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Green patents in the manufacturing sector: the influence of businesses' resources and capabilities[1]

Patentes verdes en el sector manufacturero: el impacto de los recursos y las capacidades de las empresas


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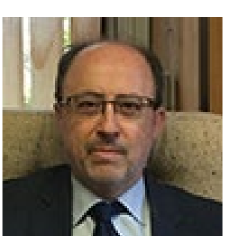
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1. INTRODUCTION

It is generally accepted that long-term business competitiveness must walk a line between productivity and a resource consumption model which maximises efficiency—that is, 'doing more with less'. In fact, the increasing importance of environmental issues in the economic decision-making processes is often articulated through strategies that aim to achieve equilibrium between economic and environmental efficiency (Valero-Gil et al., 2017).

Eco-innovation contributes to the achievement of environmental objectives, generating competitive advantages (Porter and Van der Linde, 1995) and ultimately improving the financial performance of companies that practise eco-innovation. Therefore, eco-innovation—where 'innovation' is applied in a broad sense, as defined by the Oslo Manual (OECD, 2005)— can be described as the process of developing new ideas, modes of conduct, products, and processes that help reduce burdens or attain environmental objectives (Rennings, 2000).

Based on the theoretical framework of the Resource-Based View (hereafter RBV) previous studies have pointed to certain economic financial factors — such as financial resources, access to capital (Cruz-Cázares et al., 2013; Halila and Rundquist, 2011; Paraschiv et al., 2012), and the size of firms (Leitner et al., 2010) — as drivers or antecedents of eco-innovation. However, the measurement of

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EXECUTIVE SUMMARY

This paper, which is of interest to practitioners, will analyse companies in the manufacturing sector that hold Spanish and European environmental patents, linking the registered green patents with the economic and financial characteristics of the companies. Specifically, the relationship between green patents and the collaboration of companies with research and development (R&D) centres is analysed. The results of surveying an ad-hoc database comprising 1606 Spanish companies indicate that the ways in which the companies collaborate with R&D organisations can shed light on green patent holdings in the Spanish manufacturing companies. Moreover, the authors find that financial performance, age, and size are all significant factors in the development of green patents.

RESUMEN DEL ARTÍCULO

Este artículo proporciona a los profesionales un análisis de empresas con patentes verdes del sector manufacturero, relacionando las características económico-financieras de las empresas con el número de sus patentes verdes nacionales y Europeas. En particular se analiza la relación entre la colaboración con centros de I+D y la posesión de patentes verdes. Los resultados, obtenido a través de una base de datos ad hoc de 1606 empresas españolas, indican que la capacidad colaborativa para la investigación y el desarrollo (I+D) proporciona una útil explicación de la tenencia de patentes verdes en las empresas manufactureras españolas. Además, la performance financiera de las empresas, su antigüedad y tamaño, se consideran relevantes para el desarrollo de patentes verdes.

resources and the company's potential for eco-innovation are topics that require further research (Lee and Min, 2015).

Collaborative activities with research institutes and universities should be considered in analyses of the eco-innovation process (Horbach, 2016). In general, the development of eco-innovation is accompanied by major investment efforts which take place within an environment of high-level uncertainty; therefore, the inherent risk in innovation activities tends to be mitigated through co-operation with research and development (R&D) centres (Scarpellini et al., 2012).

In this paper, green patents are considered an indicator of environmental innovation and R&D; we undertook the objective selection of companies that have played an active role in the environmental sustainability of production. In general terms, the measurement of resources and capabilities for eco-innovation and the analysis of green patents are areas which must be addressed within the framework of the RBV (Lee and Min, 2015). As such, the main purpose of this paper is to contribute to our understanding of how the economic and financial characteristics of companies influence the acquisition of green patents. Additionally, the relationship between companies' collaboration with R&D centres and green patent holdings is also analysed.

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The sample under analysis is drawn from the Spanish manufacturing sector. At present, Spain remains labelled as only 'moderately innovative' within the framework of the EU (European Commission, 2016). The study of the issue of eco-innovation benefits from two different economic perspectives: environmental and innovation economics (Rennings, 2000). For this reason, eco-innovative solutions have been implemented in a larger number of Spanish firms during the past decade (Scarpellini et al., 2016). Many authors have taken note of Spain, where companies' abilities to innovate depend not only on the exploitation of their internal resources but also, and to an increasing degree, on their abilities to apply information from other R&D organisations, such as universities and other research institutes (Barge-Gil and López, 2014). Collaboration with R&D centres is particularly critical to outcomes in the manufacturing industry, which absorbs technological knowledge from external sources to carry out eco-innovative activities (Scarpellini et al., 2012).

