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Corporate governance effects on innovation when both agency costs and asset specificity matter

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Abstract

This article explores the question whether the relationship between corporate governance and innovation is affected by the extent to which the firm is exposed to agency problems and asset specificity issues. In particular, we argue that different combinations of asset specificity and agency costs are associated to firm age and sector of activity and predict heterogenous effects of ownership concentration on innovation across different types of firms. We use a unique data set of about 35,000 Italian manufacturing corporations over the 2002–2007 period and run a hurdle model, distinguishing four subgroups of firms on the basis of their age (greater or lower than 15 years) and of whether they belong to a high-technology or low-technology sector. We find that the effects of ownership concentration on innovation are coherent with the predictions of so-called "shareholder theory" when agency cost effects dominate over asset specificity effects and that they are coherent with the predictions of so-called "stakeholder theory" when asset specificity effects dominate over agency cost effects. 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, especially as regards the role played by ownership concentration, and may help policymakers to define more effective type-specific initiatives to stimulate firm innovation.

JEL classification: C30, G30, L60, O30

1. Introduction

An increasing number of empirical studies widely acknowledge that corporate governance is crucial to the ability of corporations to produce successful technological innovations, as it influences both the degree of protection that financiers expect to receive for their investments, and therefore the cost at which investors are willing to provide capital, and the incentives of corporation's members to apply their skills and effort to the implementation of innovation strategies (for a survey, see Belloc, 2012).

There are many theoretical explanations of the mechanisms underlying this relationship, but a broad distinction may be traced among the various contributions according to whether they place emphasis on *agency costs* or on *asset specificity*. When attention is focused on *agency costs* and asymmetric information, the relationship between corporate governance variables and innovation is explained on the basis of their effects on shareholders' and creditors' ability to monitor the management, along the lines of the seminal contribution by Jensen and Meckling (1976). Contributions of this sort have been dubbed to belong to a "shareholder approach." The "stakeholder approach," by contrast, draws attention on the underinvestment problem due to the risk of hold up that may emerge in presence of *asset specificity* in an incomplete contracting framework. Corporate governance variables, from this perspective, matter for innovation because they alter the allocation of control rights and therefore affect incentives (e.g. Grossman and Hart, 1986 and Hart and Moore, 1990).

The two approaches lead to different predictions as to the expected relationship between corporate governance dimensions and innovation. This holds, in particular, for ownership concentration. Shareholder theory predicts a clear positive effect of ownership concentration on innovation because, in a nutshell, concentration reduces the well-known free rider problem emerging when the benefits of monitoring activity are dispersed among multiple shareholders, thus increasing overall incentives to monitor the management (Shleifer and Vishny, 1997). Stakeholder theory, on the other side, predicts a negative effect of ownership concentration because the latter may cause asymmetric bargaining between shareholders and other firm stakeholders, consequently reducing their incentives to apply effort to firm-specific activities ex ante to the extent they anticipate opportunistic actions ex post by concentrated shareholders (Grossman and Hart, 1988; Harris and Raviv, 1988; Aghion and Tirole, 1997; Burkart *et al.*, 1997).

Empirical analysis has not so far been able to unambiguously conclude that one approach has a greater explanatory power than the other, as there are empirical contributions supporting both sets of predictions (e.g. Hill and Snell, 1989; Baysinger *et al.*, 1991; Francis and Smith, 1995; Battaggion and Tajoli, 2001; Hosono *et al.*, 2004; and Ortega-Argilès *et al.*, 2005).

This article aims to address this empirical puzzle. We move from the hypothesis that the two theoretical approaches are complementary and both have merit. We posit that the effects singled out by the two theories most likely coexist and that whether we observe empirically one effect or the other depends on firm-specific features affecting the relative strength of agency costs and asset specificity. We test this hypothesis by estimating the impact of corporate governance features on patenting activity for four subgroups of Italian manufacturing firms, identified on the basis of whether they belong to a high-tech or low-tech sector and their age. Previous literature has clarified that a firm's sector of activity and age are associated in predictable ways to the extent of asset specificity and agency costs. In particular, both asset specificity and agency costs increase with R&D intensity (Carpenter and Petersen, 2002; Aghion *et al.*, 2004; Brown and Petersen, 2009), while agency costs decrease and asset specificity increases with firm age (Frank and Goyal, 2008; Hall and Lerner, 2010). Grouping firms according to these two features thus allows to identify firms facing different combinations of asset specificity and agency costs.

We employ a unique data set built on the matching of the European Patent Office's (EPO, 2013) Worldwide Patent Statistical Database (PATSTAT) and the Aida database containing information on a large sample of manufacturing companies in Italy provided by Bureau Van Dijk (BvD, 2013). We then implement a hurdle model to study both extensive and intensive margins of firms' innovation and obtain informative correlations linking a firm's governance to its innovation performance.

We find that the effects of corporate governance features on innovation are coherent with the predictions of shareholder theory when agency cost effects dominate over asset specificity effects; that they are coherent with the predictions of stakeholder theory when asset specificity effects dominate over agency cost effects and that the two effects balance out for firms for which the two types of effects are either both very strong or very weak and therefore tend to balance out. In particular, our estimates suggest that, in high-technology sectors, the probability of being innovative for old firms belonging to the low ownership concentration class (i.e. no shareholder controls the firm by more than 25%) is, all else being equal, 2.15 times that of firms with a medium ownership concentration rate (i.e. one or more shareholders control the firm by more than 25% and less than 50% of shares) and 2.73 times that of firms with a high ownership concentration rate (i.e. one or more shareholders control the firm by more than 50% of shares).

We improve with respect to previous literature in two main ways. First, and most importantly, we highlight a novel aspect of the corporate governance–innovation relationship by setting apart different types of firms on the basis of their age and sector of activity. This allows us to show empirically that ownership concentration affects innovation output in a heterogenous manner, depending on the relative importance of asset specificity and agency costs effects for different types of firms. While most empirical studies refer to specific sectors, due to data availability constraints, and have never explicitly considered the coexistence of agency costs and asset specificity issues, we are able to reconcile "shareholder theory" and "stakeholder theory" and to draw some new policy insights that may help policymakers to define more effective type-specific initiatives to stimulate firm innovation. Second, we use a novel database covering a very large sample of firms. This allows us to investigate simultaneously the effect of all the relevant corporate governance variables on innovation outcomes for different subgroups of firms.

In section 2 we provide some background on the relationship between corporate governance variables and innovation. In section 3 we develop the theoretical framework of analysis and put forward the main hypotheses to be tested. In section 4 we present the econometric model and the estimation results. Section 5 concludes.

2. Background on corporate ownership and innovation

Ownership concentration is the corporate governance dimension that has attracted the greatest attention and is acknowledged to be at the core of the relationship between firms' governance and innovation. 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.

To explain how this corporate governance feature influences firm-level innovation, two main approaches have developed. The first finds its roots in agency theory and focuses on the incentive issues arising from the separation of ownership and control (e.g. Berle and Means, 1932; Jensen and Meckling, 1976). It is dubbed "shareholder approach" because it emphasizes the role of shareholders as the only residual claimants of the firms' activity and, relatedly, the sole responsible for productive investments affecting firm performance. Shareholders make, in particular, key investments in monitoring the management. The second approach considers a wider range of stakeholders relevant to firm performance, which is conceptualized as dependent on firm-specific investments in assets or human capital made by shareholders, financiers, managers, and employees in a context characterized by contractual incompleteness (e.g. Blair, 1995). Innovation performance, in particular, depends on the ability to provide adequate incentives to make specific investments to all relevant stakeholders, since innovation is, by definition, a collective and cumulative investment process, through which knowledge is generated and competences accumulated.

The most apparent divergence between the two approaches relates to predictions as to the effects of different degrees of ownership concentration on innovation performance. The "shareholder approach" to corporate governance predicts, based on traditional agency theory arguments, that dispersed ownership gives rise to suboptimal levels of monitoring, as the benefits of monitoring activity are not fully internalized by shareholders due to free riding issues. According to this view, greater ownership concentration favors the alignment of cash flow and control rights of shareholders (Shleifer and Vishny, 1997). This may be particularly beneficial with respect to innovation investments when the misalignment of interests between shareholders and managers concerns the preferred degree of riskiness of the investment projects undertaken by the firm. Indeed, managers may tend to refrain from undertaking high-risk R&D investments because they tend to bear the burden of failures, while shareholders are more concerned with the upper tail of the distribution of returns from these investments. This positive effect of ownership concentration on innovation has been detected by a number of studies (Hill and Snell, 1988; Baysinger *et al.*, 1991; Francis and Smith, 1995; Hosono *et al.*, 2004), and it may be called the "agency cost minimization effect."

