) |
| Firm age$_{it}$ | -0.0047*** | -0.001*** | -0.0048*** | -0.001*** | -0.0046*** | -0.0010*** | -0.0051*** | -0.0011*** |
| | (0.0008) | (0.0002) | (0.0008) | (0.0002) | (0.0009) | (0.0002) | (0.0008) | (0.0002) |
| Sectors dummies (NACE 2) | YES | YES | YES | YES | YES | YES | YES | YES |
| Regions dummies (NUTS 2) | YES | YES | YES | YES | YES | YES | YES | YES |
| Years dummies | YES | YES | YES | YES | YES | YES | YES | YES |
| Constant | -2.3494*** | | -2.3267*** | | -2.3392*** | | -2.0387*** | |
| | (0.1288) | | (0.1263) | | (0.1489) | | (0.1140) | |
| Observations | 24850 | 24850 | 24850 | 24850 | 21154 | | 22897 | 22897 |
| Log likelihood | -10,072.579 | | -10,074.082 | | | | -9,302.6683 | |
| Wald chi2 | 1,266.70 | | 1,262.04 | | | | 1,347.83 | |
| p-value | 0.000 | | 0.000 | | | | 0.000 | |

Standard errors in parentheses; *** p < 0.01, ** p < 0.05, * p < 0.1. The dependent variable is the dummy *Patent*. Columns 1 and 2 report the estimates (coefficients and AME) when a family ownership threshold equal to 40% is considered; Columns 3 and 4 refer to the model with a family ownership threshold equal to 60%; Columns 5 and 6 report the results when the percentage of ownership of the family is considered; Columns 7 and 8 display the estimates obtained with the number of employees as measure of firm size.

