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Corporate Governance and Sectoral Patterns of Innovation:
Evidence from Italian Manufacturing Industries

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Corporate Governance and Sectoral Patterns of Innovation: Evidence from Italian Manufacturing Industries

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Abstract

The paper explores the question whether the relationship between corporate governance dimensions and innovation at the firm level is affected by sectoral characteristics, by analyzing Italian manufacturing sectors. We estimate the impact of corporate governance features on patenting activity for two sub-groups of Italian firms, identified on the basis of the well-established distinction between Schumpeter Mark I (*creative destruction*) and Schumpeter Mark II (*creative accumulation*) sectors. We use a unique dataset on about 35.000 Italian manufacturing firms over the 2002-2007 period and employ a hurdle model for zero-inflated data in order to study simultaneously (*i*) the firm's ability to be innovative rather than non innovative and (*ii*) its ability to be relatively more innovative than the other innovative firms. We find that in Schumpeter Mark I sectors, a concentrated ownership structure has a positive effect on innovation, while the opposite is true for Schumpeter Mark II sectors. We interpret this result, arguing that, in more unstable markets, a concentrated ownership reduces agency costs to a larger extent than it exacerbates asymmetric bargaining problems. We find also that Schumpeter Mark I environments are associated to a negative effect of debt exposure, due to the higher uncertainty and agency costs. These findings are robust to a number of identification issues, including the possible endogeneity of corporate ownership structures. Our results may allow to make sense of the contradictory findings of the literature on corporate governance and innovation.

Keywords: corporate governance, innovation, Italian manufacturing sectors, hurdle models.
JEL classification: C30, G30, L60, O30

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1 Introduction

Firms' innovation performance is affected by a wide range of factors, which have been extensively explored by the economic literature. For a long time, following an original intuition by Schumpeter (Schumpeter, 1934; 1942), attention has been focused mostly on the relationship between market structure and innovation: firms' rate of innovation was considered dependent on the degree of competition in the market and on related structural features. Subsequent research has proposed to consider also the role of technological factors as determinants of innovation. According to this perspective, knowledge characteristics and the technological environment, broadly defined in terms of opportunity and appropriability features, affect the intensity of firm innovation (Nelson and Winter, 1982; Winter, 1984) and determine the emergence of sectoral patterns of innovation (Malerba and Orsenigo, 1994; 1996). This view entails that market structure and technology co-evolve and highlights the existence of technology-specific learning processes within the firm, thus emphasizing the role played by firm internal organizational features in addition to external factors.

A different strand of research has elaborated on the relationship between firms' internal characteristics and innovation performance by focusing on corporate governance features (for a survey, see Belloc, 2012). Corporate governance is the set of constraints that specifies the distribution of rights and responsibilities among the different actors having a stake at risk in the corporation. Consequently, first, corporate governance affects the degree of protection that financiers expect to receive for their investments, and this influences in turn the cost at which investors are willing to provide capital. Second, it alters the incentives of a corporation's members to commit capital to innovation strategies and to apply their skills and effort to the implementation of such strategies.

The large amount of theoretical and empirical studies available on this issue has identified a number of corporate governance dimensions that do exert an influence on firms' innovativeness, among which ownership concentration, owners' identity (institutional investors, firms, banks, families, etc.) and the structure of corporate finance. Yet, there is still much we do not understand about the relationship between corporate governance and innovation, as extant literature provides contrasting results and interpretations. The reason why both theoretical and empirical investigations tend to lead to contradictory findings might be that, in this literature, the focus on firm-internal factors has so far led to disregard the role of market and technological factors. In particular, while most empirical analyses refer to specific sectors due to data availability constraints, sectoral specificities have never been explicitly considered and systematically compared. Therefore, no attention has been paid to the fact that the effect of corporate governance rules on innovation may change according to the structural features of the market and the nature of the technology underlying the different sectors.

In this paper, we integrate the literature on corporate governance and innovation with the sectoral patterns of innovation approach and explore the question whether the relationship between corporate governance dimensions and innovation at the firm level is affected by sectoral characteristics, by analyzing Italian manufacturing sectors. To address this question, we estimate the impact of corporate governance features on patenting activity for two sub-groups of Italian firms, identified on the basis of the well-established distinction between Schumpeter Mark I (SM1, *creative destruction*) and Schumpeter Mark II (SM2, *creative accumulation*) sectors. Previous literature has clarified that these two broad categories of sectors are associated to remarkably different technological and market features, which determine specific sectoral patterns of innovation (Breschi et al., 2000). We employ a unique dataset built on the matching of the European Patent Office (EPO, 2013) Worldwide Patent Statistical Database provided by the EPO on behalf of the Organisation for Economic Co-operation and Development (OECD)'s Taskforce on Patent Statistics and the Aida database containing information on a large sample of manufacturing companies in Italy provided by Bureau Van Dijk (BvD, 2013). Our final database contains variables on ownership concentration, owners' identity, owners' nationality, and financial structure, besides control regressors on firms' dimension, age and intangible assets. We then implement a hurdle model to study both extensive and intensive margins of firms' innovation and obtain a precise identification of causality effects linking a firm's governance to its innovation performance.

Our analysis confirms that the effects of corporate governance dimensions on firm-level innovation output differ significantly according to the underlying sectoral patterns, and particularly according to whether the sector can be categorized as either SM1 (*creative destruction*) or SM2 (*creative accumulation*). Our empirical findings show that a concentrated ownership structure has a positive effect in SM1 sectors and a negative effect in SM2 sectors. We interpret this result, arguing that in relatively more unstable sectors (i.e., SM1), characterized by higher technological opportunities and lower knowledge cumulativeness, a concentrated ownership reduces agency costs to a larger extent than it exacerbates asymmetric bargaining problems and therefore tends to have a positive effect on innovation, while the reverse is true for more stable sectors. We also find that, in SM1 industries, firms with a relatively higher debt exposure tend to refrain from undertaking innovative projects, probably due to the higher uncertainty characterizing the market while, in SM2 sectors, higher stability and less uncertainty are associated to lower agency costs and make the choice between alternative sources of external capital statistically less relevant.

It is worth noting that the focus on Italian manufacturing data allows us to circumvent the possible endogeneity of share ownership concentration, because the extreme stability characterizing the corporate governance structure of both listed and unlisted Italian companies (Bianchi and Bianco, 2006; 2008) makes our ownership concentration variables exogenous to the short-term variation of firm innovation output. In any event, in the baseline regression we use one-year lagged ownership variables. In addition, we show that our estimated parameters do not change sign and remain strongly significant in a two-stage instrumental variable regression. Our main findings remain virtually unchanged also controlling for the heterogeneity of patent value and the presence of partnerships in patenting activity.

We improve with respect to previous literature in three ways. First, and most importantly, we highlight a novel aspect of the corporate governance-innovation relationship by explicitly considering the role of sectoral characteristics. This allows to draw some new policy insights. Second, we use a novel database that allows to investigate simultaneously the effect of all the relevant corporate governance variables on innovation outcomes for a very large sample of firms (in the econometric analysis, we use more than 100.000 observations over the 2002-2007 period). Third, we employ more sophisticated econometric techniques than those used in currently available studies (in particular, we use a two-part model for zero inflated data), that allow to study simultaneously (*i*) the firm's ability to be innovative rather than non innovative and (*ii*) its ability to be relatively more innovative than the other innovative firms.

In section 2 we briefly describe the main corporate governance dimensions that exert an influence on innovation according to the literature. In section 3 we set out the expected relationship between corporate governance and sectoral patterns of innovation. In section 4 we present the econometric model and the estimation results. Section 5 concludes.

2 Relevant corporate governance dimensions

The notion that corporate governance influences firms' innovation abilities has been explored from many angles. Within the variety of approaches and themes put forward, it is possible to single out two corporate governance dimensions that have attracted the greatest attention and that are acknowledged to be at the core of the relationship between firms' governance and innovation: corporate ownership and corporate finance.

2.1 Corporate ownership

The corporate ownership dimension refers to the distribution of control rights and residual profit rights within the corporation, and particularly to the degree of equity concentration among shareholders and to owners' identity, i.e. whether they are families or individuals, banks, other institutional investors, or non-financial companies.

Ownership concentration. The degree of ownership concentration may affect a firm's innovation activity in different ways. On the one hand, greater ownership concentration favors the alignment of cash flow and control rights of shareholders. As the traditional agency theory of the firm predicts, in concentrated ownership structures, large shareholders have higher incentives and ability to monitor the management, therefore reducing both managerial discretion and agency costs and ultimately improving corporate performance (Shleifer and Vishny, 1997). This is particularly important for innovation performance when agency costs derive from a misalignment between owners' and managers' objectives due to managers' risk aversion in undertaking R&D projects. This positive effect of ownership concentration on innovation may be called the 'agency cost minimization effect'.