On the other side, the "stakeholder approach" predicts, based on incomplete contracts theory (Grossman and Hart, 1986; Hart and Moore, 1990), that ownership concentration may negatively affect corporate investment activity. According to this view, ownership structure shapes the ex post bargaining over (and so the final allocation of) the quasi-rent generated by the firm. Thus, ownership concentration may cause asymmetric bargaining between controlling shareholders and other stakeholders, including minority shareholders, managers, and other employees. Since innovative activities are a complex, collective, and cumulative endeavor requiring financial, physical, and human capital-specific investments, the disincentive effect of ownership concentration toward non-owners may have particularly deep effects on performance. Aghion and Tirole (1997), for instance, point to the fact that excessive control stifles managers' incentives to acquire information in presence of uncertainty. Along similar lines, Burkart *et al.* (1997) emphasize that the firm ownership structure may act as a commitment device to delegate a certain degree of control to management, so as to stimulate managerial initiative (i.e. searching for innovative investment projects) and other firm-specific investments (Grossman and Hart, 1988; Harris and Raviv, 1988). The negative effects of ownership concentration on innovation emphasized by the "stakeholder approach" to corporate governance may be called the "asymmetric bargaining effect." Empirical evidence exists that also corroborates this view (Battaggion and Tajoli, 2001; Ortega-Argilès *et al.*, 2005; Czarnitzki and Kraft, 2009).

3. Theoretical framework and hypotheses

In this section, we develop a set of hypotheses regarding the association between firm-specific features, the extent of agency costs and asset specificity involved by their activities, and the expected effects of corporate ownership variables on firm-level innovation. We focus on two firm-specific features—sector of activity and age—that past literature and empirical evidence have shown to be unambiguously associated to different levels of agency costs and different degrees of asset specificity.

To capture predictable differences in the extent of agency costs and asset specificity related to the firms' sector of activity, we distinguish between firms in the high-tech and low-tech sectors, i.e. between firms operating in sectors characterized by a high R&D intensity and low R&D intensity, respectively. R&D investments amount to a large extent (50% or more, according to Hall, 2009) to investments in scientists' and technicians' wages and salaries, whose human capital makes up the firm's knowledge base. Thus, high R&D intensity also entails a high degree of intangibility and specificity of the firm's assets. The relatively higher degree of intangibility of the assets of firms operating in an R&D intensive environment has implications also for the extent of agency costs they face. On one side, tangible assets may more easily be used as collateral to mitigate moral hazard problems, as they entail a smaller loss of value in the event firms face financial distress. On the other, intangible investments involve higher uncertainty and asymmetric information than more tangible ones both because of the higher volatility of the environment firms face and because of firms' reluctance to share information on their R&D programs so as to avoid spillovers. Carpenter and Petersen (2002), Aghion *et al.* (2004), and Brown and Petersen (2009), among others, indeed highlight that high-tech firms face more severe agency issues.

The relationship between firm age and the extent of agency costs involved by external financing is firmly established by a large literature on small and new firms' financial constraints (Hall and Lerner, 2010). For younger firms, asymmetric information problems are most severe because they lack a track record through which they may signal creditworthiness to potential investors. Thus, reputation may not be used as an effective signal to address agency issues. Young firms also lack significant collateral, as they have a lower stock of tangible assets (Hall, 2009). Finally, young firms tend to have higher growth rates, which increase their opacity as an investment opportunity for external financiers (Frank and Goyal, 2008).

The extent of asset specificity involved by the firm's activity and the scope of the ensuing potential underinvestment problem are also predictably associated to firm age. Mature firms have larger stocks of assets, which they have accumulated through past investments. These assets may be tangible, for instance, in the form of dedicated machinery, or intangible, in the form of firm-specific skills, accumulated through human capital investments of long-term employees, experience curves, learning-by-doing, and similar phenomena. Thus, the impact on performance (including innovation performance) of asset specificity-related issues of the type emphasized by the "stakeholder approach" is likely to be higher for mature firms than for younger firms.

In sum, both asset specificity and agency costs increase with R&D intensity, while agency costs decrease and asset specificity increase with firm age. The strength and shape of these relationships are, of course, not necessarily uniform. For instance, while age tends in general to raise asset specificity, the intensity of this effect depends on the technological environment firms face, being stronger in high-technology environments, where specific assets are relatively more important for performance, and weaker in low-technology environments, where firms tend to employ more generic assets. Yet, the different possible combinations of asset specificity and agency costs may provide insights as to the expected significance and sign of the corporate governance variables we consider, along the lines described in the Figure 1.

Consider, first, the firms in quadrant I. These firms operate in an R&D-intensive environment and are old. Both features suggest that they are expected to have a greater stock of tangible and intangible assets than other firms and therefore that asset specificity issues are likely to have a significant impact on firm behavior. The high level of asset specificity increases the relevance of the asymmetric bargaining problems between block-holders and small outside investors and between shareholders and managers highlighted by proponents of the "stakeholder theory." R&D intensity may, of course, also increase the extent of agency costs, for the reasons already explained, but firm age exerts a countervailing effect on their extent as the past history of the firm provides information that may mitigate

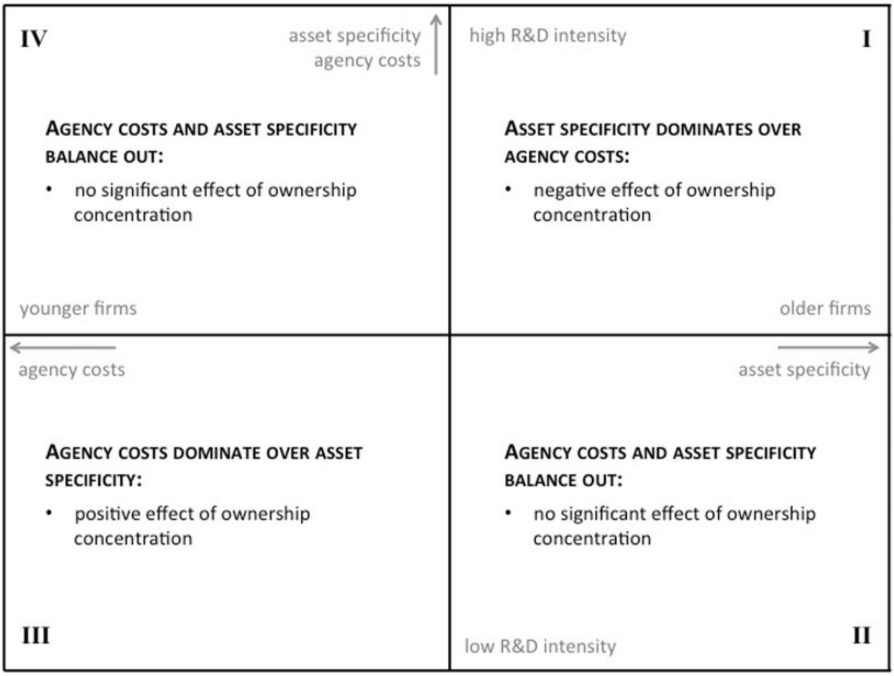

Figure 1. Asset specificity, agency costs, and firm heterogeneity.

asymmetric information. Thus, for firms in this quadrant, we expect asset specificity effects to dominate over agency cost effects. Consequently, the sign of the ownership concentration's effect should be coherent with the "stakeholder theory" rather than with the "shareholder theory" and therefore be negative.

On the basis of the above, we may put forward the following hypothesis.

Hypothesis 1: When firms are old and operate in an R&D-intensive (high tech) sector, asset specificity effects dominate over agency costs effects. This entails that ownership concentration has a negative effect on innovation.