**Figure 2**. **The predicted probability of patenting by firm ownership and size when the CEO is a family owner**

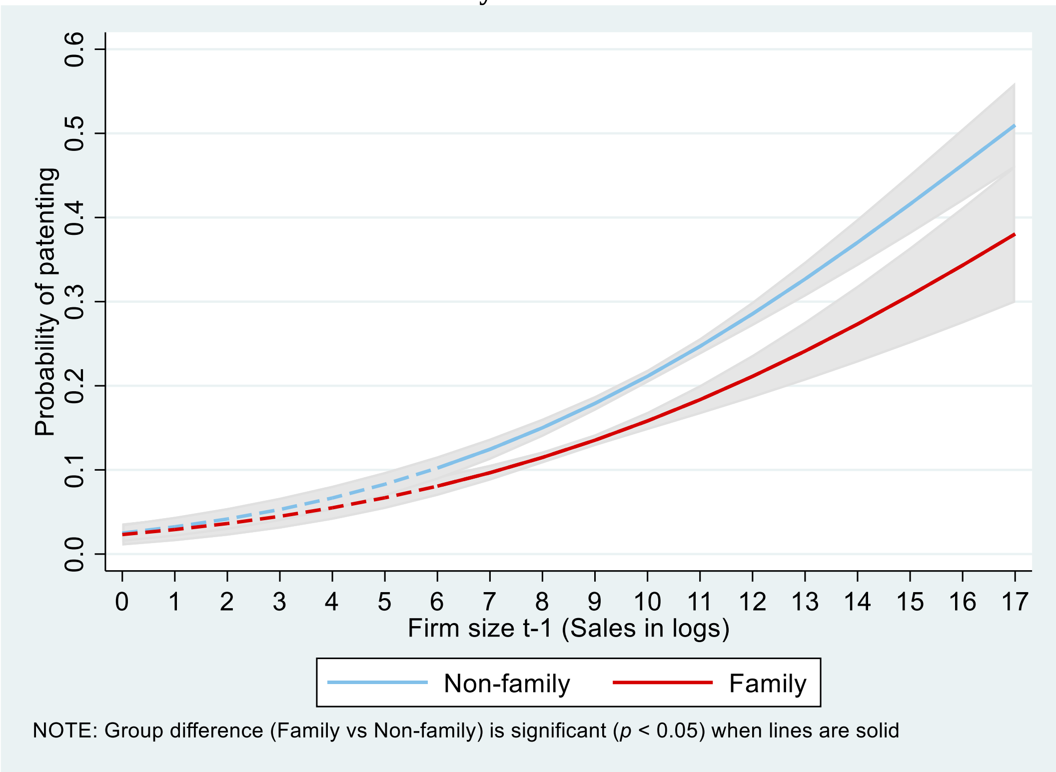
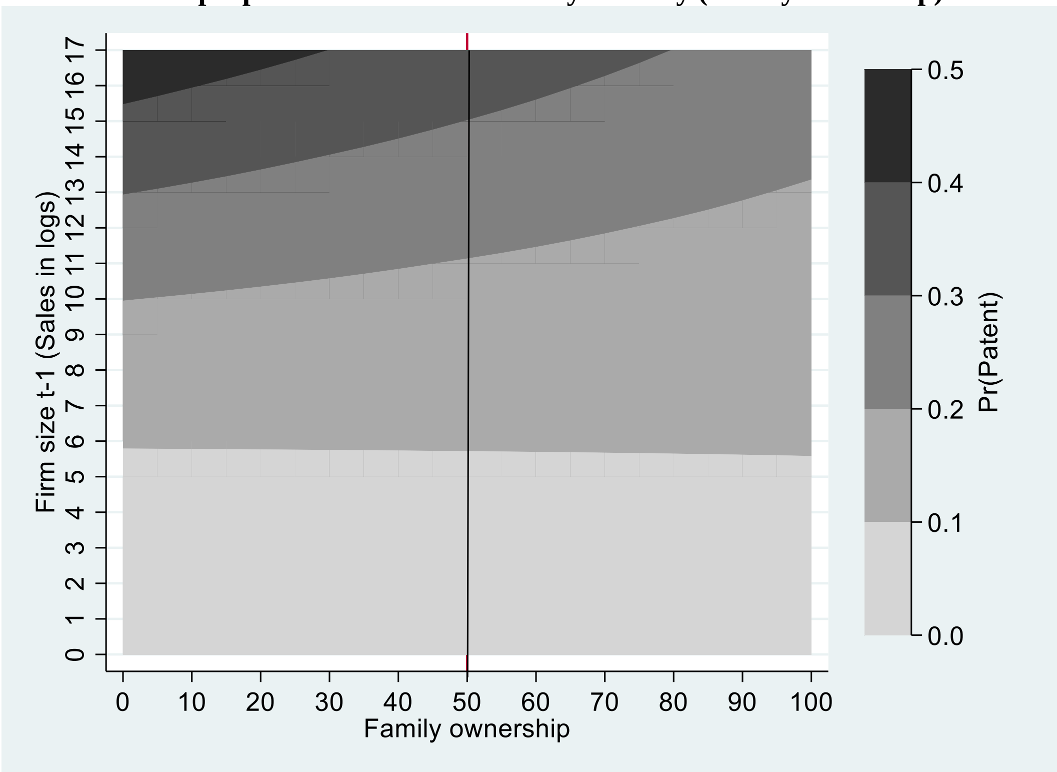
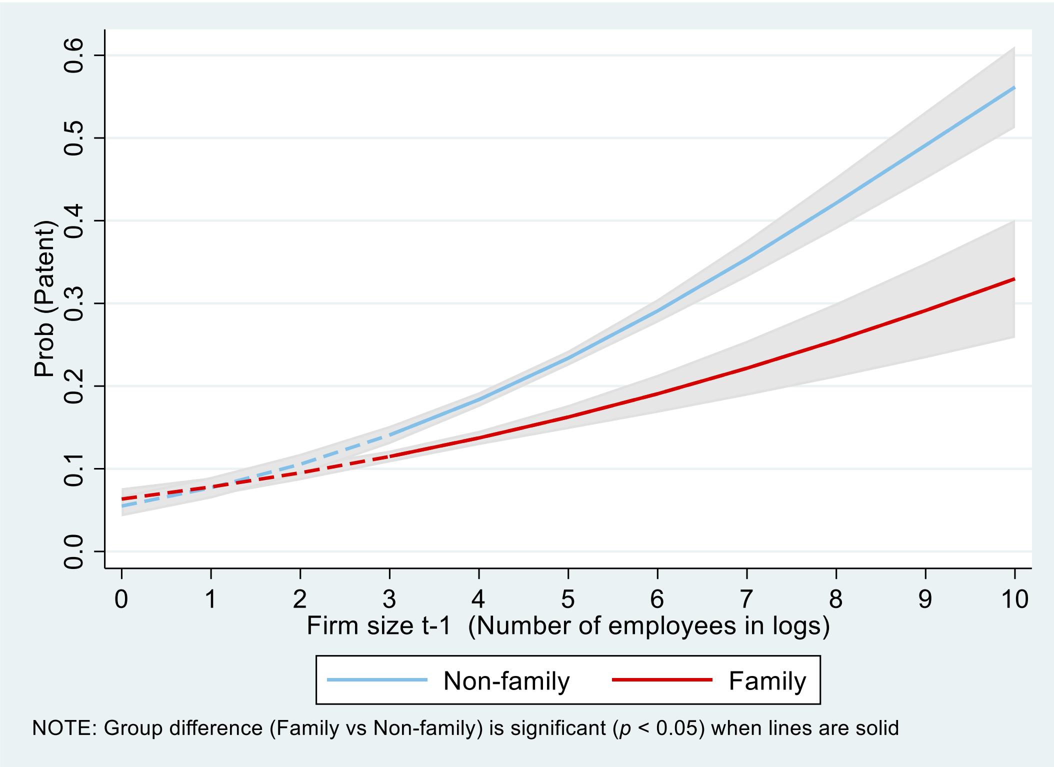



**Figure 3. The predicted probability of patenting by firm size and by the proportion of shares owned by a family (Family ownership)**



It is also of interest to test whether the results hold when using a measure of firm size other than sales. To this end, Columns 7-8 of Table 4 display the probit model estimates obtained from using the number of employees as a proxy for firm size. In this model, we turn back to the first definition of FFs, that is, when individuals or families record direct ownership of over 50%. The conclusions that can be drawn from this control are analogous to those discussed in Section 4.1. Here, the AME associated with the variable *Family Firms* remains negative (-0.0246) and that estimated for *Firm Size* is confirmed to be positive (0.036). Both are significant at 1%. Furthermore, the synthesis of the interactive effect between ownership and size - expressed as number of employees - is presented in Figure 4: while the difference in the innovation output between FFs and non-FFs is not significant for firms with less than about 20 employees, it becomes wide and significant as the number of employees increases.