On the other hand, ownership concentration may also negatively affect corporate investment activity. First, shareholders may prefer returning cash flow to investors, in the form of dividends, rather than to reinvest it in the company (Jensen, 1986). While to return profits to investors is in the (short-run) interest of shareholders, it is likely to hamper corporate long-term investment strategies. Second, and perhaps most importantly, in the light of the incomplete contracts theory (Grossman and Hart, 1986; Hart and Moore, 1990), ownership concentration may cause asymmetric bargaining between shareholders and employees, consequently reducing managers' and workers' incentives to apply their effort to firm-specific activities ex-ante to the extent they anticipate opportunistic actions ex-post by concentrated shareholders. These firm-specific investments are key to build a corporation's innovative capacity through time, through knowledge and competence accumulation. This negative effect of ownership concentration on innovation may be called the 'asymmetric bargaining effect'. Available empirical evidences are mixed. While some studies find a positive relationship between equity concentration and innovation performance (Hill and Snell, 1989; Baysinger *et al.*, 1991; Hosono *et al.*, 2004), some others propose opposite findings (Francis and Smith, 1995; Battaggion and Tajoli, 2001; Ortega-Argilès *et al.*, 2005).

Owners' identity. Also the owners' identity gathered significant attention. In particular, extant studies focus on ownership by families, banks and institutional investors. Family-controlled companies are generally found to underperform and to show lower innovation activity than corporations run by other types of blockholders. Family shareholders are undiversified stockholders who have a large part of their wealth invested in a given company. Being less diversified, they may impose risk aversion on corporate strategies (Morck and Yeung, 2003). Moreover, family ownership is often associated to managerial practices, remuneration schemes and decision-making processes that reduce the management's incentives to undertake innovative strategies (Bugamelli *et al.*, 2012), and this may exacerbate the technological inertia of family-run companies. Munari *et al.* (2010), among others, show empirically that family controlled corporations invest in long-term R&D projects less than other corporations.

The role played by banks and other institutional investors in corporate ownership is less clear. While some studies conflate different identities in a generic notion of institutional shareholder and propose contrasting evidences (e.g., Graves, 1988; Aghion *et al.*, 2013), empirical results still remain unconclusive even when disentangling the various types of institutional investors. When a bank is both a creditor and a representative shareholder of a firm, information asymmetries between firm and creditor are mitigated. This should reduce the cost of debt capital for the corporation (Petersen and Rajan, 1994) and increase the financial resources that the firm can allocate to innovation projects (Lee, 2005). However, also a negative relationship between bank ownership and innovation has been detected to the extent banks impose risk aversion in the business decision-making (Zahra, 1996; Kochnar and David, 1996; Tribo *et al.*, 2007).

Analogous heterogeneity in the empirical evidence is shown with respect to the impact of other types of institutional investors. Sherman *et al.* (1998) and Hoskisson *et al.* (2002), for instance, argue that private investment funds typically have a preference for short-term profits and find indeed that they negatively affect corporate innovation, while other institutional entities (like pension and retirement funds) may be interested in long-term corporate performance. Some recent works added to this strand of studies the effect of the owner's geographic localization with respect to the firm's one, arguing that cultural distance and information opacity may make foreign private equity investors less capable to spur innovative investments (Ughetto, 2010).

2.2 Corporate finance

The second relevant dimension, corporate finance, concerns the ways through which the firm raises and allocates financial resources necessary to innovation investments. There are two main aspects relevant in this respect. The first one is the relative composition of different sources of external funds used by the corporation. Internally generated revenues should be the preferred channel of innovation funding (Brealey *et al.*, 2006), but internal financing constraints may force corporations to combine (or to choose between) debt and equity. It is well known that stocks and debt are not perfect substitutes for innovation financing, as they provide alternative governance structures (Williamson, 1988). Debt capital, in particular, is ill-suited to finance innovative projects, due to the deep information asymmetry that can emerge between creditors and shareholders in highly risky investment programs. On the other side, however, stock issuing dilutes the future dividends among an increased number of shareholders and may reduce the individual shareholder's incentives to monitor the management. The existent econometric studies all find a negative relationship between debt and levels of innovation investments at the firm level (see, among many others, Long and Malitz (1985) and Baysinger and Hoskisson (1989)), then arguing that the choice between alternative sources of external capital is always relevant for innovative firms, irrespective of the technological and market environment they face. The second relevant aspect is the decision of the firm to list its shares on a stock exchange. While the stock market may provide a mechanism for managerial discipline so inducing managerial performance improvements, some studies argue that, in non-listed firms, insider shareholders can time the market by choosing an early exit after receiving bad signals about production, and therefore managers are more tolerant of early failures and more inclined to invest in innovative, even if riskier, projects (Ferreira *et al.*, 2012). Consistently with this latter argument, recent empirical evidences show that a firm's being listed does not help corporate technological upgrading (Battisti *et al.*, 2014).

3 The relationship between corporate governance and sectoral patterns of innovation

In this paper, we aim at empirically investigating whether the extent of technological and market uncertainty, by affecting the nature and intensity of agency costs faced by firms, is key to interpret the effect of corporate governance dimensions on innovation.

The different levels of technological turbulence and agency costs faced by firms can be captured by the well-established distinction between Schumpeter Mark I and Schumpeter Mark II sectors. From the early work of Nelson and Winter (1982) and Kamien and Schwartz (1982), this distinction has been widely used to capture a number of sectoral features relevant to innovative activity. In particular, the Schumpeter Mark I environment refers to the Schumpeterian notion of 'creative destruction', identified by Schumpeter in *The Theory of Economic Development* (1934). SM1 sectors are characterized by a prominent role of entrepreneurial initiatives, which build new firms to introduce new ideas and innovations, develop new products and processes that displace existing ones, create new markets or easily enter existing markets. From a structural standpoint, Schumpeter Mark I sectors are thus characterized by low barriers to entry and a high number of firms. On the other hand, the Schumpeter Mark II label refers to the theoretical paradigm called 'creative accumulation', described by Schumpeter in *Capitalism, Socialism and Democracy* (1942). This type of environment is characterized by a significantly lower number of firms (high concentration), high barriers to entry, economies of scale and scope and, more generally, significant advantages associated to size and previously acquired positions (in terms of finance, competences, accumulated knowledge and established complementary assets). Firms in SM2 sectors face a relatively less turbulent market environment, as previously accumulated assets allow established firms to accumulate quasi-rents. While Malerba and Orsenigo (1994 and 1996) have found empirically that the SM1/SM2 distinction helps to explain different innovation patterns of firms, more recently Breschi *et al.* (2000) have further shown that the structural features of Schumpeter Mark I and Schumpeter Mark II sectors are associated to the underlying nature of technology, as captured by the notion of technological regime, which is meant to identify the most salient knowledge and learning properties of the different technologies.

We propose that the distinction between Schumpeter Mark I (*creative destruction*) and Schumpeter Mark II (*creative accumulation*) sectors can be crucial also to measure the relationships between corporate governance and innovation.

Consider, first, corporate ownership. As illustrated in section 2, the corporate governance literature has shown that the degree of ownership concentration does affect firms' innovativeness, although the nature of this effect (positive or negative) has not been univocally determined. In this regard, we suggest that a reduced separation between ownership and control (induced by shares concentration) determines heterogenous effects in different market environments, according to the degree of uncertainty faced by innovators. In technologically unstable environments (i.e. SM1 sectors), high technological opportunities and high rates of firms entry on the market make the ability to control managers' risk aversion particularly important to seize market opportunities and agency costs a key obstacle to innovative investments. Moreover, due to low appropriability and cumulativeness, the ability to build up internal competences and resources through cumulative firm-specific investments does not confer firms a significant advantage in innovation. In this context, we expect the 'agency cost minimization effect' identified in section 2.1 to prevail and ownership concentration to have a positive effect on firm innovation. In more stable environments (i.e., SM2 sectors), conversely, relatively lower uncertainty mitigates agency costs. In this context, the asymmetric bargaining problems in the owner-stakeholders interactions described by the incomplete contracts theory assume a relatively larger relevance than agency problems. This is because, in Schumpeter Mark II sectors, a firm's competitive advantage crucially depends on its ability to accumulate knowledge and financial resources. Stakeholders' incentives to make firm-specific investments are therefore key to innovation. Moreover, in relatively stable environments, where there are less technological opportunities to exploit, concentrated shareholders may also prefer returning cash flows to investors, in the form of dividends, rather than to reinvest them in the company, thereby hampering the buildup of a financial base for the firm's investment activity. We thus expect ownership concentration to exert a positive effect on firm innovation in Schumpeter Mark I sectors, characterized by turbulent market environments and a relatively high degree of uncertainty, and a negative effect in the more stable and comparatively less uncertain Schumpeter Mark II sectors. In our view, a positive and a negative effect of ownership concentration on innovation are likely to coexist and the degree of technological and market uncertainty determines whether it is the agency minimization effect or the asymmetric bargaining effect to prevail.