In this context, those companies where more favourable conditions are present for the development of green patents, owing to their sectoral and regional circumstances, constitute interesting analytical cases regarding the characteristics of the resources and capabilities that allow a company to exploit registered innovations and improve their environmental performance.

The remainder of the paper is divided into five sections. The ensuing section presents a review of existing scholarship and outlines the research lines of enquire for green patent holdings. Subsequently, the sample, methodology, and variables used in the analyses are described. In the fourth section, the main results are summarised and conclusions are presented in the fifth section.

KEY WORDS
Green patents; RBV; R&D collaboration; manufacturing; eco-innovation.

PALABRAS CLAVE
Patentes verdes; Recursos y Capacidades; I+D colaborativo; Sector manufacturero; Eco-innovación.

2. GREEN PATENTS AND THE MANUFACTURING SECTOR

Based on a review of scholarship in the field, we can assert that firms' resources and capabilities are relevant to the success of investment in eco-innovation (Díaz-García et al., 2015) and in green patents (Aragon-Correa and Leyva-de la Hiz, 2016).

The RBV is particularly useful because it helps to explain why some companies function better than others through the analysis of internal resources and capabilities as sources of sustainable competitive advantage (Kraaijenbrink et al., 2010). Certain authors have analysed the organisational resources that firms use for strategic innovation (Keupp et al., 2012). Financial resources and access to capital, and the availability of public funds for the environmental improvement of a firm, have been also analysed (Cruz-Cázares et al., 2013; Halila and Rundquist, 2011; Paraschiv et al., 2012), as have the firms' sizes, since size is often considered important for innovation (Leitner et al., 2010).

Environmental R&D investment and internal R&D activity facilitate eco-innovation in business (Lee and Min, 2015), and have both been linked to patent registration and ongoing innovation activity (Aragon-Correa and Leyva-de la Hiz, 2016; Doran and Ryan, 2012; Peiró-Signes et al., 2011).

However, the resources and capabilities that enable the creation of value and competitive advantage continue to be subject to debate, particularly with regard to the role green patents play in eco-innovative processes (Aragon-Correa and Leyva-de la Hiz, 2016).

Companies with eco-innovative profiles do not differ from one another in terms of their main operational objectives and priorities, but manufacturing companies may be connected to greater eco-innovative orientation in comparison to companies in other sectors (Peiró-Signes et al., 2011).

The manufacturing sector analysed within this theoretical framework constitutes a suitable platform for the implementation of green solutions because its environmental impact is more visible and direct than that of other sectors (Przychodzen and Przychodzen, 2015).

The environmental impact of the manufacturing companies, and their major technological developments, results in the exposure of businesses to greater pressure, both from the stakeholders' perspective (Henriques and Sharma, 2005) and from a regulatory perspective. Environmental regulation, as well as increasing consumer awareness of the environment and its possible impact on the financial performance of companies, has contributed to the introduction of such changes. For example, the significant impact of chemical industries on the environment and health has promoted innovation and the development of more sustainable technologies. Furthermore, the automotive industry, which is subject to significant production costs and is very sensitive to changes in demand for more efficient vehicles, is a significant driver of environmental innovation. In recent years, another manufacturing sector—the iron and steel industry—has achieved important innovations that are focused on environmental improvement by saving energy and reducing CO_2 emissions (Machiba, 2010).

2.1. The role of the R&D collaboration centres

In addition to the sector's relevance to the green patents development process, other factors, such as the ability of companies to develop R&D in collaboration with research institutes and universities, should be considered (Horbach, 2016). The creation of collaborative networks and increased co-operation between organisations have emerged as two determinant factors in promoting the dissemination of eco-innovation (Tessitore et al., 2010). More directly, concerning the protection of innovation through industrial property rights, empirical studies have demonstrated how industry-university co-operation can be linked to an increase in the number of recorded patents and that the participation of several companies in a consortium supported by a university is also positively connected to the number of generated patents (Schwartz et al., 2012).