**Figure 4. The predicted probability of patenting at different values of size (proxied by the log number of employees) for family and non-family Italian firms**




A further interesting control comes from understanding the effect of ownership and firm size on the extent to which firms patent. At this end, the number of patents is used as an outcome variable, thereby allowing a focus on the intensive margin of patenting, instead of the extensive margin as far as made. Moreover, as patents differ in their economic and technological significance, we complement the analysis by using the citations received by each patent as the dependent variable. Citations can be meant as a measure of patent quality, and of the economic value of the patent (Hall et al., 2005), but their use may raise two potential issues. The first is due to the fact that old patents have had more time to be cited and thus have more citations compared to young patents. The second is a truncation issue, as citations can be accumulated over a patent life. Following prior research, we address these issues by using the count of citations that a patented invention receives within a five-year window from the first publication date (De Rassenfosse et al., 2014; Petruzzelli et al., 2018; Squicciarini et al., 2013). To be sure that the complete information for the five-year citation window is exploited, we consider the patents over the period 2010-2016, thereby allowing information up to 2021. The data are from the Citations Database released by OECD (2022).

Table 5 refers to the estimations obtained through the negative binomial model[15] when the dependent variable is the number of patents (Columns 1-2) or the number of patent citations (Columns 3-4).

As far as patent counts are concerned, a negative and highly significant AME was found for family-ownership (-0.24), suggesting that the number of firm patents is negatively correlated with the status of being a FF. Furthermore, it emerges that size positively affects the intensive margin of firm patenting (the AME is 0.16). The data also show that the product term has a negative sign, suggesting that the size effect on the number of patents differs between firm-type. To address this issue, we proceed by summarising the key result in Figure 5, which plots the predicted number of patents at different values of *Size*, distinguishing between FFs and non-FFs.

This analysis reinforces the validity of previous findings regarding the extensive margin of patenting: while family involvement in business does not matter for very small firms in terms of the intensive margin of patenting, beyond a certain size threshold (about 1.1 million of euros of sales) the predicted number of patents titled to FFs is always lower than that of non-FFs. Furthermore, the difference between the intensive margin of patents made by FFs and non-FFs widely increases with *Size* and, more importantly, this difference is always statistically significant.

Finally, Figure 6 plots the predicted number of patent citations at different levels of firm size for FFs and non-FFs. Taking into consideration the technological importance of a patent, Figure 6 clearly shows that there are no significant differences in citation impact when firms are small, and that after a size threshold of 7 (that is about 1 million euros of sales) the number of citations obtained by patents owned by FFs is significantly lower than the citations of non-FFs patents. Importantly, the differences between FFs and non-FFs increase as firms grow in size. In brief, we find that the citation impact of FF patents is low, and this may be driven by the low radicalness of innovation projects carried out by FFs (Block et al., 2013; Dahlin & Behrens, 2005).

[15] The Poisson regression is considered appropriate for the analysis of discrete data with many zeros and small values (Greene, 2011), however, in our sample there is overdispersion of patent data, as the variance is higher than the mean. In order to relax the assumption of equal conditional mean and variance functions (Greene, 2011), we thus also employ a negative binomial, which, in our case, turns out to be the most suitable method to model patent counts due to overdispersion (Poisson model results are in the appendix, Table A5). Another methodological choice made in this part of the study involves the use of random effect models. This is due to the fact that for every variable used in regressions, the total variation is prevalently due to between-variation rather than within-variation. In such a case, applying the fixed-effects estimator implies that the coefficients of the time-invariant regressors are not identified, and many observations are dropped because they are time invariant (Greene, 2011).