As for corporate finance, the most significant dimension highlighted by the literature is the choice of the external source of finance (debt or equity). Also with regard to this dimension, the degree of technological and market uncertainty that characterizes sectoral patterns of innovation may be relevant. The choice between debt and equity involves different agency costs, whose intensity is affected by the extent of uncertainty that characterizes the projects to be financed. The deep information asymmetry that can emerge between creditors and shareholders in highly risky investment programs generates high agency costs and makes debt capital ill-suited to innovation financing. Therefore, in technologically unstable environments, highly indebted firms should prefer less risky investment strategies, in order to soften agency problems in their relationship with creditors and to reduce the cost of additional debt. In these environments, the firm's ability to secure equity financing is crucial to ensure commitment of financial resources to highly risky projects, with a high variance of expected returns. The extent of agency costs involved by debt is, by contrast, likely to be more limited in Schumpeter Mark II sectors, where lower technological opportunities and high barriers to entry make the outcome of investment projects relatively more predictable. In these sectors, we expect the choice between alternative external sources of finance to have a more limited impact on a firm's propensity to innovate.

Also the effects of the other dimensions of corporate governance – specifically, owner identity and the decision to go public – may be affected by the level of market uncertainty. On the one hand, we expect ownership by more risk-averse subjects (e.g., families) to have a negative effect on innovation in both types of technological environments, but to a larger extent in Schumpeter Mark I (i.e. more turbulent) sectors rather than in Schumpeter Mark II sectors. On the other hand, the decision to be listed on the stock market may exert both positive and negative effects due to a trade-off between increased managerial discipline and greater propensity to undertake risky investments. In particular, the decision to be listed should have a positive effect on innovation in market environments where the required innovative investments involve limited degrees of uncertainty and managers show less risk aversion, like in Schumpeter Mark II sectors. However, it is important to note that these effects will arise only if the stock market is sufficiently developed, so as to exert a significant influence on agents' behavior, and that this does not appear to be the case in Italy.

4 Empirical analysis

4.1 Data and variables

We use data on individual corporations' characteristics and patents granted by the EPO to empirically explore the relationship between corporate governance and sectoral patterns of innovation.

We measure corporation-level innovation activity by means of the yearly number of patents awarded to the firm. Although patents do not fully capture firm innovation, they are commonly used as measures of firm-level innovation because they are a relatively homogeneous indicator of innovative activity (as innovations have to satisfy specific requirements to be patented) and allow for analyses at the level of the entire relevant population (Griliches, 1990).[1]

[1]We are aware of the fact that patents suffer from many well-known limitations. They surely do not capture the entire output of innovation activity, as firms may develop non patentable innovations and/or may decide to protect their innovations with alternative appropriability strategies (e.g., trade secrets, other forms of intellectual property, complementary assets etc.) even if

We build a new database including information on worldwide-valid patents and Italian firms, limiting time coverage to the 2002-2007 period in order to avoid data censoring problems (the process to formally obtain patent registration at the EPO may take more than one year). Specifically, we matched two already existing databases: the Patent Statistical Database (PATSTAT) provided by the EPO (2013) and the Aida database, containing balance sheet information on Italian firms, provided by BvD (2013). The matching procedure is not trivial. PATSTAT contains patent data on any type of innovative entity (i.e. the applicant) but does not permit to identify the type of applicant (i.e. whether it is a public research entity, a university, a physical person or a firm). Thus we have developed an original pattern-matching procedure to uniquely match each patent record with the VAT number of its individual applicant. We then matched this extended records with the balance sheet report of each Italian firm contained in the Aida sample[2]. In this way we obtained a representative sample of Italian manufacturing firms, with the additional information on their patent activity. After data cleaning, we remain with about 100.000 observations on about 35.000 manufacturing corporations for the 2002-2007 period. All innovative firms in our final sample (i.e. those firms that show at least one patent in the considered period) are capital companies (*Società per azioni* - S.P.A. or *Società a responsabilità limitata* - S.R.L.), none of them is a labour-controlled firm (i.e. a cooperative).

Thanks to the use of the Aida dataset, we can exploit a large number of variables in our empirical analysis. In particular, we use information on firm age, number of employees, firm presence on the stock market, debt-equity ratio, intangible assets per employee, degree of ownership concentration, representative owner's identity and her nationality. A detailed variables' description is provided in Table 1.

Table 1 about here

Being the information on the sector in which each firm operates at a 4-digit sectoral level, we were able to assign each firm either to the SM1 environment or to the SM2 environment, according to the classification of sectors proposed by Breschi *et al.* (2000). Specifically, the two Schumpeterian patterns of innovative activities are identified by Breschi *et al.* by means of a principal component analysis (PCA). They used EPO patent-level data on the whole population of patenting firms for Italy, Germany and United Kingdom, and run the PCA on three variables of Schumpeterian patterns of innovation measured for 26 technological classes. These three variables are the percentage share of patent applications by firms applying for the first time in a given technological class in a given period over the total patent applications in the same period, the Spearman rank correlation coefficient between the hierarchies of firms patenting in two subsequent given periods, and the concentration ratio of the top four patenting firms in a given technological class. For each country and each technological class, Breschi *et al.* obtain a new variable defined by the factor score coefficient resulting from principal component analysis, to be used to discriminate between alternative Schumpeterian models of innovative activity.

To develop our empirical study, we converted the Breschi *et al.*'s technological class-level classification

they are patentable. However, other innovation indicators, like the number of new products and processes introduced, reflect greater subjectivity in the assessment of what actually constitutes an innovation and are available only for the subset of the population that has answered to the relevant survey where these data have been collected.

[2]The two-steps pattern-matching procedure allows to achieve a success rate of 98%. First, we used information retrieval techniques to infer PATSTAT partition according to type of applicant. Second, we applied methods of data integration systems, relying on a precise entity resolution algorithm. The latter basically performs a metric indexing of the involved databases and extracts top-k correspondences, which are the entities (the firms in this case) that match with the highest likelihood. Indeed, the algorithm runs within a self-developed software system, *Glimpse*, allowing to match any two datasets, according to different customizable criteria.

into a NACE sectoral classification (i.e. the Statistical Classification of Economic Activities in the European Community, through which Italian firms are classified in the Aida database), and divided our sample of firms between the two alternative types of Schumpeterian pattern of innovation. In Table 2 we summarize the relevant characteristics, in terms of technological regime and market structure of the SM1 and SM2 categories (as measured by Breschi *et al.* (2000)), and report a summary of our sectoral classification.

Table 2 about here

Once firms are classified into SM1 (*creative destruction*) and SM2 (*creative accumulation*) sectors, some interesting differences in the variables' averages across the two groups can be noticed. First, innovative firms in SM2 sectors tend to hold a relatively higher number of patents than their SM1 counterparts (in Figure 1 we show the cumulate distribution, truncated at zero, of firm-level patents per year). Second, innovative firms in SM2 sectors tend to show a lower level of intangible assets per employee and a smaller size than innovative SM1 firms, while the opposite holds for non-innovative firms. Third, debt to equity ratios tend to be relatively larger for both innovative and non-innovative firms in SM1 sectors than for, respectively, innovative and non-innovative firms in SM2 sectors. Fourth, listed firms are only a very small percentage of the total number of firms in both groups, but a relatively larger share of innovative firms is listed in SM1 sectors than in SM2 sectors. Fifth, the percentage of innovative firms with a low degree of ownership concentration in the SM2 group is twice over the percentage of the SM1 group. Sixth, in both groups family shareholders are the most diffuse type of controlling shareholder among non-innovative firms (but to a relatively larger extent in SM1 sectors), while ownership by industrial companies is relatively more diffuse among innovative companies (but to a relatively larger extent in SM2 sectors); moreover, in both groups only small percentages of firms show a bank or a financial holding company as a controlling shareholder. Both in SM1 and SM2 sectors, finally, the percentage of Italian controlling shareholders is relatively larger in non-innovative rather than in innovative firms. Variables' averages within groups are collected in Table 3.