Firms in quadrant II are old and operate in a low-tech environment. Here, agency costs are extremely low due to both low R&D intensity and higher age. On the other side, asset specificity also is very low. While mature firms may have accumulated assets over time, thus increasing their firm-specific components, it is also true that operating in a low-technology environment mainly requires traditional and well-established tangible capital, pushing firms, even if old, to adopt more generic assets. The extent of asset specificity involved by this type of firms is thus much more limited than for their counterparts in quadrant I, so that neither asset specificity effects nor agency cost effects are likely to be binding on firms' strategies. In particular, the positive effects of ownership concentration predicted by the "shareholder theory" can be expected to be of a similar order of magnitude of the negative effects of ownership concentration predicted by the "stakeholder theory" so that, on average, they balance out, making ownership concentration nonsignificant.

These considerations lead to the following hypothesis.

Hypothesis 2: When firms are old and operate in a low-tech sector, neither agency costs nor asset specificity effects matter greatly for performance, so that they balance out. This entails that ownership concentration is not expected to have a significant effect on innovation.

Firms in quadrant III are young and operate in a low-tech sector. Both features tend to reduce the extent of asset specificity involved by their activities. In particular, their young age entails that their stock of intangible capital is likely to be more limited than accumulated by more established firms, and their sector of operation suggests a similar conclusion. However, their young age also entails that they are exposed to relevant agency problems. Thus, for these firms, agency problems are likely to dominate over asset specificity effects. More specifically, while in mature firms investors may rely on a greater amount of information on the firm and they may be better able to understand, evaluate, and measure the risks of their investment projects, firm history and information available to third parties are more limited for young firms. For the latter, greater ownership concentration may make it easier to identify those exercising control and may strengthen fiduciary and reputational connections in the relationship between the owner(s) and external investors. Given the relatively limited stock of firm-specific assets, the negative effects of ownership concentration predicted by the "stakeholder theory" are not sufficiently strong to offset these positive effects of ownership concentration.

Hypothesis 3: When firms are young and operate in a low-tech sector, agency costs effects dominate over asset specificity effects. This entails that ownership concentration has a positive effect on innovation.

For firms in quadrant IV, agency costs are even higher than for firms in quadrant III, but asset specificity costs also increase, due to a higher R&D intensity. Technology intensity, in fact, induces firms to exploit newer and more original production processes, and both old and young firms, in this type of environment, are likely to need specific assets in their innovative productions. Asset specificity and agency costs effects, thus, are both very relevant for firm performance and they may therefore balance out. More specifically, while in low-tech sectors the easier identification of proprietors that is allowed for by ownership concentration may address agency issues without giving rise to significant asymmetric bargaining problems, in high-tech firms the latter problems appear more severe. Indeed, while in low-tech sectors investment opportunities are relatively well-known and standardized, in high-tech sectors managerial initiative in the pursuit of valuable and less predictable investment opportunities is crucial to firm performance. Thus, the positive effects of ownership concentration predicted by the "shareholders theory" are not sufficiently strong to outweigh the negative effects of ownership concentration predicted by the "stakeholder theory" that are strengthened by the higher R&D intensity of these firms.

On the basis of the above, we put forward the following hypothesis.

Hypothesis 4: When firms are young and operate in an R&D-intensive (high tech) sector, agency costs and asset specificity effects are both very relevant for firm performance, so that they balance out. This entails that ownership concentration is not expected to have a significant effect on innovation.

In testing for the above hypotheses, we take into account the effects of a number of additional corporate governance variables, including corporate finance, owners' identity, and listing on a stock exchange.

As for the first control variable, it is widely acknowledged that internally generated revenues should be the preferred channel of innovation funding (Hall, 1992; Brealey *et al.*, 2006), but internal financing constraints may force corporations to raise additional capital in the form of debt and/or equity. The empirical literature has clarified that a negative relationship exists between the proportion of debt in the firm's capital structure and its innovation performance (Bradley *et al.*, 1984; Long and Malitz, 1985; Baysinger and Hoskisson, 1989). The reasons why debt capital is ill-suited to finance innovative projects have to do with the deep information asymmetry (and the associated agency costs) that emerge between creditors and shareholders in highly risky investment programs, often characterized by high levels of asset specificity. Debt contracts may include debt covenants, through which lenders may protect themselves from too risky investment choices made by shareholders, with the possible effect, however, of limiting the firm ability to finance innovative projects through debt. Debt financing may also induce the firm to forgo some positive net present value investment projects like R&D-intensive programs (which would be undertaken if the firm was totally financed through equity), due to payoffs insufficient to repay debt holders. When a firm is highly leveraged, moreover, it may tend to refrain from R&D investments because the latter may increase both the probability of financial distress, being associated to highly uncertain returns, and the cost of financial distress, as they involve specific assets with low resale value and investments in human capital. Finally, the schedule of interest payments associated to debt is not coherent with the distribution of returns from innovation, which may take a long time to materialize and may be subject to a high volatility. This, again, may discourage highly leveraged firms from undertaking investments in R&D, which have a high variance of returns (Gugler, 2001). Equity, by contrast, is better suited to support innovation-related investments. It is risk capital meant to back risky projects, as investors benefit from the upper part of the project returns' distribution, unlike debt (Stiglitz, 1985). Moreover, it does not impose the firm a fixed schedule of payments and does not involve rising costs of financial distress (Carpenter and Petersen, 2002).

With respect to the owners' identity, extant studies focus on ownership by families, banks, and institutional investors. While family-controlled companies are generally found to perform lower innovation activity than corporations run by other types of blockholders (Munari *et al.*, 2010; Bugamelli *et al.*, 2012), the role played by banks and other institutional investors in corporate ownership is less clear. Bank ownership may mitigate information asymmetries between firm and creditor, so increasing the financial resources that the firm can allocate to innovation projects (Lee, 2005); however, they may also impose risk aversion in the business decision-making (Zahra, 1996; Kochhar and David, 1996; Tribo *et al.*, 2007). Private investment funds, on the other hand, typically have a preference for short-term profits and are shown to negatively affect corporate innovation (Sherman *et al.*, 1998; Hoskisson *et al.*, 2002), while other institutional entities (e.g. pension and retirement funds) may be interested in long-term corporate performance.

Finally, we also consider the decision of the firm to list its shares on a stock exchange. While the stock market may provide a mechanism for managerial discipline, hence 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).

4. Empirical analysis

4.1 Data and variables

We use data on individual corporation's characteristics and patents granted by the EPO to empirically explore the relationship between corporate governance and 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]

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 1 year). Specifically, we matched two already existing databases: the 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 these 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

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) even if 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-step 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 data sets, according to different customizable criteria.

Table 1. Summary of variables' description

Variable	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	Intangible assets (thousands of euro) to total assets ratio. Intangible assets include formation expenses, research expenses, goodwill, and development expenses.	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)
Profitability	EBITDA (earnings before interest, taxes, depreciation, and amortization) weighted by firm total assets	Authors' elaboration on Aida (BvD, 2013)
Revenues	Revenues (thousands of euro) to number of employees ratio	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)
Sectoral_growth	2-digit sectoral average of firm revenues' yearly growth rate.	Authors' elaboration on Aida (BvD, 2013)

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 labor-controlled firm (i.e. a cooperation).

Thanks to the use of the Aida data set, 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, revenues per employee, operational profitability, debt-equity ratio, intangible assets over total assets, degree of ownership concentration, and representative owner's identity and nationality. A detailed variables' description is provided in Table 1.

Given the information on the sector in which each firm operates at a four-digit sectoral level, we were able to assign each firm either to the high-technology environment or to the low-technology environment, according to the classification of manufacturing industries into categories based on technological intensity proposed by OECD (2011). Specifically, the OECD (2011) classification provides the division of manufacturing industries into high

Table 2. High technology and low technology sectoral clusters

Low technology	High technology
Building and repairing of ships and boats	Aircraft and spacecraft
Rubber and plastics products	Pharmaceuticals
Coke, refined petroleum products, and nuclear fuel	Office, accounting and computing machinery
Other nonmetallic mineral products	Radio, TV and communications equipment
Basic metals and fabricated metal products	Medical, precision, and optical instruments
Recycling	Electrical machinery and apparatus
Wood, pulp, paper, paper products, printing, and publishing	Motor vehicles, trailers, and semi-trailers
Food products, beverages, and tobacco	Chemicals excluding pharmaceuticals
Textiles, textile products, leather, and footwear	Machinery, railroad equipment, and transport equipment

technology, medium-high technology, medium-low technology, and low technology groups based on the ranking of manufacturing industries according to their average over 1991–1999 against aggregate OECD R&D intensities. Industries classified to higher categories have a higher average intensity for both R&D expenditures divided by value added and R&D expenditures divided by production than in industries in lower categories.