The number of patents has been used to measure the results of R&D activity and knowledge transfer (Hall and Ziedonis, 2001; van Dongen et al., 2014).

Spain is not unique in this regard. Patenting continues to be one of the most frequently employed policy instruments for the promotion of innovation and the development of new technologies. Moreover, within the Spanish industrial sector, companies must incorporate technology and technological knowledge from external sources in order to compete both nationally and internationally in eco-innovation (Scarpellini et al., 2012). Thus, we suggest that the positive effects of collaboration between research organisations and such companies also extend to green patents. The following line of inquire can therefore be proposed: “The more R&D centres that collaborate with a given Spanish manufacturing company, the more likely it is that, *ceteris paribus*, that green patents will be awarded”.

3. GREEN PATENTS ANALYSIS

For this study, an ad-hoc database comprising a sample of 1606 companies located in the Spanish regions of Catalonia, Navarre, or the Basque Country was developed. These regions were chosen for their interesting trajectories with regard to innovation and eco-innovation (OECD, 2015),[3] within the framework of a research collaborative project carried out in these regions.[4] The records of national and European green patents and the economic-financial data of the companies have been analysed in relation to the companies’ resources and capabilities (as applied to the green-innovation process) in order to test the proposed line of inquire.

For the purposes of this analysis, the data have been taken from two sources of information: the SABI database for the year 2014 and the Spanish and European Patent Trademark Offices[5]. The number of patents is one of the variables used in the elaboration of the European ranking, and is, in fact, regularly used as a parameter of innovation in business. As such, green patent holdings can be considered an indicator of eco-innovation as carried out by private companies (Aragon-Correa and Leyva-de la Hiz, 2016; Segarra-Oña et al., 2014). The classification of the patents as green, a matter which is still under review in scholarship, is accepted in our research as corresponding to the codes listed by the United Nations Framework Convention on Climate Change (UNFCCC)[6].

In the empirical phase of the study, a logistic regression model was developed to prove the effect of R&D collaboration on obtaining green patents (GP). In addition to the variables of R&D centres (RD), different economic and financial variables previously tested in other studies were also applied (Scarpellini et al., 2016). Therefore, the contrast model states, as a dependent variable, that 'the existence of patents related to environmental technologies, or green patents (Eco-innovation)' is a dichotomous variable which takes a value of 1 when the firm has a green patent and of 0 when the firm does not have a green patent. The model exhibits the following form:

Green Patents (GP) = f (R&D centres, financial performance, size, age, foreign activities, location),

where

- Green Patent (GP), is a dichotomous variable that takes the value of 1 if the firm has green patent and of 0 otherwise. An objective method of measuring the eco-innovation variable may be examining the existence of patents taken out by the company — more specifically, patents that are environmental in nature (Teirlinck and Spithoven, 2013). Just as patents can exert an influence over innovative behaviour (Segarra-Ona et al., 2014), patents with an environmental content can exert an influence over eco-innovative behaviour. Along these lines, several works, such as those by Wagner (2007), Johnstone et al. (2010) and Marin (2014) use patent data to analyse environmental innovation.
- R&D centres variable (RD) is measured by the number of R&D centres collaborating with the company. The relevance of the collaborative framework to R&D development has been analysed fully in the previous section. The close collaboration between the industries and the companies and different R&D centres and other intermediate agents in the eco-innovation process is of great strategic importance (Kobayashi et al., 2011; Scarpellini et al., 2016) , and has been measured through this specific variable.
- Financial performance variable (R) is quantified based on the return on equity (ROE), which is calculated as the ratio between the net income and common equity. Financial performance as a causal relation of innovative behaviour is measured through financial return (Mortazavi Ravari et al., 2016; Przychodzen and Przychodzen, 2015). Economic results positively affect

an enterprise's environmental responsiveness (Potocan et al., 2016). In line with Waddock and Graves (1997), better financial performance provides more freedom to invest in more socially responsible projects, such as innovation initiatives in products and environmentally favourable processes. In a revision of previous studies (Mortazavi Ravari et al., 2016) highlighted the return on investment as an assessment criterion for technological innovation capabilities.