**Table 5 Family-ownership, firm size, the intensive margin of patenting and the citation impact. Results from a negative binomial model.**

| | Number of patents | | Number of patent citations | |
|---|---|---|---|---|
| | (1) | (2) | (3) | (4) |
| | Coefficients | AME | Coefficients | AME |
| Family $firms_i$ | 0.5213** | -0.2048*** | 0.6702** | -0.0663 |
| | (0.2199) | (0.0453) | (0.3337) | (0.0755) |
| Firm $size_{it-1}$ (in logs) | 0.2043*** | 0.1664*** | 0.0882*** | 0.063*** |
| | (0.015) | (0.0127) | (0.0214) | (0.0181) |
| Family $firms_i$*Firm Size $_{it-1}$ | -0.0800*** | | -0.0738** | |
| | (0.0235) | | (0.0350) | |
| Stock of patents $_{it-1}$ (in logs) | 0.5585*** | 0.5585*** | 0.3510*** | 0.3510*** |
| | (0.0306) | (0.0306) | (0.0332) | (.0332081) |
| Firm $age_{it}$ | -0.0053*** | -0.0053*** | -0.0015 | -0.0015 |
| | (0.0012) | (0.0012) | (0.0018) | (0.0018) |
| Sectors dummies (NACE 2) | YES | YES | YES | YES |
| Regions dummies (NUTS 2) | YES | YES | YES | YES |
| Years dummies | YES | YES | YES | YES |
| Constant | -2.5344*** | | -1.2152*** | |
| | (0.2177) | | (0.3236) | |
| Observations | 24850 | 24850 | 4214 | 4214 |
| ln_r | 2.0982*** | | 1.4383*** | |
| | (0.0713) | | (0.0842) | |
| ln_s | .8584*** | | 1.1616*** | |
| | (0.0936) | | (0.1267) | |

Standard errors in parentheses; *** p < 0.01, ** p < 0.05, * p < 0.1. Columns 1 and 2 report the estimates (coefficients and AME) when the dependent variable is the number of patents; Columns 3 and 4 refer to the model with the count of patent citations as the dependent variable.

**Figure 5. Predicted number of patents by firm ownership and size.**
**Results from binomial negative model**

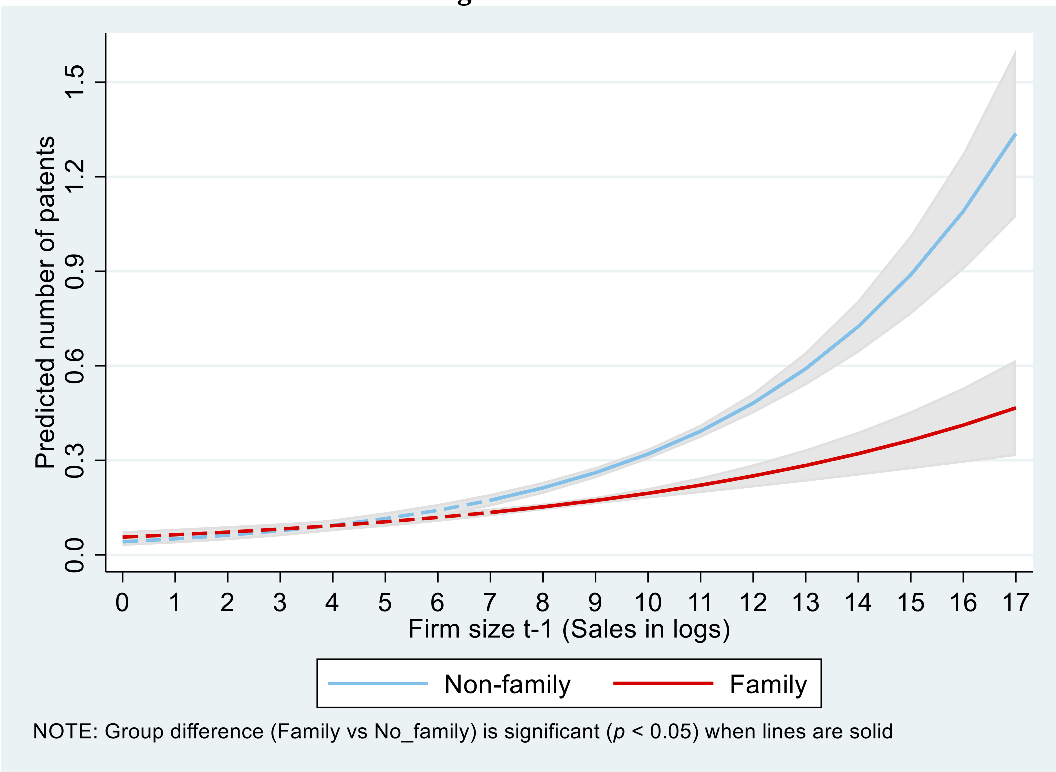
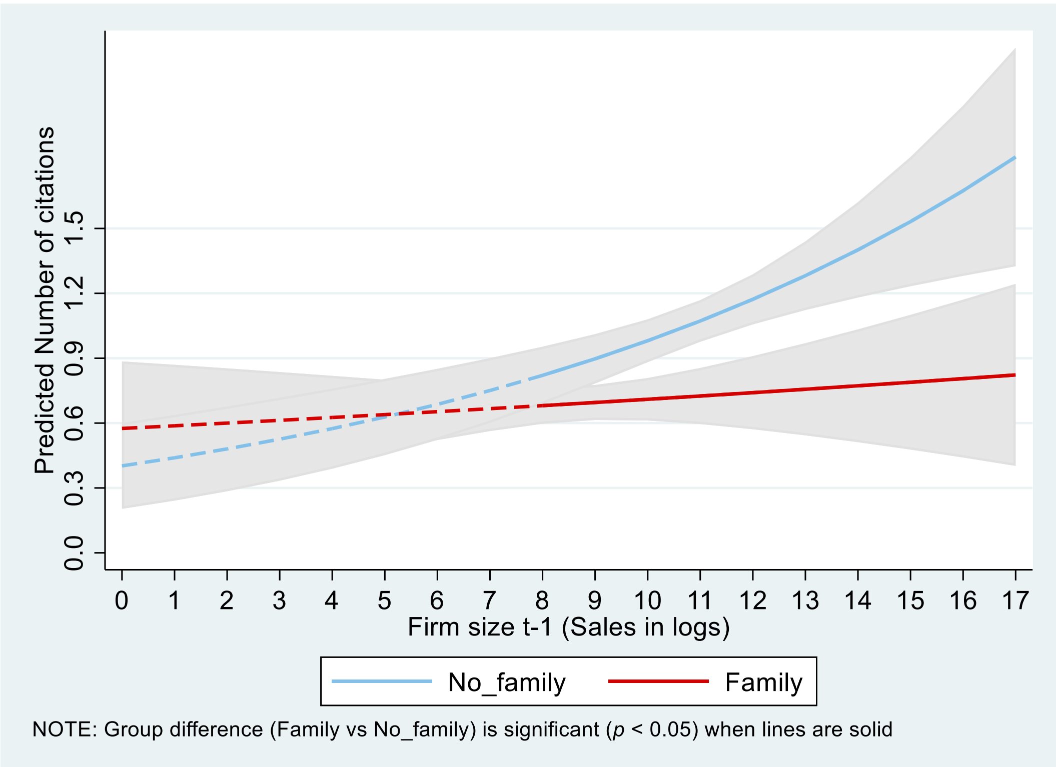