To develop our empirical study, we converted the four-class OECD classification into a two-class classification (high and medium-high technology are classified as high technology, while low and medium-low technology are classified as low technology). In Table 2 we list the sectoral composition of the high-technology and low-technology industrial clusters. We then divided our sample of firms between the two alternative technology clusters and distinguished young firms from older ones, finally obtaining four subgroups of observations. In particular, the two age-based subgroups include, respectively, firms with age up to 15 years and firms with age starting from 16 years.[3] On the one side, we are thus able to analyze the innovative behavior of young firms, allowing them to conclude their long-term investment programs (R&D projects may take more than 10 years to be completed) before switching to the old firms' group; on the other, we keep the two age-based subgroups with comparable size, being the median age in our full sample of firms equal to 16 years.

Once firms are classified into high-technology and low-technology sectors and having divided our yearly observations according to firm age, some interesting differences in the variables' averages across the subgroups can be noticed.

Innovative firms in high-technology sectors tend to hold a relatively higher number of patents than their low-technology counterparts, with the difference in patents endowment between high- and low-technology sectors being relatively larger in the subgroup of older firms. High-technology firms (in particular, older innovative firms) also show larger size than low technology ones. Moreover, innovative firms, on average, tend to exhibit relatively larger intangible assets to total assets ratios.

With respect to corporate governance variables, cross-group heterogeneity becomes more difficult to disentangle. First, debt to equity ratios of both innovative and non-innovative firms tend to be relatively larger for young firms in low-technology sectors than for young firms in high-technology sectors, while, in the case of older firms, debt-to-equity ratios across technology groups show a relatively small difference. On average, the lowest debt-to-equity ratios can be observed among old high-technology firms. Second, the relatively largest share of listed firms can be observed in the subgroup of innovative young firms in the high-technology cluster, while being listed is less frequent among non-innovative firms (in particular, in low-technology sectors). Third, high ownership concentration rates are relatively common for innovative firms, with higher values for young firms. Young firms also show relatively higher percentages of family owners; family owners, more specifically, tend to dominate among non-innovative firms. Industrial companies, at the opposite, tend to be the dominant shareholders in innovative firms, with the exception of the low-technology young firms subgroup. Fourth, and finally, Italian nationality largely characterizes firm ownership in all the groups, with higher rates among non-innovative low-technology firms. Variables' averages within groups are collected in Tables 3 and 4.

3 A firm's age is defined as the number of years since the firm's incorporation date.

Table 3. Descriptive statistics of firm-level variables: young firms (age ≤ 15 years)

Variable	Low-technology sectors		High-technology sectors	
	Innovative firms (0.34% of the low-tech young firms sample)	Non-innovative firms (99.66% of the low-tech young firms sample)	Innovative firms (1.37% of the high-tech young firms sample)	Non-innovativefirms (98.63% of the high-tech young firms sample)
Total_patents (mean [std.dev.])	2.48 [3.18]	0.00 [0.00]	3.34 [4.17]	0.00 [0.00]
Intangibles (mean [std.dev.])	0.21 [0.24]	0.15 [0.21]	0.30 [0.27]	0.21 [0.25]
Firm_age (mean [std.dev.])	8.51 [4.36]	7.50 [4.34]	7.92 [4.37]	7.85 [4.30]
Firm_size (mean [std.dev.])	142.98 [290.50]	24.31 [91.47]	163.90 [523.54]	43.53 [362.99]
Listed (%)	0.79	0.01	1.35	0.14
Profitability (mean [std.dev.])	0.15 [2.35]	0.32 [22.69]	0.02 [0.06]	0.42 [46.34]
Revenues (mean [std.dev.])	300.52 [400.33]	260.46 [418.62]	270.11 [204.88]	281.67 [574.83]
Debt_to_equity (mean [std.dev.])	4.05 [27.12]	3.09 [14.82]	1.78 [4.27]	2.65 [12.70]
OC-high (%)	72.11	53.68	72.16	58.04
OC-medium (%)	22.70	37.77	21.62	34.91
OC-low (%)	4.78	5.93	4.59	5.11
RS-family (%)	48.25	75.52	40.06	65.49
RS-bank (%)	2.48	0.77	1.98	1.06
RS-holding (%)	5.47	4.20	7.94	5.58
RS-ind_company (%)	18.78	23.14	46.68	26.70
RS-other (%)	1.49	0.71	3.31	1.15
Italian_RS (%)	85.05	96.69	82.35	90.78

Table 4. Descriptive statistics of firm-level variables: old firms (age > 15 years)

Variable	Low-technology sectors		High-technology sectors	
	Innovative firms (0.62% of the low-tech.young firms sample)	Non-innovative firms (99.38% of the low-tech.young firms sample)	Innovative firms (1.62% of the high-tech.young firms sample)	Non-innovativefirms (98.38% of the high-tech.young firms sample)
Total_patents (mean [std.dev.])	3.86 [5.57]	0.00 [0.00]	5.61 [12.67]	0.00 [0.00]
Intangibles (mean [std.dev.])	0.10 [0.14]	0.08 [0.15]	0.17 [0.20]	0.13 [0.19]
Firm_age (mean [std.dev.])	29.74 [14.63]	28.31 [11.91]	27.17 [11.15]	27.39 [11.36]
Firm_size (mean [std.dev.])	211.44 [487.43]	51.52 [171.57]	257.51 [639.81]	73.75 [238.03]
Listed (%)	1.06	0.10	0.79	0.22
Profitability (mean [std.dev.])	0.01 [0.02]	0.16 [21.47]	0.01 [0.03]	0.07 [8.70]
Revenues (mean [std.dev.])	251.32 [192.05]	262.90 [448.38]	234.43 [135.74]	247.80 [481.74]
Debt_to_equity (mean [std.dev.])	1.40 [2.59]	2.08 [9.39]	1.44 [2.65]	1.89 [10.56]
OC-high (%)	59.18	46.85	62.10	54.62
OC-medium (%)	31.41	39.71	27.57	36.07
OC-low (%)	8.54	9.69	9.52	7.54
RS-family (%)	36.64	63.65	36.02	58.61
RS-bank (%)	1.98	0.95	1.25	0.89
RS-holding(%)	12.5	6.62	14.10	6.56
RS-ind_company (%)	47.15	27.73	47.35	32.66
RS-other (%)	1.70	1.03	1.25	1.26
Italian_RS (%)	91.97	96.04	87.33	89.77

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 (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 the first equation describes the process generating the zeros (i.e. the event $y_{i,t} = 0$ versus $y_{i,t} > 0$) and the 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. Hurdle models differ from traditional zero-inflated models in having a joint probability function for the two model parts. In particular, the hurdle model is based on a mixture of the two binary and count processes' distributions. This implies a single log-likelihood function maximization problem and rules out model identification issues (Cragg, 1971; Mullahy, 1986).[4]

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

$$\begin{cases} \Pr(Y_{i,t} > 0|\mathbf{x}_{i,t}, D_t) = \alpha_0 + \boldsymbol{\alpha}\mathbf{x}_{i,t} + \boldsymbol{\varphi}\mathbf{D}_t + \epsilon_{i,t} \\ \Pr(Y_{i,t} = y_{i,t}|\mathbf{x}_{i,t}, D_t) = \delta_0 + \boldsymbol{\delta}\mathbf{x}_{i,t} + \boldsymbol{\vartheta}\mathbf{D}_t + \eta_{i,t}, \quad y_{it}\geq 1 \end{cases}$$

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), and $\epsilon_{i,t}$ and $\eta_{i,t}$ are the residuals. The vector of regressors $\mathbf{x}_{i,t}$ contains the following variables: *Total_patents*, *Intangibles*, *Firm_size*, *Listed*, *Profitability*, *Revenues*, *Debt_to_equity*, *OC-high*, *OC-medium*, *OC-low*, *RS-family*, *RS-bank*, *RS-holding*, *RS-ind_company*, *RS-other*, *Italian_RS*, and *Sectoral_growth*.[5] *Sectoral_growth*, in particular, is introduced to control for market conditions and specifically to proxy bearish versus bullish markets. Both equations are estimated on the four subpopulations of young and old firms belonging to either low-technology or high-technology sectors separately. Standard errors are heteroskedasticity robust and clustered at a firm level.[6]

It is useful to interpret the logit equation and the negative binomial equation as models of, respectively, extensive and intensive margins of firms' patenting activity. In particular, with logit equation we are able to estimate the effect of corporate observable characteristics on the probability of a firm being innovative rather non-innovative (i.e. the wideness of innovation activity in a population of both innovative and non-innovative firms). With the negative binomial equation, 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, through a hurdle model strategy we are able 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, allowing the two processes (i) and (ii) to be different. Therefore, this strategy also allows a more refined measuring of parameters' magnitudes than single-equation models, which conflate the two processes and provide only average effects.