Table 3 about here

Figure 1 about here

4.2 Econometric modeling

The use of patent data in econometric modeling can be problematic, since patent data are counts (i.e. non-negative integers) and present typically a zero inflated distribution (see Hausman *et al.*, 1984). To conduct our empirical study, we implement a hurdle model, in which a logit model and a negative binomial regression are combined in a two-part model.

Formally, we consider a random variable Y of patent counts in a panel of n firms ($i = 1, 2, \ldots, n$) over T times ($t = 1, 2, \ldots, T$) and two sets of exogenous variables $\mathbf{x}_{i,t1}$ and $\mathbf{x}_{i,t2}$. The hurdle model has a hierarchical structure, where a first equation describes the process generating the zeros (i.e. the event $y_{i,t} = 0$ versus $y_{i,t} > 0$) and a second equation describes the process accounting for positive values (i.e. $y_{i,t} > 0$). In simple terms, a binomial probability model governs the binary outcome of whether $y_{i,t}$ has a zero or a positive value, while, if $y_{i,t} > 0$, the "hurdle is crossed" and the conditional distribution of the positive values is governed by a zero-truncated negative binomial model. Given a vector of regressors, $\mathbf{x}_i$, the canonical parameters for the binary and the (truncated at zero) count processes, $\pi_{i,t}$ and $\lambda_{i,t}$, can be modeled, respectively, as $\text{logit}(\pi_{i,t}) = \mathbf{x}_{i,t1}\boldsymbol{\beta}$ and $\text{NB}(\lambda_{i,t}) = \mathbf{x}_{i,t2}\boldsymbol{\gamma}$, where $\boldsymbol{\beta}$ and $\boldsymbol{\gamma}$ are vectors of fixed regression parameters.

In our regression context, the logit - negative binomial hurdle model can be specified as follows:

$$\Pr(Y_{i,t} > 0|\mathbf{x}_{i,t}, D_t) = \alpha_0 + \boldsymbol{\alpha}\mathbf{x}_{i,t} + \boldsymbol{\varphi}\mathbf{D}_t + \epsilon_{i,t} \tag{1}$$

$$\Pr(Y_{i,t} = y_{i,t}|\mathbf{x}_{i,t}, D_t) = \delta_0 + \boldsymbol{\delta}\mathbf{x}_{i,t} + \boldsymbol{\vartheta}\mathbf{D}_t + \eta_{i,t}, \qquad y_{it} \geq 1 \tag{2}$$

where α_0 and δ_0 are the model constants, $\boldsymbol{\alpha}$ and $\boldsymbol{\delta}$ are vectors of parameters associated with the vector of explanatory variables $\mathbf{x}_{i,t}$, $\boldsymbol{\varphi}$ and $\boldsymbol{\vartheta}$ are vectors of parameters associated with the vector of year-specific fixed effects $\mathbf{D}_t$ (from 2002 to 2007), $\epsilon_{i,t}$ and $\eta_{i,t}$ are the residuals. The vector of regressors $\mathbf{x}_{i,t}$ contains the following variables: *Total_patents*, *Intangibles_to_employees*, *Firm_age*, *Firm_size*, *Listed*, *Debt_to_equity*, *OC-high*, *OC-medium*, *OC-low*, *RS-family*, *RS-bank*, *RS-holding*, *RS-ind_company*, *RS-other*, and *Italian_RS*.[3] Both equations are estimated on the two sub-populations of firms belonging to either SM1 or SM2 sectors separately. Standard errors are heteroskedasticity robust and clustered at a firm-level.[4]

It is useful to interpret equation 1 and equation 2 as models of, respectively, extensive and intensive margins of firms' patenting activity. In particular, with equation 1 we are able to estimate the effect of corporate observable characteristics on the probability of a firm's being innovative rather non-innovative (i.e. the wideness of innovation activity in a population of both innovative and non-innovative firms). With equation 2 we estimate the effect of corporate observable characteristics on the extent to which innovative firms do obtain patents (i.e. the depth of innovation in a population of only innovative firms). Phrased differently, this allows us to study simultaneously how a set of corporate governance variables and a vector of controls impact on both (*i*) the firm's ability to be innovative rather than non-innovative and (*ii*) its ability to be relatively more innovative than the other innovative firms.

4.3 Results

Estimation results for the two sub-populations of SM1 (*creative destruction*) and SM2 (*creative accumulation*) firms are reported, respectively, in Table 4 and Table 5. We run six regressions for each sub-population. In both tables, from the model specification (1) to the model specification (5) corporate governance characteristics are included one-by-one in addition to the same set of firm-specific controls, in the model specification (6) all of the corporate governance variables and the controls are included simultaneously.

As a general remark, it is interesting to note that we observe from model (6) that sectoral differences emerge only with respect to corporate governance variables, while all of the other control variables exert effects of the same sign in both SM1 and SM2 sectors. This is consistent with the idea that the relationship between corporate governance dimensions and innovation at the firm level is affected by sectoral characteristics.

[3] We cannot include R&D expenses among the control variables as we observe a high number of missing data in our sample, due to the fact that reporting R&D expenditures as a separate balance sheet item is not required by accounting and fiscal regulations in Italy. Nonetheless, our *Total_patents* variable, which is a proxy of the knowledge endowment available to the corporation, partially captures also the past innovative effort of the firm.

[4] Notice that, in our hurdle model, equation 1 and equation 2 are independent. This rules out model identification issues.

Table 4 about here

Table 5 about here

Corporate governance effects. As for the corporate governance variables considered in the study, notable differences emerge between SM1 and SM2 sectors.

Debt_to_equity has a negative impact (at a 5% level of statistical significance) in the extensive margin equation in SM1 sectors, while it has no effect both in the logit and in the negative binomial regression for SM2 sectors. This finding confirms the expectation that in technologically turbulent industries (our SM1 sectors) firms with a relatively higher debt exposure tend to refrain from undertaking innovative projects. At the opposite, in SM2 sectors, higher stability and less uncertainty are associated to lower agency costs and make the choice between alternative sources of external capital statistically less relevant.

OC-high and *OC-medium* (*OC-low* being the benchmark dummy) have a positive and statistically significant effect in both the extensive and the intensive margin equation in SM1 sectors, but also do have a negative effect (at a 1% level of statistical significance) in the extensive margin equation in SM2 sectors. Also this result is consistent with the theoretical argument put forward in section 3: in relatively more stable sectors, characterized by low technological opportunities and high knowledge cumulativeness, the asymmetric bargaining problems highlighted by the incomplete contracts literature prevail and ownership concentration tends to have a negative effect on innovation. The reverse is true for more unstable sectors.

RS-holding and *RS-ind_company* show a positive and statistically significant effect on the extensive margin and *RS-bank* an insignificant effect in the intensive margin equations (*RS-family* being the benchmark) in both SM1 and SM2 sectors. It is worth noting that the magnitude of the estimated parameters is slightly larger in SM1 sectors. This finding highlights that, while the intensive margin of innovative firms is not affected by the identity of the owner in a statistically significant way, the transition from a non-innovative to innovative status is relatively more problematic for family-run firms, irrespective of whether the firm operates in a SM1 or SM2 sector.

It is also interesting to notice that *RS-other* - which is composed mainly by private equity firms, mutual and pension funds - has a negative and statistically significant influence with respect to *RS-family* in the extensive margin equation when other corporate governance variables are not included (see the model specification (4), in both Table 4 and Table 5), and that this effect vanishes in the model (6). This result unveils that, once all the relevant corporate characteristics are considered, in the recent experience of Italian companies ownership by private equity firms and mutual funds has an effect statistically analogous to family ownership. This may be due to the fact that, as previous studies show for other countries, managers of equity and mutual funds tend to be pressure-sensitive and to have a preference for immediate profits even to the detriment of long-term investment strategies (Sherman *et al.*, 1998; Hoskisson *et al.*, 2002). As shown in Table 3, however, the diffusion of private equity firms, mutual and pension funds as representative shareholders is very limited in Italy.

Italian_RS is associated to a statistically insignificant parameter in the full model specification (6) both in SM1 and SM2 sub-populations of firms. However, it shows a negative impact in the extensive margin equation in SM1 sectors when the other corporate governance variables are excluded from the regression (see the model specification (5)). This result suggests that owners' nationality does not exert a direct effect on a firm's innovation activity, while it probably interacts with other governance characteristics. Here, therefore, we cannot support previous evidence showing that cultural distance and information opacity make foreign investors less capable to spur innovative investments (Ughetto, 2010).