**Figure 6. Predicted number of citations by firm ownership and size.**
**Results from binomial negative model**



## 5. Discussion and Conclusions

This study analyses the role of firm size in explaining the differences between family and non-family firms in the probability to patent of a sample of Italian manufacturing firms over the 2010–2017 period. The findings demonstrate that ownership, firm size, and their interaction have a strong effect on the probability to patent. There are three main results.

First, on average, being an FF reduces the probability of patenting compared to non-FFs. Here, the paper provides new evidence for an unfolding debate. On the one hand, some scholars have suggested that family involvement can have a positive effect on patenting (Duran et al., 2016; Matzler et al., 2015; Memili et al., 2015a; Jell et al., 2015). According to Matzler et al. (2015), this is driven by the beneficial effects of family management instead of ownership. In contrast, others (e.g., Aiello et al., 2021a; Bannò, 2016; Block et al., 2013; Decker and Günther, 2017; Tognazzo et al., 2013) have demonstrated that FFs patent less than or at the same rate as non-FFs. Importantly, Czarnitzki and Kraft (2009) showed that firms with concentrated ownership, such as FFs, tended to file fewer patent applications. Chirico et al. (2020) show that patenting depends on the level of family ownership: when it is low, FFs patent less than others, whereas they patent more as family involvement in business increases. Our results complement the existing research and confirm that patenting in FFs is hindered by their risk aversion, low preference for collaborative relationships (Aiello et al., 2021b; Nieto et al., 2015; Serrano-Bedia et al., 2016), difficulty recruiting qualified managers (Lubatkin et al., 2005), and less inclination to allow the entry of other investors (Block et al., 2013; Kets de Vries, 1993). These characteristics probably outweigh their high flexibility, access to external sources of knowledge due to their unique social contexts, and long-term orientation, which could favour innovation.

Secondly, we find that firm size has a positive effect on patenting, whatever the firm type, confirming that the conditions for patenting may work differently in larger and smaller firms (among many others, Athreye et al., 2021; Frietsch et al., 2013; Hughes and Mina, 2010; Pajak, 2016; Pianeselli, 2019). Indeed, SMEs have disadvantages in innovation when compared to larger firms for a number of reasons. For instance, the availability of capital and human resources is constrained by their small size (Cockburn and Henderson, 2001; Hall and Ziedonis, 2001) as is access to external financial resources (Hottenrott and Peters, 2012; Mancusi and Vezzulli, 2014). Furthermore, innovation is cost-intensive, thereby requiring specific costly resources (a formal R&D department and R&D personnel). Finally, SMEs possess less market power to enforce their rights and it may be overly costly for small firms to defend them effectively (Neuhäusler, 2012; Perez-Cano and Villen-Altamirano, 2013). This might dissuade small firms from patenting (Cohen et al., 2000). In brief, the financial constraints of SMEs and the high cost of patenting, associated with uncertainty about the success of the developed inventions, may lead to differing patent strategies.