4 As explained by Cameron and Trivedi (2009) and Hilbe (2010), in a hurdle model, the likelihood function is composed by two parts, functionally independent, that are separately maximized. The first part uses the full sample; the second part uses only the positive count observations. This independence assumption may be viewed as a limitation.

5 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.

6 Notice that *Firm_age*, *Sectoral_growth,* and *Profitability* are included in the model as observed at time *t*, with the aim of measuring their current impact on innovation activity. All the other regressors, instead, are 1-year-lagged in order to circumvent possible reverse causality.

Table 5. Logit-negative binomial hurdle model: basic estimation results

Variable	(1)		(2)		(3)		(4)	
	Young firms (age ≤ 15 years)		Young firms (age ≤ 15 years)		Old firms (age > 15 years)		Old firms (age > 15 years)	
	Low-technology sectors		High-technology sectors		Low-technology sectors		High-technology sectors	
	Dependent variable: *Y*		Dependent variable: *Y*		Dependent variable: *Y*		Dependent variable: *Y*	
	Extensive margin	Intensive margin	Extensive margin	Intensive margin	Extensive margin	Intensive margin	Extensive margin	Intensive margin
Total_patents[a]	0.731	0.020	0.443	0.108	0.388	0.088	0.361	0.019
	(0.193)***	(0.046)	(0.077)***	(0.013)***	(0.077)***	(0.015)***	(0.095)***	(0.005)***
Intangibles[a]	0.633	0.223	0.750	−0.488	0.637	1.451	0.575	0.071
	(0.396)	(0.495)	(0.287)***	(0.452)	(0.383)*	(0.744)**	(0.289)**	(0.547)
Firm_size[a]	0.001	−0.001	0.001	0.001	0.001	−0.000	0.001	0.001
	(0.000)***	(0.000)	(0.000)*	(0.000)***	(0.000)***	(0.000)	(0.000)***	(0.000)*
Profitability	−0.001	10.297	−0.003	−17.291	−0.002	9.226	−0.019	−7.979
	(0.000)	(4.696)**	(0.002)	(1.584)***	(0.004)	(8.576)	(0.015)	(6.715)
Revenues[a]	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)	(0.000)
Sectoral_growth	0.000	−0.000	0.036	0.035	0.001	0.000	0.089	0.106
	(0.000)	(0.000)	(0.026)	(0.031)	(0.000)***	(0.000)	(0.025)***	(0.031)***
Listed[a]	−30.343	−8.051	−1.665	0.045	1.192	0.724	−0.491	1.605
	(35.618)	(0.896)***	(1.650)	(0.239)	(0.743)	(0.588)	(0.928)	(0.359)***
Debt_to_equity[a]	−0.051	0.041	−0.011	−0.052	−0.057	−0.131	−0.004	−0.007
	(0.023)**	(0.055)	(0.013)	(0.012)***	(0.025)**	(0.118)	(0.012)	(0.030)
OC-high[a]	−0.352	8.399	−0.644	−0.402	−0.376	−0.048	−1.006	0.086
	(0.745)	(0.879)***	(0.489)	(0.365)	(0.296)	(0.461)	(0.409)**	(0.311)
OC-medium[a]	0.342	7.435	−0.621	−0.507	−0.079	−0.096	−0.768	−0.196
	(0.778)	(0.998)***	(0.550)	(0.428)	(0.325)	(0.633)	(0.440)*	(0.376)
OC-low[a]	Benchmark	Benchmark	Benchmark	Benchmark	Benchmark	Benchmark	Benchmark	Benchmark
RS-bank[a]	1.596	−0.647	0.711	−2.030	0.935	−33.623	−0.435	1.404
	(0.739)**	(0.566)	(0.766)	(0.304)***	(0.635)	(0.553)***	(1.025)	(0.349)***
RS-holding[a]	0.484	−0.643	0.653	−0.878	0.940	−0.102	0.850	−0.298
	(0.454)	(0.453)	(0.346)*	(0.277)***	(0.244)***	(0.382)	(0.248)***	(0.403)
RS-ind_company[a]	0.667	0.623	0.823	−0.275	0.649	−0.347	0.325	0.029
	(0.269)**	(0.389)	(0.241)***	(0.227)	(0.191)***	(0.308)	(0.217)	(0.273)
RS-other[a]	0.165	−17.905	1.428	0.788	−0.078	−0.576	−14.575	−0.332
	(0.978)	(0.903)***	(0.481)***	(0.383)**	(1.312)	(0.337)*	(0.289)	(0.325)
RS-family[a]	Benchmark	Benchmark	Benchmark	Benchmark	Benchmark	Benchmark	Benchmark	Benchmark
Italian_RS[a]	−0.397	−1.026	−0.006	0.197	0.056	0.189	0.094	−0.163
	(0.382)	(0.466)**	(0.298)	(0.266)	(0.358)	(0.450)	(0.268)	(0.302)
Constant	−4.671	−7.994	−3.304	0.605	−4.976	−0.742	−2.969	−0.203
	(0.896)***	(1.123)***	(0.675)***	(0.660)	(0.580)***	(0.729)	(0.544)***	(0.609)
Estimation	Logit	Negative binomial	Logit	Negative binomial	Logit	Negative binomial	Logit	Negative binomial
Year dummies		Yes		Yes		Yes		Yes
Firm-clustered SE		Yes		Yes		Yes		Yes
Number of observation.		20040		8372		25856		11116
Number of firms		9949		3938		9171		3832
Log pseudo-likelihood		−796.22052		−931.09642		−1508.722		−1414.5604
Wald χ^2 [prob. > χ^2]		237.56 [0.000]		236.72 [0.000]		177.81 [0.000]		6339.31 [0.000]

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

4.3 Results

Estimation results for the four subpopulations of young and old firms in high-technology and low-technology sectors are reported in Table 5. In Table 5, model specifications (1) and (2) show estimation results obtained for young firms in, respectively, low-technology and high-technology sectors, while model specifications (3) and (4) show the estimates for the subgroups of low-technology and high-technology old firms.

As a general remark, it is interesting to note from our estimation results that sectoral differences emerge with respect to corporate governance variables, while the other basic firm characteristics (in particular, patent endowments, intangibles to total assets ratios, size, and revenues) exert virtually similar effects in both high-technology and low-technology environments. This is consistent with the idea that the relationship between corporate governance dimensions and innovation at the firm level is affected by sectoral features (in particular, R&D intensity).

4.3.1 Corporate governance effects

Our research hypotheses concern the role of agency costs and asset specificity in the innovation process, by considering, in particular, the main corporate governance variable to which they are linked, i.e. ownership concentration. We thus first focus on the effects exerted by ownership concentration rates and then we move to analyze the role of the other corporate governance features and control variables.

Estimated ownership concentration effects corroborate our theoretical predictions summarized in *Hypotheses 1*, *2*, *3*, and *4*. We find that *OC-high* and *OC-medium* (*OC-low* being the benchmark dummy) have a positive and statistically significant effect (at a 1% level) in the intensive margin equation of young low-technology firms, no effect for young high-technology firms and old low-technology firms, and a negative and statistically significant effect (between a 5% and a 10% level) in the extensive margin equation of old high-technology firms. This result confirms that, where asset specificity is extremely low (as for young firms in industries characterized by low R&D intensity), agency problems dominate over asset specificity issues and a higher ownership concentration tends to reduce agency costs significantly. The reverse is true for old high-technology firms, in which firm-specific asset development is more intense and firms progressively improve their production technologies on the basis of their own specific business strategies and innovation projects.