Listed, finally, has a statistically insignificant impact on extensive and intensive margins in both SM1 and SM2 sectors. The Italian stock market is still not enough developed to be a concrete source of external finance helping firms' technological upgrading, due to the two-way relationship between concentrated ownership and controlling shares's premiums. In SM1 sectors, only 0.97% of innovative companies are listed, while in SM2 industries the percentage of innovative listed companies decreases to 0.59 (see Table 3). Consistently with our results, previous studies have highlighted that Italian firms tend to finance their innovative investments thorugh a number of means other than listing their shares on a stock exchange (Hall *et al.*, 2009; Magri, 2009).

Other firm-level effects. All of the other control regressors exert effects of a same sign in both SM1 and SM2 sectors. In particular, *Total_patents* has a positive and statistically significant effect on both extensive and intensive margins of innovation. The strong linkages between innovative technologies in modern industrial sectors explain why firms with larger endowments of patents show both a higher probability to become innovative in a given year and a higher patenting performance than firms poor of proprietary knowledge.

Intangibles_to_employees positively impacts on the extensive margin and does not have statistically significant effects on the intensive margin. This result unveils that the firms' level of intangible assets is a key variable for the wideness of innovation activity in Italian industrial sectors. Intangible assets (including the quality of management, firm's trade secrets, and investments in R&D) form the "knowledge base" of corporations and are widely recognized as a determinant of firms' productivity in modern knowledge-intensive production (e.g., Bontempi and Mairesse, 2008; Battisti *et al.*, 2014). Here, we show that the impact of a firm's stock of intangibles is relevant, in particular, on the technological upgrade of the firm from the non-innovative to the innovative status.

Firm_size positively impacts on the extensive margin and does not have statistically significant effects on the intensive margin. Also this finding refines previous evidence. Bugamelli *et al.* (2012), among others, find that firm size, measured through the number of employees, has a positive impact on the propensity to patent of Italian firms, where, however, the relative effects on extensive and intensive margins are not disentangled. Our results show that firm size is important to explain the gap between innovative and non-innovative firms, while it is statistically not relevant to explain the depth of innovation in the sub-population of already innovative firms.

Finally, *Firm_age* does not exert statistically significant effects on extensive and intensive margins in both SM1 and SM2 sectors.

4.4 Robustness checks

Although our baseline estimates are shown largely stable across different model specifications, here we further check the robustness of our results with respect to three issues.

Heterogeneity of patent values. Patented inventions may have vastly different economic value and market potential. As a consequence, firms might show a same number of patents while having different innovative capabilities, to the extent that they produce innovations with a different economic value. If the value of patents systematically vary across SM1 and SM2 sectors, a bias might be introduced in our estimates. In a first robustness check, we verify whether our main estimation findings remain unchanged after correcting the patenting activity dependent variable for unobservable factors that may increase (or reduce) the economic relevance of a firm's patents. In particular, we construct a new patents indicator, to be used as the dependent variable in our regression analysis, in four steps (that follow the standard procedure generally used to measure factor productivity, see Del Gatto *et al.* (2011)). First, we estimate the impact (ϱ) of a firm's patents ($Y_{i,t}$) on an index ($\Psi_{i,t}$) of the company's current operational profitability (the EBITDA, i.e. earnings before interest, taxes, depreciation, and amortization) weighted by firm sales, controlling for unobservable firm-level specific effects (μ_i), as in the following regression equation: $\Psi_{i,t} = \zeta_0 + \varrho Y_{i,t} + \mu_i + \varepsilon_{i,t}$. Second, we use the estimated parameter $\hat{\varrho}$ together with the actual number of firms' patents to compute each firm's predicted operational profitability as: $\hat{\Psi}_{i,t} = \zeta_0 + \hat{\varrho} Y_{i,t}$. Third, we calculate an index ($\omega_{i,t}$) as the observed profitability to predicted profitability ratio (i.e. $\Psi_{i,t}/\hat{\Psi}_{i,t}$), which measures how a firm is able to obtain greater (or lower) profits from a given number of patents with respect to the average of the other firms showing the same number of patents, all else (captured by firm fixed effects) being equal. If a firm couples its patents with other innovative strategies and/or produces relatively high-value innovations, its patents will lead to an observed economic performance ($\Psi_{i,t}$) higher than the predicted one ($\hat{\Psi}_{i,t}$), then $\omega_{i,t} > 1$. Viceversa, if a firm has patents with a relatively poor impact on its economic performance, then $\omega_{i,t} < 1$. Fourth, finally, we construct a new patenting activity variable ($Y\_augmented_{i,t}$) combining multiplicatively the rough number of patents $Y_{i,t}$ and $\omega_{i,t}$. $Y\_augmented_{i,t}$ is then used as the dependent variable in the first robustness check of our SM1 and SM2 estimates, presented in columns (1) and (4) of Table 6.

Partnerships in patenting activity. Another important issue in patent data analysis is how to compare patents obtained by a firm autonomously with those obtained by a (possibly high) number of firms in partnership. In our baseline regressions we used a patents count variable ($Y_{i,t}$) in which each patent awarded to n firms in partnership equals 1 for each firm. Although such coding strategy can be justified by the fact that a patent has the same economic value whether or not it has been obtained by inter-firm partnerships, from a different point of view it might be argued that a patent obtained by a firm autonomously requires a relatively greater innovative effort and should weight relatively more. If innovation partnership strategies are adopted by firms heterogeneously across SM1 (*creative destruction*) and SM2 (*creative accumulation*) sectors, again a bias might be introduced in our estimates. In a second robustness check, we therefore consider a weighted patenting activity index ($Y\_weighted_{i,t}$) as our dependent variable, measuring the firm level number of patents awarded in a given year, where patents awarded to n firms in partnership are weighted by $1/n$. Estimation results are presented in columns (2) and (5) of Table 6.

Endogeneity of ownership. Where stock markets are particularly active, external investors who anticipate the success of firm investment strategies may decide to enter corporate ownership before innovations are completed and patented, so enlarging the number of shareholders. In principle, this might introduce an endogeneity issue in the empirical analysis of corporate governance effects. Several studies, however, show that the corporate governance structure of both listed and unlisted Italian companies is extremely stable (Bianchi and Bianco, 2006; 2008) and that the Italian market for corporate control is characterized by a lack of contestability and opacity, irrespective of the sector considered. Dyck and Zingales (2004), among others, find that Italy is one of the countries with the highest control premiums, giving incumbent owners great scope to dilute minority shareholder powers and incentive to maintain existing blockholdings. It is, therefore, highly unlikely that expected changes in firm innovation performance, as measured by patenting activity, trigger changes in our ownership concentration variables, in particular in view of the fact that ownership concentration levels in our data are coded in a three-class indicator. In any event, we check the robustness of our baseline estimates in a two-stage instrumental variable regression. In an additional estimation, we instrument the ownership concentration indicator at a firm level by means of the average ownership concentration level observed in the sector in which the firm operates. While, indeed, the degree of shares concentration in a firm is likely to be affected by the pattern of ownership structure dominant in the industry, on the other hand the innovation performance of the firm does not impact on sectoral patterns of ownership structure in a significant way. Specifically, we first re-code our ownership concentration dummies in a discrete index (*OC_discrete*) ranging from 1 to 3; we then regress firm-level values of *OC_discrete* on 2-digit sector-level averages and obtain firm-level instrumented values (*OC_instrumented*); finally, we use *OC_instrumented* as an explanatory variable in the hurdle model regression, keeping all other regressors equal. The results of this robustness check are presented in columns (3) and (6) of Table 6.

Table 6 about here

The results of the robustness checks confirm the statistical validity of our main findings. In particular, the estimated parameter of *Debt_to_equity* has a negative impact in SM1 sectors, while it has no effect in SM2 sectors, in all the model specifications considered in Table 6. Moreover, similarly to our baseline results, *OC-high* and *OC-medium* (*OC-low* being the benchmark dummy) have a positive and statistically significant effect in the extensive margin equation in SM1 sectors, but also do have a negative effect (at a 1% level of statistical significance) in the extensive margin equation in SM2 sectors. When the ownership concentration indicator is instrumented, these results remain strongly significant.[5]

5 Policy implications and conclusions

This paper has uncovered an under-explored aspect of the relationship between corporate governance and innovation, highlighting the role of sectoral differences. In particular, it has shown that the most important corporate governance dimensions (in particular, a firm's ownership and financial structure) have distinct effects on firm-level innovation, according to whether the firm operates in 'Schumpeter Mark I' (*creative destruction*) or 'Schumpeter Mark II' (*creative accumulation*) sectors, differences being driven by the underlying extent of technological and market uncertainty. This perspective allows to make sense of the contradictory findings of the literature on corporate governance and innovation and suggests new policy insights.