- Size variable (S) is measured by the natural logarithm of the number of workers. The firms' potential access to R&D grows when greater access to resources gained, and thus small firms are disadvantaged when it comes to green innovations. Size may thus be regarded as a structural factor (Díaz-García et al., 2015; González-Benito et al., 2016). Small firms, therefore, face more obstacles when incorporating green concerns into their economic practices, and have more difficulty gaining competitive advantages, and, it follows, find it harder to profit from environmentally friendly investments (Revell and Rutherfoord, 2003). Despite this, there is evidence that some small firms have promoted green initiatives (Revell and Rutherfoord, 2003).
- Age variable (A) is the number of years since the date of incorporation of the company, as of 31 December 2014. The firm's age may be the factor that tilts the balance in favour of innovation, especially environmental innovation. Older firms have more public exposure, and their corporate image is more vulnerable to reputational risk, which makes them more likely to engage in eco-innovation (Jensen and Roy, 2008). Conversely, young firms may be more inclined to innovate as they have a greater ability to offer solutions to new challenges (Díaz-García et al., 2015; Jensen and Roy, 2008).
- For foreign activities (FA), three dummy variables have been included in order to study the relationship between green patent holdings and the openness of the company.
- Location variable (L) corresponds to two dummy variables which have been included in the model to examine the relationship between green patent holdings and the company's location.

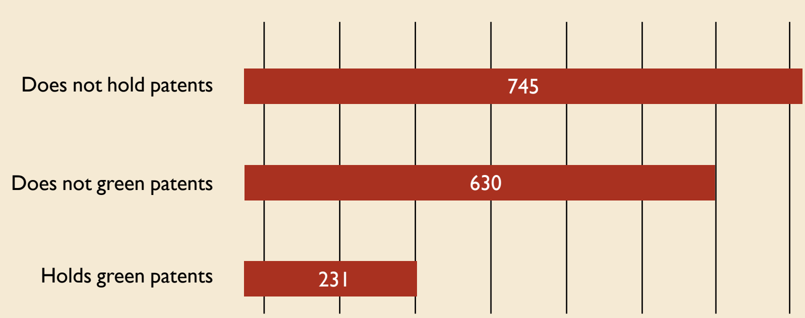
The variables: financial performance (R), size (S) and age (A), are included as control variables in the logistic regression analysis. Moreover, other variables, such as foreign activities and location, are also included as control variables. For the reasons explained above, and considering the results of previous studies, we expect R, S and A variables to have a positive impact on the probability of obtaining green patents.

4. THE INFLUENCE OF BUSINESSES' RESOURCES AND CAPABILITIES FOR GREEN PATENTS

Having combined the different data sources mentioned in the previous section, we obtained a final sample comprising 1606 observations. Most of the companies in the sample are unlisted, are engaged in activities abroad ('import/export'), and have their headquarters in Catalonia. The firms in the sample have assets worth, on average, €62.6 million. Their average turnover is €67.4 million, and the average number of employees is 146.

Figure 1 illustrates that of the 1606 companies in the sample, those with green patents (231 companies) make up 14.4%, compared to 1375 companies without green patents, which account for the remaining 85.6%. In contrast, of the 861 companies that own some kind of patent, 231 (26.8%) have green patents whereas the remaining 630 companies (73.2%) do not.

Figure 1. **Companies holding patents and green patents**



An analysis has been carried out on the number of green patents and the proportion of green patents to total patents. **Table 1** summarises the results. Sample companies that own green patents (231 companies) have on average 357 patents and 14 green patents.

Additionally, we conducted an analysis comparing top and bottom, i.e. companies with both high and low proportions of green patents in

Table 1. **Number of Patents and Green Patents**

	MEAN	STD. DEV.	MINIMUM	MAXIMUM
Number of patents	357	905.54	1	7410
Number of green patents	14	43.40	1	355
Proportion of green patents to total patents	0.08	0.11	0	1

total. We generated two groups of companies: those with a proportion of green patents higher than the mean of 8% (67 companies) and those with a lower proportion (164). We used ANOVA analysis to compare the two groups of generated companies, the mean values of the variables of R&D centres (RD), financial performance (R), size (S) and company age (A). With the exception of the size variable (S), the differences noted in the mean values between companies of both groups are not statistically significant in the ANOVA test. That is, among the companies with higher proportions of green patents, the average value of the size variable (4.86) is lower than that of companies with a higher proportion of green patents (5.45).