Thirdly and more importantly, the novelty of the study arises from combining the ownership and size effects, thereby responding to the call for additional investigations into the innovation performance of FFs and the role of firm size as a contextual element in the heterogeneity of FFs (De Massis et al., 2013). In so doing, we contribute to the debate on the complexity of family-related effects where innovative behaviour is concerned. We prove that FFs and non-FFs register comparable performances when they are micro-sized, however, significant differences emerge when a firm grows in size. In this case, size amplifies the disadvantages of FFs. This result is confirmed when we consider the number of patents (intensive margin) instead of the probability to patent (extensive margin). The gap between FFs and non-FFs persists when using a measure of economic and technological importance, and of the radicalness of innovations (Block et al., 2013; Dahlin & Behrens, 2005; Hall et al., 2005) such as the citations received by a patent. It is demonstrated that as firm size increases, the quality of an FF's patents compared to a non-FF's patents worsens. This can be explained as follows.

We find that micro-FFs and non-FFs perform similarly in terms of attitude to patenting. In other words, for a proportion of Italian entrepreneurs, the low level of patenting is not affected by firm ownership as the size effect smooths potential differences between the two groups. This does not necessarily mean that FFs lose their unique characteristics. High risk aversion and weak use of external finance are strong limitations for FFs, and patenting activities are more limited in FFs than in non-FFs. However, an FF gains from an informal system, high flexibility, and effective management. Balancing these gains and losses allows FFs to achieve similar outcomes to non-FFs, thereby showing the complexity in how FF ownership affects firm performance. This implies that, in some cases, non-FFs may benefit from looking at the peculiar traits that positively affect an FF's performance.

As far as large firms are concerned, the advantages of family-owned firms disappear, especially the flexibility-related benefits. This occurs because the two sides (internal and external) of the context in which an FF operates are characterised by higher complexity and formalisation. In this case, the professionalisation of the organisation becomes an imperative, thereby making it hard for an FF to effectively innovate compared to a non-FF. FFs can overcome this gap only by opening up to highly skilled non-family members, and at the same time avoiding dysfunctional bifurcation bias (Debellis et al., 2021; Verbeke and Kano, 2012), due to the cognitive heterogeneity and the rivalry in top positions provoked by these kinds of directors, which could jeopardise reaching the consensus needed to innovate. This implies that increasing firm size should be a priority in order to induce a higher probability to patent. This holds true whatever the ownership type, but this paper demonstrates that it is not sufficient for FFs to grow in size to fill the innovation gap from non-FFs.

In other words, family ownership tends to result in lower levels of innovation output, probably caused by more conservative leadership, reflecting a concern with maintaining the status quo and serving family-centric non-economic goals. A first indication is therefore that FFs should adequately balance family logic with business logic. Economic objectives should become more relevant than non-economic issues, which can hinder innovative activities. This does not mean losing sight of the advantages that family involvement can bring to the business. A balance must be found.

FFs should open up the company to external staff in order to eliminate the risks associated with employing family members. Indeed, it is the FF that makes less use of professional human resources. Nepotism promotes family members, reducing the number of candidates willing to occupy a management position in the family business (Fang et al., 2016). Family owners should also interact with professional managers and regularly evaluate whether they recognise the non-economic goals of the family, and develop the ability to manage innovation activities to attain goals related to both family socioemotional wealth and economic performance. Non-family members, given their freedom from any emotional ties with the family, are more prone to change (Poza et al., 1997) and more able and willing to participate in innovative activities (Matzler et al., 2015; Van Essen et al., 2012) as well as to expand the innovation they have already carried out (Nahapiet and Ghoshal, 1998). Possible explanations for these findings may lie in the fact that the participation of this type of director facilitates the exchange of knowledge within the family organisation, which may affect the capacity of a company to innovate.

Nevertheless, hiring non-family directors can create conflicts of interest (Chrisman et al., 2014) and the lack of a cultural fit between the directors and the family (Stewart and Hitt, 2012). The intertwining of an FF's socioemotional and financial goals might be difficult for non-family members to understand (Fang et al., 2016). The presence of highly skilled non-family members on the board is thus a necessary but not sufficient condition for acquiring strategic sensitivity (Debellis et al., 2021). Indeed, it is important that the different values and visions of outside directors are not too misaligned from those of family members, in order to avoid reducing the efficiency of decision-making processes (Verbeke and Kano, 2012). In this regard, hiring trusted non-family members with whom they already have social ties may facilitate the alignment of interests between family and non-family members (Cruz et al., 2010).

This research is not free from limitations that offer interesting opportunities for future research. First, we used patents as a measure of innovation. Patents do not seem to be an appropriate measure for SMEs, as many innovations are never patented. Patent applications are often too expensive for SMEs, and many innovations do not justify such high investments, although this concern is alleviated by the fact that we do not investigate the relationship between size and innovation, but focus on the role of firm size in explaining the innovative gap between family and non-family firms. Secondly, our data are limited to Italian firms and may thus specifically pertain to this national context. Future studies in other geographic settings could strengthen the general validity of our findings.