In particular, the analysis indicates that one-size-fits-all attempts to leverage on corporate governance features to stimulate innovation are likely to miss their target because they overlook technology-specificities. Corporate governance-related policy measures require a sector-specific approach, as it is now widely acknowledged for other domains of innovation policy.

The first sector-specific policy conclusion stems from the finding that debt financing has a negative impact on the firm's propensity to become innovative in SM1 (i.e. *creative destruction*) sectors. This confirms the general understanding that initiatives that increase the convenience of equity financing of the sort that many OECD countries have adopted are certainly to be welcomed. However, it also suggests that the technology-specific nature of corporate finance implies the need for additional, more specialized, forms of equity financing such as venture capital financing. This is because this financial tool entails institutional arrangements that allow to fully take into account sectoral specificities. More specifically, our analysis suggests that venture capital may

[5]We have also checked the statistical robustness of our results to the sector-level clustering of standard errors and to separate estimation of the logit and the zero-truncated negative binomial equations. Again, estimation findings remain substantially unchanged. Results are provided upon request.

play a particularly relevant role in SM1 sectors.

A second sector-specific policy conclusion may be drawn with reference to the ownership structure dimension. Our empirical investigation shows that concentrated ownership is likely to reduce agency costs in SM1 sectors to a larger extent than it may exacerbate asymmetric bargaining problems. Nevertheless, it is well known how concentrated ownership structures may make external funding more difficult for the firm, especially in technologically unstable environments where external investors may lack the capabilities to efficiently monitor the firm's investment initiatives and business strategies. Again, this highlights the need for reinforcing the availability of sector-specific forms of external corporate funding, taking into account how different degrees of ownership concentration across different sectors may raise innovation financing costs in specific industrial environments. On the other hand, firms in SM2 (i.e. *creative accumulation*) sectors may be able to take larger advantage from policies aimed at favoring more dispersed ownership structures and the development of public companies.

This conclusion needs to be coupled with the acknowledgment that family ownership, in Italy, still tends to show a highly risk averse profile with respect to innovation investments. Although family owners should not be considered per se hostile to innovative and risky business strategies, our results suggest that family-run companies are likely to benefit from a wider adoption of managerial practices, remuneration schemes and decision-making processes providing stronger managerial incentives to undertake innovative projects.

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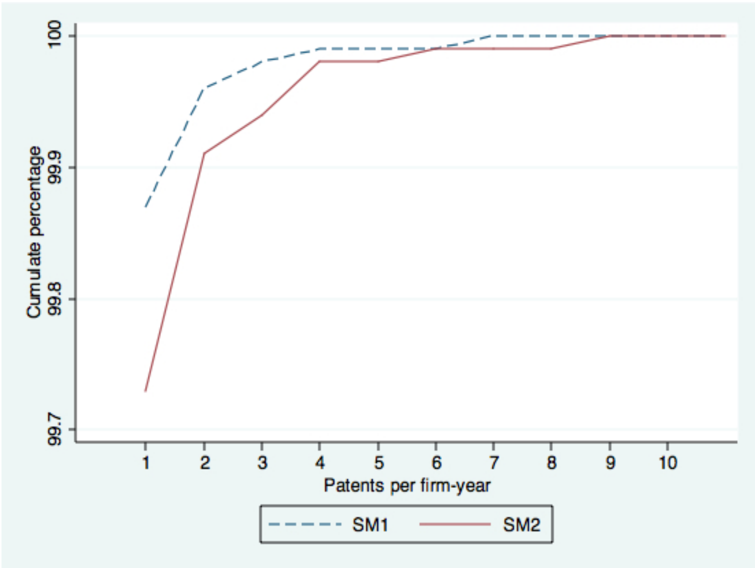
Figure 1: Cumulate distribution of firm-level patents per year (truncated at zero).



The vertical axis measures the cumulate distribution of Italian firm-level patents per year. The horizontal axis measures the number of patents showed by each firm in each year in the 2002-2007 period.

Table 1: Summary of variables' description.

	DESCRIPTION	SOURCE
Y	Firm level number of patents awarded in a given year. Each patent awarded to n firms in partnership equals 1 for each firm.	Authors' elaboration on PATSTAT (2013)
Total_patents	Total number of patents hold by the firm (over the 1978-2007 period). Patents awarded to n firms in partnership are weighted by $1/n$.	Authors' elaboration on PATSTAT (2013)
Intangibles_to_employees	Intangible assets (thousands of euro) to number of employees ratio. Intangible assets include formation expenses, research expenses, goodwill, development expenses.	Authors' elaboration on Aida (BvD, 2013)
Firm_age	Number of years since the firm's incorporation date.	Authors' elaboration on Aida (BvD, 2013)
Firm_size	Number of employees.	Authors' elaboration on Aida (BvD, 2013)
Listed	Dummy variable (1 = the firm is listed in the stock market, 0 = otherwise)	Authors' elaboration on Aida (BvD, 2013)
Debt_to_equity	All of firm's future obligations on the balance sheet relative to equity	Authors' elaboration on Aida (BvD, 2013)
OC-high	Dummy variable (1 = one or more shareholders have direct or total (indirect) control of the firm by more than 50% of shares, 0 = otherwise).	Authors' elaboration on Aida (BvD, 2013)
OC-medium	Dummy variable (1 = one or more shareholders have direct or total (indirect) control of the firm by more than 25% and less than 50% of shares, 0 = otherwise).	Authors' elaboration on Aida (BvD, 2013)
OC-low	Dummy variable (1 = no shareholder has direct or total (indirect) control of the firm by more than 25%, 0 = otherwise).	Authors' elaboration on Aida (BvD, 2013)
RS-family	Dummy variable (1 = the representative shareholder is an individual or a family, 0 = otherwise).	Authors' elaboration on Aida (BvD, 2013)
RS-bank	Dummy variable (1 = the representative shareholder is a bank, 0 = otherwise).	Authors' elaboration on Aida (BvD, 2013)
RS-holding	Dummy variable (1 = the representative shareholder is a financial holding company, 0 = otherwise).	Authors' elaboration on Aida (BvD, 2013)
RS-ind_company	Dummy variable (1 = the representative shareholder is an industrial company, 0 = otherwise).	Authors' elaboration on Aida (BvD, 2013)
RS-other	Dummy variable (1 = the representative shareholder is a mutual or pension fund, a private equity company, an insurance company or does not fit in the previous categories, 0 = otherwise).	Authors' elaboration on Aida (BvD, 2013)
Italian_RS	Dummy variable (1 = the representative is Italian, 0 = otherwise).	Authors' elaboration on Aida (BvD, 2013)

Table 2: Description of SM1 and SM2 sectors.

SM1 [*creative destruction*]	SM2 [*creative accumulation*]
TECHNOLOGICAL REGIME	
High technological opportunities Low appropriability Low cumulativeness	Low technological opportunities High appropriability High cumulativeness
MARKET STRUCTURE	
Low concentration High rates of entry of new firms High instability in the hierarchy of innovators	High concentration Low rates of entry of new firms Low instability in the hierarchy of innovators
MAIN SECTORS⋆	
Manufacture of electrical equipment Manufacture of railway locomotives, ships and boats Manufacture of textiles, wearing apparel, paper products Manufacture of pharmaceutical products and preparations, medical instruments, optical and electromedical equipment	Manufacture of chemicals and chemical products Manufacture of rubber and plastic products Manufacture of electronic components Manufacture of motor vehicles, trailers and semi-trailers and other transport equipment not elsewhere classified

⋆The reported list of SM1 and SM2 sectoral aggregates is illustrative. The classification implemented in the empirical analysis is at a 4-digit level. The complete list of 4-digit NACE codes for each group is available upon request.

Table 3: Descriptive statistics of explanatory variables.