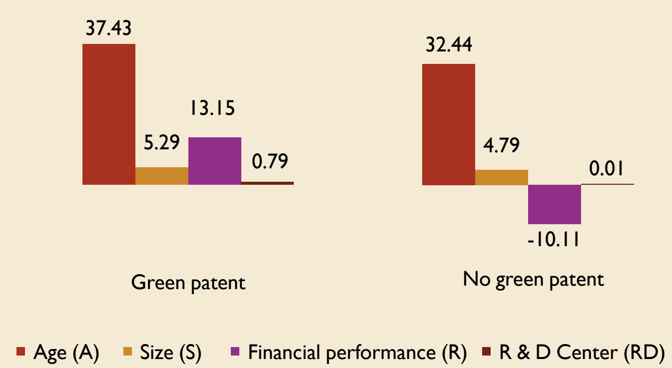
On the basis of these results, we analysed the factors that characterised those companies with green patents, compared to those without. A preliminary analysis was conducted to determine the relationships between pairs of the following variables: listing on stock exchange, foreign activities, location of companies, and the eco-innovation variable (GP). To this end, we applied the Pearson $\chi 2$ test to the contingency tables. Regarding foreign activity, the results indicate that at a significance level of 99% ($\chi 2=12.76$ $p=0.005$), importing companies (18.67%) have a greater share in green patents compared to import and export companies (14.35%), export-only companies (12.32%), and those that do not perform activities abroad (4.32%).

The results also indicate that 16.29% of the companies in the Catalonia region have green patents, compared to slightly lower proportions of companies in Navarre (11.64%) and the Basque Country (10.40%). Therefore, we may conclude that the proportion of firms with green patents varies according to companies' locations and whether or not they are engaged in foreign activities.

Moreover, we used ANOVA to study the relationship between the eco-innovation variable (GP) and the following variables: R&D centres

(RD), financial performance (R), size (S) and age (A). **Figure 2** summarises the mean values of these variables: RD, R, S, and A for each of the two groups that define the eco-innovation-dependent variable. The two groups are those firms that have green patents and those that do not. Of the firms with green patents, the mean value of each independent variable is greater than that for firms without such patents. For all variables, significant differences were observed at 1% (for RD, F=66.34 sig=0.000; for S, F=113.85 sig=0.000 and for A, F=12.61 sig=0.000), and 5% levels for R (F=2.94 sig=0.032), relative to its value in both groups of companies.

Figure 2. **Mean values of the variables for the groups that define the green patents**



4.1. R&D collaboration and Green Patents

A binomial logit model was used to analyse the determinants of eco-innovation and, specifically, to respond to the question of whether collaboration with the R&D centres has positive effects on the acquisition of green patents by manufacturing companies.

Table 2 summarises the description of the variables in the logit model. The Pearson correlations (**Table 3**) for each pair of variables indicate weak or moderate associations in most cases, with values ranging between 0.04 and 0.26. Therefore, the inclusion of these variables is justified in order to explain the green patent possession.

Table 2. **Description of the final variables of the regression analysis**

	MEAN	D.T.	MINIMUM	MAXIMUM	OBSERVATIONS
R&D centres (RD)	0.12	1.39	0	47	1606
Financial performance (R)	-6.78	220.17	-5502.09	1306.81	1601
Size (S)	4.78	0.77	3.91	9.35	1605
Age (A)	33.15	19.84	0.20	115.66	1606
Green Patents (GP)	Dichotomous dependent variable 1/0		0	1	1606

Table 3. **Pearson correlations in the green patent holdings model**

	GP	AGE (A)	SIZE (S)	FINANCIAL PERF. (R)	R&D CENTRES (RD)
GP	1				
Age (A)	0.088**	1			
Size (S)	0.257**	0,157**	1		
Financial Perf. (R)	0.037*	-0.007	-0.001	1	
R&D Centres (RD)	0.199**	0.071**	0.111**	0.006	1