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# Appendix

## Table A1 Description of variables

| Variable | Description |
|---|---|
| **Dependent variables** | |
| Patents | Dummy indicating whether firm is engaged in patenting from 2009 to 2017 |
| Number of patent applications | Number of patents applied for from 2010 to 2017 and eventually granted by 2021 |
| Number of citations | Number of citations that an invention receives within a 5-year window from the first publication date |
| **Explanatory variables** | |
| Family firms | Dummy taking the value 1 if a firm is over 50% owned by individuals or families, and 0 otherwise |
| | Dummy taking the value 1 if a firm is over 40% owned by individuals or families, and 0 otherwise |
| | Dummy taking the value 1 if a firm is over 60% owned by individuals or families, and 0 otherwise |
| | Dummy taking the value 1 if a firm is over 50% owned by individuals or families and the CEO belongs to the family circle, and 0 otherwise |
| | Sum of shareholding by family members relative to the total shares |
| Firm size | Turnover (in log) |
| | Number of employees (in log) |
| **Control variables** | |
| Stock of patents | Stock of patents calculated using perpetual inventory method |
| Firm age | Number of years since the company was established |
| Sectors (NACE 2) | Dummy equal to 1 if the firm belongs to a sector *i* and 0 otherwise |
| Territorial area (NUTS 2) | Dummy equal to 1 if the firm belongs to a region *j* and 0 otherwise |

## Table A2 Distribution of firms by sectors

| | Total | | FFs | | Non-FFs | |
|---|---|---|---|---|---|---|
| Sectors (NACE 2) | N. | | N. | % | N. | % |
| ***High Tech*** | ***343*** | ***9.23%*** | ***114*** | ***6.52%*** | ***229*** | ***11.65%*** |
| 21 Manufacture of basic pharmaceutical products and pharmaceutical preparations | 125 | 3.36% | 24 | 1.37% | 101 | 5.14% |
| 26 Manufacture of computer, electronic and optical products | 218 | 5.87% | 90 | 5.15% | 128 | 6.51% |
| ***Medium–high tech*** | ***1822*** | ***49.04%*** | ***804*** | ***45.97%*** | ***1018*** | ***51.78%*** |
| 20 Manufacture of chemicals and chemical products | 191 | 5.14% | 77 | 4.40% | 114 | 5.80% |
| 27 Manufacture of electrical equipment | 227 | 6.11% | 92 | 5.26% | 135 | 6.87% |
| 28 Manufacture of machinery and equipment | 1210 | 32.57% | 569 | 32.53% | 641 | 32.60% |
| 29 Manufacture of motor vehicles, trailers and semi-trailers | 117 | 3.15% | 33 | 1.89% | 84 | 4.27% |
| 30 Manufacture of other transport equipment | 77 | 2.07% | 33 | 1.89% | 44 | 2.24% |
| ***Medium–low tech*** | ***1037*** | ***27.91%*** | ***562*** | ***32.13%*** | ***475*** | ***24.16%*** |
| 19 Manufacture of coke and refined petroleum products | 5 | 0.13% | 1 | 0.06% | 4 | 0.20% |
| 22 Manufacture of rubber and plastic products | 307 | 8.26% | 138 | 7.89% | 169 | 8.60% |
| 23 Manufacture of other non-metallic mineral products | 95 | 2.56% | 40 | 2.29% | 55 | 2.80% |
| 24 Manufacture of basic metals | 67 | 1.80% | 26 | 1.49% | 41 | 2.09% |
| 25 Manufacture of fabricated metal products, except machinery and equipment | 563 | 15.15% | 357 | 20.41% | 206 | 10.48% |
| ***Low tech*** | ***513*** | ***13.81%*** | ***269*** | ***15.38%*** | ***244*** | ***12.41%*** |
| 10 Manufacture of food products | 97 | 2.61% | 36 | 2.06% | 61 | 3.10% |
| 11 Manufacture of beverages | 6 | 0.16% | 2 | 0.11% | 4 | 0.20% |
| 13 Manufacture of textiles | 69 | 1.86% | 35 | 2.00% | 34 | 1.73% |
| 14 Manufacture of apparel | 44 | 1.18% | 28 | 1.60% | 16 | 0.81% |
| 15 Manufacture of leather and related products | 48 | 1.29% | 25 | 1.43% | 23 | 1.17% |
| 16 Manufacture of wood and of products of wood and cork, except furniture; manufacture of articles of straw and plaiting materials | 33 | 0.89% | 19 | 1.09% | 14 | 0.71% |
| 17 Manufacture of paper and paper products | 45 | 1.21% | 23 | 1.32% | 22 | 1.12% |
| 18 Printing and reproduction of recorded media | 23 | 0.62% | 16 | 0.91% | 7 | 0.36% |
| 31 Manufacture of furniture | 79 | 2.13% | 43 | 2.46% | 36 | 1.83% |
| 32 Other manufacturing | 69 | 1.86% | 42 | 2.40% | 27 | 1.37% |
| ***TOTAL*** | ***3715*** | | ***1749*** | | ***1966*** | |