The economic significance of the estimated coefficients is non-negligible. The magnitude of the effect of ownership concentration rates on innovation probability can be easily obtained by calculating the odds ratios of the logit regression parameters. We thus observe that, in high-technology sectors, the probability of being innovative for old firms belonging to the low ownership concentration class (i.e. no shareholder controls the firm by more than 25%) is, all else being equal, 2.15 times that of firms with a medium ownership concentration rate (i.e. one or more shareholders control the firm by more than 25% and less than 50% of shares), and 2.73 times that of firms with a high ownership concentration rate (i.e. one or more shareholders control the firm by more than 50% of shares).

Besides the main corporate governance variable on which we focus our analysis, the regression estimates provide interesting findings also concerning the other governance characteristics included in the model.

We find that *Debt_to_equity* has a negative impact (between a 1% and a 5% level of statistical significance) on innovation for young firms both in low and high-technology sectors (specifically, in the extensive and intensive margin equations, respectively) and for old firms in low-technology sectors. Debt-to-equity ratios of high-technology old firms, instead, turn out statistically insignificant both in the logit and in the negative binomial regression. This result indicates that debt financing is unlikely to bind corporate innovation strategies only in established high-technology firms, which tend to exploit debt finance to a lower extent than their low technology and younger counterparts. Indeed, industry debt ratios tend to be low when profitability and business risk are high and when the stock of firm intangibles is large (e.g. Long and Malitz, 1985; Barclay *et al.*, 1995; Barclay and Smith, 1999). On the contrary, for low-technology and younger firms, our estimates suggest that a relatively larger use of debt funds tends to intensify agency costs in a statistically significant way. In particular, a 1-point reduction in the debt-to-equity ratio increases, on average, the probability of being innovative from 5.23% (in the case of young low-technology firms) to 5.86% (in the case of old low technology firms).

RS-holding and *RS-ind_company* show a positive and statistically significant impact (*RS-family* being the benchmark) on the extensive margin equation in both high-technology and low-technology sectors. *RS-bank*, more specifically, is associated to a positive and statistically significant parameter only in the extensive margin equation for young low-technology firms. Interestingly enough, both bank and financial holding ownership have a negative and statistically significant (at a 1% level) effect in the intensive margin equation for young high-technology firms. This may suggest that, while controlling ownership by bank and other financial institutions may help the firm to overcome financial constraints at the earlier stages of business projects' development, and this can explain their positive effect in the extensive margin equations, once a young high-technology firm has become innovative, financial institutions may prefer to divest their interests by selling off their shares in the company, so narrowing the possibility for the firm to have privileged access to debt capital and to carry its R&D projects forward. It is worth pointing out that the negative effect of bank ownership emerges for both young high-technology and old low-technology firms, columns (2) and (3) of Table 5, which are the two groups of firms showing, on average, the highest percentages of banks as dominant shareholders (1.24% and 1.02%, respectively). This is coherent with the idea that, while bank owners may be relatively more effective in monitoring managerial activities, so reducing the possibility of suboptimal use of free cash flows by the management, they may also exert pressure on managers to focus on investment opportunities that are less uncertain and more rewarding in the short term (Ughetto, 2010).

It is also interesting to notice that *Italian_RS* is associated to a statistically insignificant parameter in the extensive margin equation both in the high technology and in the low technology subpopulations of firms. However, it shows a negative impact in the intensive margin equation for young low-technology firms. This result unveils that owners' nationality does not impact on the transition from a non-innovative to innovative status; 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). Rather, young firms in sectors characterized by lower level of R&D intensity seem to be negatively affected by Italian ownership in the ability to increment their innovation output.

Listed, finally, has a negative impact on the intensive margin of innovation in young low-technology firms and a positive impact on the intensive margin for old high-technology firms. This confirms that equity finance is better suited to finance innovation projects when asset specificity issues are relatively more important (as for old high technology companies).

4.3.2 Other firm-level effects

The other main firm-level control regressors exert effects of the same sign in both low and high technology sectors, for both young and old firms.

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 positively impacts on extensive margins in both high and low technology industries (with the exception of young low-technology firms). This shows how 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 in both types of sectors and for both young and old firms, while it has a statistically insignificant effect in the intensive margin equations for low-technology firms. 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 subpopulation of already innovative firms in low technology industries.

Profitability and *Revenues* do not exert statistically relevant effects on extensive margins of innovation in both types of industries. The capabilities of a firm to engage with innovation projects indeed tend to depend on the firm's long-term investment strategies rather than on short-term financial performance. This result is consistent with previous studies finding that innovation strategies of firms in Continental economies tend to be less responsive to cash flow variations than those of their Anglo-Saxon counterparts (Bond *et al.*, 1999; Mulkay *et al.*, 2001). With *Profitability*, in particular, we measure the possible effect of current operational profitability (i.e. an approximation of the level of free cash flow) on innovation, while 1-year-lagged *Revenues* is a proxy of short-term past financial background. It is interesting to note, however, that *Profitability* has a positive effect on intensive margins for low-technology firms and a negative effect on intensive margins for high-technology firms. This latter result is somewhat at odds with previous results indicating cash flow sensitivity of high-tech firms (e.g. Brown and Petersen, 2009), but can be explained by the fact that, while in low-technology firms a company's profitability is probably a good proxy of short-term cash flow available for short-run innovative investments, in high technology sectors, innovation may require longer periods of development and short-term cash flow therefore may be negatively correlated with innovation output.

Finally, *Sectoral_growth* has a positive impact on innovation only for old firms. This finding suggests that relatively older incumbent firms may be positively stimulated by higher rates of sectoral revenues growth and encouraged to overcome technological inertia. For this subgroup of firms, therefore, the bullish market argument can be supported.

4.4 Robustness checks

We checked the robustness of our results with respect to three issues.

4.4.1 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 varies across low technology and high technology 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; 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 $\omega_{i,t} > 1$. Vice versa, 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 estimates, presented in columns (1) and (4) of Table 6 for young firms and in columns (1) and (4) of Table 7 for old firms.

4.4.2 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. 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 low technology and high technology 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 and columns (2) and (5) of Table 7 for young and old firms, respectively.

4.4.3 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

Table 6. Logit-negative binomial hurdle model, estimation results—young firms (age ≤ 15 years): robustness checks