	SM1 sectors		SM2 sectors	
	Innovative firms (0.31% of the SM1 sample)	Non innovative firms (99.69% of the SM1 sample)	Innovative firms (0.75% of the SM2 sample)	Non innovative firms (99.25% of the SM2 sample)
Total_patents (mean [std.dev.])	4.15 [6.73]	0.00 [0.00]	4.53 [10.50]	0.00 [0.00]
Intangibles_to_employees (mean [std.dev.]	13.63 [48.71]	6.32 [53.15]	10.48 [31.10]	9.15 [91.48]
Firm_age (mean [std.dev.]	21.00 [14.79]	16.94 [13.47]	19.48 [13.51]	17.93 [13.23]
Firm_size (mean [std.dev.]	235.91 [524.68]	34.92 [150.69]	188.17 [552.68]	46.28 [270.74]
Listed (%)	0.97	0.07	0.59	0.14
Debt_to_equity (mean [std.dev.]	2.28 [16.99]	2.97 [14.18]	1.80 [4.92]	2.61 [12.39]
OC-high (%)	64.77	53.94	65.82	57.20
OC-medium (%)	30.36	39.40	26.11	36.42
OC-low (%)	4.87	6.66	8.06	6.39
RS-family (%)	38.65	74.04	38.68	65.80
RS-bank (%)	3.16	0.76	0.74	0.79
RS-holding(%)	9.25	4.72	11.10	5.53
RS-ind_company (%)	47.05	19.78	47.53	26.90
RS-other (%)	1.89	0.70	1.96	0.98
Italian_RS (%)	87.10	96.18	85.14	92.05

Table 4: Logit - negative binomial hurdle model, estimation results - SM1 sectors: baseline regressions.

	(1)		(2)		(3)		(4)		(5)		(6)	
	Dep. var.: Y		Dep. var.: Y		Dep. var.: Y		Dep. var.: Y		Dep. var.: Y		Dep. var.: Y	
	EXTENSIVE MARGIN	INTENSIVE MARGIN	EXTENSIVE MARGIN	INTENSIVE MARGIN	EXTENSIVE MARGIN	INTENSIVE MARGIN	EXTENSIVE MARGIN	INTENSIVE MARGIN	EXTENSIVE MARGIN	INTENSIVE MARGIN	EXTENSIVE MARGIN	INTENSIVE MARGIN
Total_patents†	0.582	0.080	0.569	0.077	0.548	0.075	0.554	0.086	0.490	0.077	0.453	0.078
	(0.073)***	(0.009)***	(0.071)***	(0.009)***	(0.073)***	(0.008)***	(0.076)***	(0.015)***	(0.070)***	(0.009)***	(0.070)***	(0.015)***
Intangibles_to_employees†	0.001	0.000	0.001	0.000	0.001	0.000	0.001	0.000	0.001	0.000	0.001	-0.000
	(0.000)***	(0.002)	(0.000)***	(0.002)	(0.000)***	(0.002)	(0.000)***	(0.001)	(0.000)***	(0.000)	(0.000)***	(0.001)
Firm_age	0.007	-0.000	0.006	-0.001	0.007	-0.000	0.007	-0.000	0.009	0.001	0.005	-0.001
	(0.003)**	(0.006)	(0.003)*	(0.006)	(0.003)**	(0.006)	(0.003)**	(0.006)	(0.004)**	(0.010)	(0.004)	(0.008)
Firm_size†	0.001	-0.000	0.001	-0.000	0.001	-0.001	0.001	-0.000	0.001	-0.000	0.001	-0.000
	(0.000)***	(0.000)	(0.000)***	(0.000)	(0.000)***	(0.000)	(0.000)***	(0.000)	(0.000)***	(0.000)	(0.000)***	(0.000)
Listed†	0.391	0.619									0.421	0.506
	(1.679)	(0.661)									(1.416)	(0.674)
Debt_to_equity†			-0.041	-0.059							-0.043	-0.116
			(0.012)***	(0.038)							(0.017)**	(0.060)*
OC-high†					0.668	1.984					1.213	13.233
					(0.299)**	(0.577)***					(0.721)*	(0.533)***
OC-medium†					0.321	1.949					1.832	13.416
					(0.306)	(0.583)***					(0.728)**	(0.499)***
OC-low†					benchmark	benchmark					benchmark	benchmark
RS-bank†							0.790	-0.647			0.632	-0.330
							(0.620)	(0.636)			(0.781)	(0.634)
RS-holding†							0.768	-0.513			0.802	-0.541
							(0.231)***	(0.295)*			(0.238)***	(0.330)
RS-ind_company†							0.754	-0.020			0.586	-0.122
							(0.149)***	(0.249)			(0.179)***	(0.271)
RS-other†							-0.346	-0.252			0.764	0.180
							(0.152)**	(0.245)			(0.612)	(0.384)
RS-family†							benchmark	benchmark			benchmark	benchmark
Italian_RS†									-0.558	-0.352	-0.348	-0.222
									(0.238)**	(0.320)	(0.254)	(0.396)
Constant	-5.034	-0.302	-4.906	-0.186	-5.276	-2.594	-4.911	-0.810	-4.249	-0.047	-5.917	-13.053
	(0.158)***	(0.349)	(0.162)***	(0.329)	(0.320)***	(0.673)***	(0.160)***	(0.386)**	(0.304)***	(0.549)	(0.822)***	(0.635)
Estimation	logit	neg.binomial	logit	neg.binomial	logit	neg.binomial	logit	neg.binomial	logit	neg.binomial	logit	neg.binomial
Year dummies	yes		yes		yes		yes		yes		yes	
Firm-clustered SE	yes		yes		yes		yes		yes		yes	
No. obs.	62792		59063		53784		62792		35274		28687	
No. firms	22653		22258		20887		22653		12336		11208	
Log pseudo-likelihood	-3029.7267		-2941.6877		-2702.1796		-2984.9782		-2161.0317		-1880.939	
Wald χ^2 [prob. $> \chi^2$]	144.94 [0.000]		169.47 [0.000]		141.15 [0.000]		250.92 [0.000]		140.65 [0.000]		198.29 [0.000]	

† One-year lagged. Statistical significance: * (=10%), ** (=5%), *** (=1%). Standard errors (in parenthesis) are heteroskedasticity robust.

Table 5: Logit - negative binomial hurdle model, estimation results - SM2 sectors: baseline regressions.

	(1)		(2)		(3)		(4)		(5)		(6)	
	Dep. var.: *Y*		Dep. var.: *Y*		Dep. var.: *Y*		Dep. var.: *Y*		Dep. var.: *Y*		Dep. var.: *Y*	
	EXTENSIVE MARGIN	INTENSIVE MARGIN	EXTENSIVE MARGIN	INTENSIVE MARGIN	EXTENSIVE MARGIN	INTENSIVE MARGIN	EXTENSIVE MARGIN	INTENSIVE MARGIN	EXTENSIVE MARGIN	INTENSIVE MARGIN	EXTENSIVE MARGIN	INTENSIVE MARGIN
Total_patents†	0.420	0.057	0.413	0.055	0.403	0.051	0.399	0.054	0.396	0.040	0.354	0.033
	(0.056)***	(0.076)	(0.055)***	(0.060)	(0.062)***	(0.048)	(0.055)***	(0.055)	(0.063)***	(0.029)	(0.064)***	(0.013)**
Intangibles_to_employees†	0.000	0.003	0.000	0.002	0.000	0.001	0.000	0.002	0.001	0.002	0.001	0.000
	(0.000)	(0.002)	(0.000)	(0.002)	(0.000)	(0.001)	(0.000)	(0.001)	(0.000)**	(0.001)	(0.000)*	(0.001)
Firm_age	0.003	0.000	0.002	-0.000	0.002	-0.000	0.002	-0.000	0.003	0.001	-0.002	0.000
	(0.003)	(0.008)	(0.004)	(0.007)	(0.004)	(0.007)	(0.003)	(0.007)	(0.004)	(0.007)	(0.005)	(0.007)
Firm_size†	0.001	-0.000	0.001	-0.000	0.001	-0.000	0.001	-0.000	0.001	-0.000	0.001	0.000
	(0.000)**	(0.000)	(0.000)**	(0.000)	(0.000)**	(0.000)	(0.000)**	(0.000)	(0.000)**	(0.000)	(0.000)*	(0.000)
Listed†	-0.066	0.642									-0.080	0.669
	(0.921)	(0.646)									(0.649)	(0.462)
Debt_to_equity†			-0.007	-0.032							-0.005	-0.026
			(0.007)	(0.019)*							(0.007)	(0.021)
OC-high†					-0.034	0.313					-1.044	0.264
					(0.187)**	(0.264)					(0.280)***	(0.344)
OC-medium†					-0.505	0.075					-1.070	-0.505
					(0.203)	(0.340)					(0.312)***	(0.336)
OC-low†					benchmark	benchmark					benchmark	benchmark
RS-bank†							0.352	0.110			0.122	-0.389
							(0.606)	(0.713)			(0.748)	(1.042)
RS-holding†							0.768	-0.079			0.772	-0.105
							(0.196)***	(0.471)			(0.208)***	(0.414)
RS-ind_company†							0.662	0.131			0.588	0.283
							(0.126)***	(0.210)			(0.168)***	(0.270)
RS-other†							-0.378	-0.061			0.100	0.359
							(0.133)***	(0.278)			(0.213)	(0.558)
RS-family†							benchmark	benchmark			benchmark	benchmark
Italian_RS†									-0.242	-0.291	0.010	-0.039
									(0.168)	(0.290)	(0.213)	(0.318)
Constant	-3.927	-1.427	-3.911	-1.015	-3.818	-1.272	-4.050	-1.327	-3.466	-0.459	-2.864	-0.511
	(0.125)***	(2.438)	(0.128)***	(1.618)	(0.213)***	(1.333)	(0.142)***	(1.695)	(0.213)***	(0.772)	(0.434)***	(0.758)
Estimation	logit	neg.binomial	logit	neg.binomial	logit	neg.binomial	logit	neg.binomial	logit	neg.binomial	logit	neg.binomial
Year dummies	yes		yes		yes		yes		yes		yes	
Firm-clustered SE	yes		yes		yes		yes		yes		yes	
No. obs.	38873		36758		33675		38873		23652		19613	
No. firms	13090		12912		12283		13090		7699		7158	
Log pseudo-likelihood	-3645.3047		-3537.1462		-3212.7999		-3592.1045		-2687.6783		-2291.9924	
Wald χ^2 [prob. > χ^2]	137.04 [0.000]		150.17 [0.000]		123.66 [0.000]		231.42 [0.000]		105.86 [0.000]		166.13 [0.000]	