## Table A3 Distribution of firms by location

| | Total | | FFs | | Non-FFs | |
|---|---|---|---|---|---|---|
| Regions (NUTS 2) | N. | % | N. | % | N. | % |
| ***Northeast*** | ***1463*** | ***39.38%*** | ***672*** | ***38.42%*** | ***791*** | ***40.23%*** |
| Trentino Alto Adige | 87 | 2.34% | 41 | 2.34% | 46 | 2.34% |
| Veneto | 660 | 17.77% | 320 | 18.30% | 340 | 17.29% |
| Friuli Venezia Giulia | 120 | 3.23% | 51 | 2.92% | 69 | 3.51% |
| Emilia Romagna | 596 | 16.04% | 260 | 14.87% | 336 | 17.09% |
| ***Northwest*** | ***1640*** | ***44.15%*** | ***745*** | ***42.60%*** | ***895*** | ***45.52%*** |
| Piemonte | 367 | 9.88% | 163 | 9.32% | 204 | 10.38% |
| Valle d'Aosta | 3 | 0.08% | 1 | 0.06% | 2 | 0.10% |
| Liguria | 45 | 1.21% | 20 | 1.14% | 25 | 1.27% |
| Lombardia | 1225 | 32.97% | 561 | 32.08% | 664 | 33.77% |
| ***Centre*** | ***459*** | ***12.36%*** | ***246*** | ***14.07%*** | ***213*** | ***10.83%*** |
| Toscana | 203 | 5.46% | 108 | 6.17% | 95 | 4.83% |
| Umbria | 36 | 0.97% | 20 | 1.14% | 16 | 0.81% |
| Marche | 105 | 2.83% | 58 | 3.32% | 47 | 2.39% |
| Lazio | 115 | 3.10% | 60 | 3.43% | 55 | 2.80% |
| ***South*** | ***153*** | ***4.12%*** | ***86*** | ***4.92%*** | ***67*** | ***3.41%*** |
| Abruzzo | 36 | 0.97% | 13 | 0.74% | 23 | 1.17% |
| Campania | 49 | 1.32% | 29 | 1.66% | 20 | 1.02% |
| Puglia | 35 | 0.94% | 25 | 1.43% | 10 | 0.51% |
| Basilicata | 5 | 0.13% | 4 | 0.23% | 1 | 0.05% |
| Calabria | 8 | 0.22% | 5 | 0.29% | 3 | 0.15% |
| Sicilia | 16 | 0.43% | 8 | 0.46% | 8 | 0.41% |
| Sardegna | 4 | 0.11% | 2 | 0.11% | 2 | 0.10% |
| | 3715 | | 1749 | | 1966 | |

## Table A4 Correlation matrix

| Variable | (1) | (2) | (3) | (4) | (5) | (6) |
|---|---|---|---|---|---|---|
| Patent (dummy) | 1.00 | | | | | |
| Number of patent applications | 0.48 | 1.00 | | | | |
| Family firms | -0.12 | -0.11 | 1.00 | | | |
| Size (Sales in logs) | 0.19 | 0.22 | -0.35 | 1.00 | | |
| Stock of patents | 0.31 | 0.47 | -0.18 | 0.32 | 1.00 | |
| Age | 0.01 | 0.02 | 0.00 | 0.28 | 0.10 | 1.00 |

**Table A5 Family-ownership, firm size, the intensive margin of patenting and the citation impact. Results from a Poisson model.**

| | Number of patents | | Number of patent citations | |
|---|---|---|---|---|
| | (1) | (2) | (3) | (4) |
| | Coefficients | AME | Coefficients | AME |
| Family $firms_{it}$ | 0.5452 | -0.3058*** | 0.5419 | -0.2449*** |
| | (0.4896) | (0.0957) | (0.3402) | (0.0872) |
| Firm $size_{it-1}$ (in logs) | 0.2317*** | 0.1872*** | 0.1138*** | 0.0873*** |
| | (0.0463) | (0.0293) | (0.0201) | (.0178) |
| Family firms*Firm Size | -0.0938* | | -0.0789** | |
| | (0.0487) | | (0.0367) | |
| Stock of patents $_{it-1}$ (in logs) | 0.4504*** | 0.4504*** | 0.2711*** | 0.2710 *** |
| | (0.153) | (0.153) | (0.0309) | (.0309) |
| Firm $age_{it}$ | -0.0056*** | -0.0056*** | -0.0031 | -.0031 |
| | (0.002) | (0.002) | (0.0021) | (.0021) |
| Sectors dummies (NACE 2) | YES | YES | YES | YES |
| Regions dummies (NUTS 2) | YES | YES | YES | YES |
| Years dummies | YES | YES | YES | YES |
| Constant | -3.7504*** | | -1.0486*** | |
| | (0.5214) | | (0.3267) | |
| Observations | 24850 | 24850 | 4214 | 4214 |
| Ln(alpha) | -0.1237 | | 0.3581*** | |
| | (0.5965) | | (0.0621) | |

Standard errors in parentheses; *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$. Columns 1 and 2 report the estimates (coefficients and AME) when the dependent variable is the number of patents; Columns 3 and 4 refer to the model with the count of patent citations as dependent variable.