Variable	(1)		(2)		(3)		(4)		(5)		(6)	
	Young firms (age ≤ 15 years)		Young firms (age ≤ 15 years)		Young firms(age ≤ 15 years)		Young firms (age ≤ 15 years)		Young firms (age ≤ 15 years)		Young firms (age ≤ 15 years)	
	Low-technology sectors		Low-technology sectors		Low-technology sectors		High-technology sectors		High technology sectors		High technology sectors	
	Dependent variable: *Y_augmented*		Dependent variable: *Y_weighted*		Dependent variable: *Y*		Dependent variable.: *Y_augmented*		Dependent variable: *Y_weighted*		Dependent variable: *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[a]	0.737 (0.196)***	0.009 (0.028)	0.737 (0.196)***	0.029 (0.047)	0.591 (0.210)***	0.010 (0.048)	0.443 (0.077)***	0.060 (0.009)***	0.445 (0.077)***	0.108 (0.018)***	0.405 (0.063)***	0.094 (0.020)***
Intangibles_to_employees[a]	0.453 (0.395)	0.057 (0.181)	0.453 (0.395)	0.216 (0.557)	0.511 (0.373)	0.218 (0.472)	0.750 (0.287)***	−0.192 (0.118)	0.771 (0.291)***	−0.593 (0.592)	0.767 (0.291)***	−0.228 (0.324)
Firm_size[a]	0.001 (0.000)***	−0.000 (0.000)	0.001 (0.000)***	−0.000 (0.001)	0.001 (0.000)***	−0.000 (0.000)	0.001 (0.000)**	0.001 (0.000)***	0.001 (0.000)**	0.001 (0.000)***	0.001 (0.000)**	0.001 (0.000)*
Profitability	−0.001 (0.000)	3.516 (0.873)***	−0.001 (0.000)	10.798 (5.408)**	−0.000 (0.000)	10.534 (4.061)***	−0.003 (0.002)	−3.472 (1.347)***	−0.003 (0.002)	−26.269 (3.597)**	−0.001 (0.001)	−9.373 (3.566)***
Revenues[a]	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 (0.000)	−0.000 (0.000)	−0.001 (0.000)	−0.000 (0.000)	−0.000 (0.000)	−0.000 (0.000)
Sectoral_growth	0.001 (0.000)	−0.000 (0.000)	0.000 (0.000)	−0.000 (0.000)	0.000 (0.000)	−0.000 (0.000)	0.036 (0.026)	0.020 (0.013)	0.037 (0.026)	0.027 (0.037)	0.012 (0.029)	0.028 (0.045)
Listed[a]	4.276 (0.740)***	−0.133 (0.260)	4.276 (0.740)***	−8.521 (0.906)***	3.975 (0.798)***	−15.241 (0.853)***	−1.665 (1.650)	0.206 (0.106)*	−1.655 (1.646)	−0.032 (0.256)	−1.366 (1.378)	0.277 (0.224)
Debt_to_equity[a]	−0.048 (0.023)**	0.011 (0.021)	−0.048 (0.023)**	0.043 (0.059)	−0.044 (0.020)**	0.033 (0.059)	−0.011 (0.013)	−0.011 (0.005)*	−0.010 (0.013)	−0.061 (0.006)***	−0.016 (0.014)	−0.029 (0.014)*
OC-high[a]	−0.011 (0.652)	0.340 (0.209)*	−0.011 (0.652)	8.587 (0.910)***			−0.644 (0.489)	−0.402 (0.365)	−0.666 (0.490)	−0.518 (0.368)		
OC-medium[a]	0.602 (0.684)	0.028 (0.205)	0.602 (0.684)	7.438 (1.087)***			−0.621 (0.550)	−0.507 (0.428)	−0.621 (0.550)	−0.616 (0.410)		
OC-low[a]	Benchmark	Benchmark	Benchmark	Benchmark			Benchmark	Benchmark	Benchmark	Benchmark		
OC_instrumented[a]					2.637 (2.435)	9.027 (4.037)**					−3.295 (2.410)	3.624 (2.294)
RS–bank[a]	1.463 (0.812)*	−0.168 (0.144)	1.463 (0.812)*	−0.740 (0.584)	1.398 (0.844)*	−0.454 (0.675)	0.711 (0.766)	−0.544 (0.134)***	0.735 (0.769)	−2.249 (0.595)	0.632 (0.758)	−0.775 (0.658)
RS-holding[a]	0.506 (0.455)	−0.143 (0.116)	0.506 (0.455)	−0.713 (0.459)	0.501 (0.415)	−0.739 (0.529)	0.653 (0.346)**	−0.249 (0.107)**	0.681 (0.347)**	−1.044 (0.376)***	0.600 (0.318)*	−0.941 (0.347)**
RS-ind_company[a]	0.684 (0.270)**	0.243 (0.151)	0.684 (0.270)**	0.464 (0.445)	0.757 (0.229)***	0.123 (0.342)	0.823 (0.241)***	−0.021 (0.103)	0.830 (0.245)***	−0.499 (0.233)**	0.819 (0.197)***	−0.241 (0.239)
RS-other[a]	0.189 (0.978)	−0.496 (0.397)	0.189 (0.879)	−14.943 (0.986)***	0.088 (0.980)	−12.922 (0.815)***	1.428 (0.481)***	0.358 (0.202)*	1.445 (0.484)***	0.805 (0.357)**	1.282 (0.472)***	0.647 (0.375)*
RS-family[a]	Benchmark	Benchmark	Benchmark	Benchmark	Benchmark	Benchmark	Benchmark	Benchmark	Benchmark	Benchmark	Benchmark	Benchmark

(continued)

Table 6. (Continued)

Variable	(1)		(2)		(3)		(4)		(5)		(6)	
	Young firms (age ≤ 15 years)		Young firms (age ≤ 15 years)		Young firms(age ≤ 15 years)		Young firms (age ≤ 15 years)		Young firms (age ≤ 15 years)		Young firms (age ≤ 15 years)	
	Low-technology sectors		Low-technology sectors		Low-technology sectors		High-technology sectors		High technology sectors		High technology sectors	
	Dependent variable: *Y_augmented*		Dependent variable: *Y_weighted*		Dependent variable: *Y*		Dependent variable.: *Y_augmented*		Dependent variable: *Y_weighted*		Dependent variable: *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
Italian_RS[a]	−0.432	−0.523	−0.432	−1.143	−0.235	−1.282	−0.006	0.093	−0.025	0.115	0.030	0.139
	(0.383)	(0.301)*	(0.383)	(0.491)**	(0.361)	(0.494)***	(0.298)	(0.120)	(0.300)	(0.290)	(0.278)	(0.244)
Constant	−4.851	5.505	−4.851	−8.036	−11.625	−21.580	−3.304	5.534	−3.294	0.989	4.350	−9.023
	(0.851)***	(0.441)***	(0.851)***	(1.213)***	(5.987)***	(10.169)**	(0.675)***	(0.313)***	(0.679)***	(0.623)	(6.112)	(5.744)
Estimation	Logit	Negative binomial	Logit	Neg.ative binomial	Logit	Negative binomial	Logit	Negative binomial	Logit	Negative binomial	Logit	neg.binomial
Year dummies	Yes		Yes		Yes		Yes		Yes		yes	
Firm-clustered SE	Yes		Yes		Yes		Yes		Yes		yes	
Number of observation	20040		20040		23568		8372		8372		9778	
Number of firms	9949		9949		11014		3938		3938		4306	
Log pseudo-likelihood	−1294.9119		−725.66768		−828.84579		−1802.292		−906.81186		−1103.3071	
Wald χ^2 [prob. > χ^2]	157.35 [0.000]		157.35 [0.000]		156.49 [0.000]		236.72 [0.000]		240.91 [0.000]		209.11 [0.000]	

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

Table 7. Logit-negative binomial hurdle model, estimation results—old firms (age > 15 years): robustness checks