† One-year lagged. Statistical significance: * (=10%), ** (=5%), *** (=1%). Standard errors (in parenthesis) are heteroskedasticity robust.

Table 6: Logit - negative binomial hurdle model, estimation results: robustness checks.

	(1)		(2)		(3)		(4)		(5)		(6)	
	SM1 sectors		SM1 sectors		SM1 sectors		SM2 sectors		SM2 sectors		SM2 sectors	
	Dep. var.: *Y_augmented*		Dep. var.: *Y_weighted*		Dep. var.: *Y*		Dep. var.: *Y_augmented*		Dep. var.: *Y_weighted*		Dep. var.: *Y*	
	EXTENSIVE MARGIN	INTENSIVE MARGIN	EXTENSIVE MARGIN	INTENSIVE MARGIN	EXTENSIVE MARGIN	INTENSIVE MARGIN	EXTENSIVE MARGIN	INTENSIVE MARGIN	EXTENSIVE MARGIN	INTENSIVE MARGIN	EXTENSIVE MARGIN	INTENSIVE MARGIN
Total_patents†	0.444	0.040	0.448	0.089	0.471	0.082	0.380	0.016	0.381	0.028	0.374	0.037
	(0.077)***	(0.006)***	(0.077)***	(0.017)***	(0.072)***	(0.015)***	(0.070)***	(0.004)***	(0.071)***	(0.007)***	(0.060)***	(0.018)**
Intangibles_to_employees†	0.001	-0.000	0.001	-0.000	0.001	0.000	0.000	0.000	0.000	-0.000	0.000	0.002
	(0.000)***	(0.000)	(0.000)***	(0.002)	(0.000)***	(0.002)	(0.000)	(0.000)	(0.000)	(0.002)	(0.000)	(0.001)
Firm_age	0.004	0.000	0.004	0.002	0.004	0.002	-0.005	-0.000	-0.005	-0.001	-0.000	0.000
	(0.004)	(0.000)	(0.004)	(0.010)	(0.004)	(0.009)	(0.005)	(0.002)	(0.005)	(0.007)	(0.005)	(0.007)
Firm_size†	0.001	-0.000	0.001	-0.000	0.001	-0.000	0.001	0.000	0.001	0.000	0.001	-0.000
	(0.000)***	(0.000)	(0.000)***	(0.000)	(0.000)***	(0.000)	(0.000)*	(0.000)	(0.000)**	(0.000)	(0.000)**	(0.000)
Listed†	0.519	0.233	0.540	0.447	0.161	0.456	-0.117	0.320	-0.109	0.869	-0.145	0.784
	(1.384)	(0.353)	(1.392)	(0.658)	(1.407)	(0.678)	(0.699)	(0.278)	(0.702)	(0.350)**	(0.709)	(0.552)
Debt_to_equity†	-0.052	-0.015	-0.053	-0.031	-0.041	-0.084	-0.005	-0.010	-0.004	-0.023	-0.007	-0.030
	(0.018)***	(0.019)	(0.019)***	(0.060)	(0.015)***	(0.055)	(0.007)	(0.006)	(0.007)	(0.023)	(0.008)	(0.023)
OC-high†	0.760	0.080	0.736	0.185			-1.066	0.056	-1.076	0.078		
	(0.592)	(0.221)	(0.592)	(0.873)			(0.295)***	(0.111)	(0.296)***	(0.291)		
OC-medium†	1.411	0.098	1.386	0.291			-0.890	-0.172	-0.888	-0.649		
	(0.602)**	(0.098)	(0.603)**	(0.900)			(0.321)***	(0.112)	(0.321)***	(0.327)**		
OC-low†	benchmark	benchmark	benchmark	benchmark			benchmark	benchmark	benchmark	benchmark		
OC_instrumented†					2.365	0.490					-7.653	5.598
					(1.153)**	(1.841)					(2.949)***	(4.007)
RS-bank†	1.069	-0.348	1.082	-1.468	0.766	-0.601	0.136	-0.047	0.144	-0.159	0.118	-0.261
	(0.515)**	(0.171)**	(0.515)**	(0.670)**	(0.611)	(0.622)	(0.755)	(0.281)	(0.755)	(1.138)	(0.744)	(1.023)
RS-holding†	0.738	-0.210	0.742	-0.731	0.754	-0.563	0.802	-0.065	0.788	-0.273	0.798	-0.108
	(0.255)***	(-0.210)**	(0.255)***	(0.346)**	(0.230)***	(0.306)*	(0.210)***	(0.119)	(0.214)***	(0.395)	(0.200)***	(0.423)
RS-ind_company†	0.574	-0.066	0.548	-0.355	0.711	-0.124	0.581	0.076	0.579	0.155	0.731	0.098
	(0.176)***	(0.110)	(0.178)***	(0.297)	(0.157)***	(0.253)	(0.169)***	(0.119)	(0.171)***	(0.244)	(0.138)***	(0.212)
RS-other†	0.829	0.103	0.869	0.303	0.650	0.279	-0.283	0.172	-0.280	0.462	0.269	0.200
	(0.615)	(0.194)	(0.605)	(0.495)	(0.645)	(0.434)	(0.750)	(0.311)	(0.751)	(0.592)	(0.527)	(0.612)
RS-family†	benchmark	benchmark	benchmark	benchmark	benchmark	benchmark	benchmark	benchmark	benchmark	benchmark	benchmark	benchmark
Italian_RS†	-0.206	-0.139	-0.151	-0.518	-0.084	-0.330	-0.129	-0.086	-0.142	-0.251	0.083	-0.187
	(0.260)	(0.169)	(0.272)	(0.411)	(0.248)	(0.333)	(0.207)	(0.130)	(0.208)	(0.285)	(0.181)	(0.306)
Constant	-5.605	5.782	-5.616	-0.044	-10.437	-1.629	-2.571	5.478	-2.565	-0.099	-15.241	-14.386
	(0.702)***	(0.315)	(0.708)***	(1.162)	(2.906)***	(4.581)	(0.447)***	(0.222)***	(0.449)***	(0.611)	(7.394)**	(10.320)
Estimation	logit	neg.binomial	logit	neg.binomial	logit	neg.binomial	logit	neg.binomial	logit	neg.binomial	logit	neg.binomial
Year dummies	yes		yes		yes		yes		yes		yes	
Firm-clustered SE	yes		yes		yes		yes		yes		yes	
No. obs.	28827		28851		33429		19546		19571		22540	
No. firms	11266		11280		12144		7145		7154		7603	
Log pseudo-likelihood	-3316.7674		-1782.3141		-2086.278		-4282.0123		-2192.8076		-2597.4444	
Wald χ^2 [prob. > χ^2]	178.23 [0.000]		172.96 [0.000]		209.23 [0.000]		178.34 [0.000]		181.03 [0.000]		181.88 [0.000]	

† One-year lagged. Statistical significance: * (=10%), ** (=5%), *** (=1%). Standard errors (in parenthesis) are heteroskedasticity robust.