* $p<0.05$ ** $p<0.01$

The estimated results of the logit model are summarised in **Table 4** (see **Appendix**). Two analyses were carried out—one on the whole sample (1606 companies) and another on the companies holding patents (816). Similar results were obtained in both analyses. The line of inquire is expressed by the coefficient of the R&D centres variable (RD). As expected, the results are positive and significant, indicating that collaboration with R&D centres leads to the acquisition of green patents. Moreover, the findings in this model are consistent with predictions regarding the relationship between economic-financial characteristics and eco-innovation in firms. The results demonstrate that the decision to register green patents is related to the size and age of the firm. On the other hand, the analysed data also demonstrates that better financial performance has a positive effect on the decision to register green patents. The remaining positive and significant coefficients indicate that engagement in foreign activities is related to the decision to register, or not to register, green patents for the protection of environmental innovations.

5. CONCLUSION

The main objective of this study has been achieved through a quantitative analysis of a sample of 1606 manufacturing companies located in Spain.

The analysis of both the main economic and financial resources of the companies and their R&D collaborative behaviour for green patents reveals that collaboration between firms and R&D centres working towards the development of green patents is significant and leads to a shared custody of these patents, which clearly demonstrates the efficiency of the process. Moreover, although companies have very different resources at their disposal, we suggest that resources such as age, size, and financial performance are key to attaining the crucial abilities necessary to develop green patents within an RBV theoretical framework.

Specific empirical evidence for eco-innovative firms is provided in this paper, in order to confirm the use of green patents as an indicator of eco-innovation for the decision-making processes in companies that have undertaken an active role in eco-innovation. These criteria may also be applied by practitioners: this would mean greater flexibility in the environmental management but would require more detailed knowledge of each instance of investment in environmental R&D.

This study highlights some of the relevant resources and capabilities of eco-innovative manufacturing firms. As such, it will be useful for future studies on the subject and for practitioners making decisions on investments in environmental R&D and its protection through industrial property in the form of green patents, as well as those practitioners seeking external sources of knowledge. First, our findings directly translate into practices which are the main determinants of green patents, and our findings provide information on how to strengthen these determinants in collaborative R&D activity in this field. Secondly, this study addresses the gap between academics and practitioners by examining the determinants of green patents within the conceptual framework of the resource-based view: the main results can be applied by managers to define and measure the specific firms' resources for application to the eco-innovative processes.

This study will be useful for future research, given the unprecedented number of companies analysed and the wide range of variables, in terms of the number of years analysed and the number of green patents recorded. However, the limitations of the obtained results must be noted, in relation to the size of the sample and its regional profile. Our empirical analysis is limited to Spain and therefore may not be representative of other countries with different cultures of innovation. Therefore, further comparative studies are recommended.

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NOTES

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3. See Eco-Innovation Observatory: www.eco-innovation.eu/ (accessed May 2017).
4. For more information about the project, please see the Acknowledgements section.
5. Iberian Balances Analysis System (SABI) [online database], 2014. Madrid.
6. For more information, see: http://www.wipo.int/classifications/ipc/en/est/index.html (accessed May 2017).

Appendix

Table 4. **Results of logistic regression.**

	COEFFICIENT	MARGINAL EFFECT	COEFFICIENT	MARGINAL EFFECT
R&D centres (RD)	1.911 ***	0.217***	1.397 ***	0.296***
Financial Performance (R)	0.002 **	0.001 **	0.002 **	0.001 **
Size (S)	0.794***	0.090***	0.549***	0.116***
Age (A)	0.007**	0.001**	-0.002	-0.001
Importer	0.944 **	0.144 **	0.789	0.185
Exporter	0.450	0.057	0.245	0.053
Importer/Exporter	0.516**	0.055	0.157	0.328
Basque Country	0.187	0.022	-0.018	-0.004
Catalonia	0.553	0.059	0.376	0.078
Nagelkerke R^2	21.63%		18.38%	
Likelihood ratio Test	206.25		111.3	
Hosmer-Lemeshow Test	p=0.51		p=0.96	
Predicted capacity	87.69%		75.34%	
Sensitivity	16.23%		18.42%	
Specificity	99.56%		97.44%	
Model	Sample companies		Companies holding patents	

Note: Marginal effects are computed at sample means. Sensitivity: % of observations correctly predicted as 1; specificity: % of observations correctly predicted as 0.
, * indicate parameter significance at the 10, 5, and 1% level, respectively.