Variable	(1)		(2)		(3)		(4)		(5)		(6)	
	Old firms (age > 15 years)		Old firms (age > 15 years)		Old firms (age > 15 years)		Old firms (age > 15 years)		Old firms (age > 15 years)		Old firms (age > 15 years)	
	Low-technology sectors		Low-technology sectors		Low-technology sectors		High-technology sectors		High-technology sectors		High-technology sectors	
	Dependent variable: *Y_augmented*		Dependent variable: *Y_weighted*		Dependent variable: *Y*		Dependent variable: *Y_augmented*		Dependent variable: *Y_weighted*		Dependent variable: *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[a]	0.388	0.088	0.390	0.083	0.403	0.080	0.361	0.012	0.364	0.021	0.403	0.028
	(0.077)***	(0.015)***	(0.077)***	(0.014)***	(0.071)***	(0.014)***	(0.095)***	(0.004)***	(0.095)***	(0.006)***	(0.089)***	(0.014)**
Intangibles_to_employees[a]	0.637	1.451	0.692	1.211	0.480	1.436	0.575	−0.013	0.535	−0.002	0.562	−0.126
	(0.381)*	(0.733)*	(0.000)***	(0.002)	(0.368)	(0.613)**	(0.289)**	(0.224)	(0.296)**	(0.582)	(0.276)**	(0.621)
Firm_size[a]	0.001	−0.000	0.001	−0.000	0.001	−0.000	0.001	0.000	0.001	0.001	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)
Profitability	−0.002	9.226	−0.002	7.343	−0.003	9.115	−0.019	−1.766	−0.018	−7.380	−0.028	−10.334
	(0.004)	(8.576)	(0.004)	(8.448)	(0.004)	(7.931)	(0.015)	(1.225)	(0.015)	(6.694)	(0.015)*	(5.644)*
Revenues[a]	−0.000	0.000	−0.000	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)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
Sectoral_growth	0.001	0.000	0.001	0.000	0.001	0.000	0.089	0.051	0.090	0.105	0.084	0.129
	(0.000)***	(0.000)	(0.000)***	(0.000)	(0.000)***	(0.000)	(0.025)***	(0.051)***	(0.025)***	(0.031)***	(0.021)***	(0.037)***
Listed[a]	1.192	0.724	1.222	0.626	1.174	0.685	−0.491	0.963	−0.469	1.572	−0.674	2.075
	(0.743)	(0.588)	(0.737)*	(0.579)	(0.775)	(0.480)	(0.928)	(0.149)***	(0.923)	(0.362)**	(0.936)	(0.423)***
Debt_to_equity[a]	−−0.057	−0.131	−0.058	−0.107	−0.047	−0.166	−0.004	−0.003	−0.004	−0.010	−0.007	−0.020
	(0.025)**	(0.118)	(0.026)**	(0.098)	(0.021)**	(0.084)**	(0.012)	(0.011)	(0.011)	(0.031)	(0.013)	(0.033)
OC-high[a]	−0.376	−0.048	−0.384	−0.052			−1.006	0.054	−1.028	−0.014		
	(0.296)	(0.461)	(0.296)	(0.458)			(0.409)**	(0.112)	(0.411)**	(0.314)		
OC-medium[a]	−0.079	−0.096	−0.109	−0.189			−0.768	−0.077	−0.764	−0.322		
	(0.325)	(0.633)	(0.327)	(0.647)			(0.440)*	(0.135)	(0.440)*	(0.392)		
OC-low[a]	Benchmark	Benchmark	Benchmark	Benchmark			Benchmark	Benchmark	Benchmark	Benchmark		
OC_instrumented[a]					2.043	−0.127					−0.792	3.604
					(1.575)	(3.467)					(0.218)*	(2.600)
RS-bank[a]	0.953	−33.623	0.974	−34.877	0.657	−14.087	−0.435	0.937	−0.429	1.401	−0.468	1.271
	(0.635)	(0.553)***	(0.636)	(32.670)	(0.728)	(0.634)***	(1.026)	(0.249)***	(1.020)	(.359)***	(1.009)	(0.472)
RS-holding[a]	0.940	−0.102	0.918	−0.149	0.897	−0.035	0.850	−0.086	0.822	−0.383	0.927	−0.173
	(0.244)***	(0.382)	(0.248)***	(0.386)	(0.229)***	(0.326)	(0.248)***	(0.136)	(0.251)***	(0.429)	(0.233)***	(0.484)
RS-ind_company[a]	0.649	−0.347	0.650	−0.371	0.789	−0.280	0.325	0.033	0.300	−0.068	0.541	0.174
	(0.191)***	(0.308)	(0.193)***	(0.319)	(0.229)***	(0.262)	(0.217)	(0.109)	(0.218)	(0.284)	(0.184)***	(0.286)
RS-other[a]	−0.078	−0.576	−0.054	−0.584	0.151	−0.317	−13.105	0.172	−14.064	0.444	−0.145	−14.350
	(1.312)	(0.337)*	(1.319)	(0.323)*	(1.181)	(0.266)	(0.289)***	(0.311)	(0.292)***	(0.582)	(0.698)	(4.582)***
RS-family[a]	Benchmark	Benchmark	Benchmark	Benchmark	Benchmark	Benchmark	Benchmark	Benchmark	Benchmark	Benchmark	Benchmark	Benchmark

(continued)

Table 7. (Continued)

Variable	(1)		(2)		(3)		(4)		(5)		(6)	
	Old firms (age > 15 years)		Old firms (age > 15 years)		Old firms (age > 15 years)		Old firms (age > 15 years)		Old firms (age > 15 years)		Old firms (age > 15 years)	
	Low-technology sectors		Low-technology sectors		Low-technology sectors		High-technology sectors		High-technology sectors		High-technology sectors	
	Dependent variable: *Y_augmented*		Dependent variable: *Y_weighted*		Dependent variable: *Y*		Dependent variable: *Y_augmented*		Dependent variable: *Y_weighted*		Dependent variable: *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
Italian_RS[a]	0.056	0.189	0.123	0.163	0.260	0.211	0.094	−0.034	0.099	−0.240	0.172	−0.202
	(0.358)	(0.450)	(0.374)	(0.455)	(0.349)	(0.343)	(0.268)	(0.145)	(0.275)	(0.315)	(0.234)	(0.334)
Constant	−4.976	−0.742	−5.030	−0.491	−10.509	−0.165	−2.969	5.399	−2.932	−0.025	−3.078	−10.356
	(0.580)***	(0.729)	(0.592)***	(0.724)	(3.851)***	(8.555)	(0.544)***	(0.233)***	(0.550)***	(0.633)	(5.580)	(6.729)
Estimation	Logit	Negative binomial	Logit	Negative binomial	Logit	Negative binomial	Logit	Negative binomial	Logit	Negative binomial	logit	negative binomial
Year dummies	yes		yes		yes		yes		Yes		Yes	
Firm-clustered SE	yes		yes		yes		yes		Yes		Yes	
Number of observation	25856		25856		29656		11116		11116		12664	
Number of firms	9171		9171		9676		3832		3832		4012	
Log pseudo-likelihood	−1508.722		−1487.0219		−1761.627		−2777.6044		−1394.4166		−1618.5981	
Wald χ^2 [prob. > χ^2]	177.81 [0.000]		175.41 [0.000]		188.20 [0.000]		5177.34 [0.000]		5908.44 [0.000]		153.84 [0.000]	

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

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 any event, we check the robustness of our baseline estimates in a two-stage instrumental variable regression. 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 the degree of share's 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 recode 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 two-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 and columns (3) and (6) of Table 7 for young and old firms, respectively.

The results of the robustness checks confirm the statistical validity of our main findings. In particular, higher ownership concentration rates have a positive and statistically significant effect on innovation for young low-technology firms and a negative effect for old firms in high technology industries. When the ownership concentration indicator is instrumented, these results remain virtually unchanged. Moreover, similar to our baseline results, the estimated parameter of *Debt_to_equity* has a negative impact on innovation activity of young firms in both low technology and high technology sectors and of old firms in low technology sectors, while it has no effect for old firms in high technology sectors, in all the model specifications considered in Tables 6 and 7.[7]

5. Summary and conclusions

This article has found that the statistical significance and sign of the relationship between corporate governance variables and innovation vary according to the relative extent of asset specificity and agency costs involved by firms' activities, as predicted by firms' age and sector of activity. More specifically, it has shown that the effects of a firm's ownership are coherent with the theoretical predictions of the shareholder theory and of the stakeholder theory, respectively, according to whether agency cost effects dominate over asset specificity effects, and vice versa. The article thus allows to address an empirical puzzle concerning the correlation between ownership concentration and innovation, whose sign has not been so far unambiguously established, as there are studies identifying both a positive and a negative relationship.

From a policy perspective, 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. Moreover, we confirm that innovation policies should be also graduated in relation to firm age, an approach that appears ever more widespread among governments.

A joint reading of the evidence this article provides on ownership concentration and financial structure may offer some insights on how these general policy conclusions may be articulated. Our empirical investigation shows that concentrated ownership exerts negative effects on established firms' innovation propensity in high-tech sectors and that debt has a negative impact on the firm's propensity to become innovative for the majority of the firms in our data set besides established high-technology firms.

The combination of these two findings suggests that, while initiatives that increase the convenience of equity financing are generally to be welcomed, the type of initiative that is likely to be most effective may change according to the type of firm considered. In this regard, it is worth recalling that the stock of equity in a firm's balance sheet may increase because of an increase in retained earnings or because of new equity issues. In the first case, the degree

7 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.

of ownership concentration does not vary. New equity issues, by contrast, may determine a change in ownership structure, possibly in terms of a dilution of existing concentration. In light of this, our findings suggest, first, that policy initiatives aiming at encouraging the reinvestment of the corporation's profits may be effective across the board and may be particularly suited to stimulate innovation for young firms in low-tech sectors, for which a high degree of ownership concentration appears to have a positive effect on innovativeness and public listing on the stock market appears to have detrimental effects. Examples of these policies include the provision of a reduced tax rate for (young) firms conditional on earnings being retained for a specified period of time and other measures having the effect of raising the dividend tax and lowering the capital gain tax. Second, the empirical evidence we provide indicates that established high-tech firms may be able to take the largest advantage from policies that favor an increase in equity funding while also promoting more dispersed ownership structures. Examples of these are initiatives encouraging new equity issues as well as support to venture capital funding.[8]

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8 One such measure has been introduced in Italy at the end of 2011. It is a form of "Allowance for corporate equity—ACE" consisting in the deductibility of the returns on new equity from the income tax and meant to redress the tendency of the corporate tax system to discriminate in favor of debt financing by allowing the deduction of interest.

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