Patented Inventions in Mechanical Small and Medium Enterprises

Does Quality Influence Performances?

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Abstract

In the era of the knowledge economy, intangible assets become more important than physical ones for a firm to succeed, but they need to be managed, not only accumulated, in order to be effectively used. One possible way of doing this is protecting them through intellectual property rights (IPRs) which refers mainly to patents if we consider technology firms pursuing innovation. Since on the one had patents are costly to maintain and on the other hand small and medium enterprises (SMEs) are considered important innovators whose rate of patent filing has increased significantly in the last years, we will focus our analysis on SMEs. In particular, this paper aims at investigating the impact of patents, considering also different aspects related to their quality, on SMEs performance. The analysis will be carried out using a fixed-effect cross-sectional time-series regression model over a period of nine years, from 2002 to 2010.

Introduction

In today's knowledge economy, intangible assets become more important than physical ones for a firm to succeed (Chen and Chang, 2010). However, the accumulation of intangible assets is not sufficient for increased R&D performance (Knott *et al*., 2003) and differences in R&D performance are the result of effective management of the available resources (Del Canto and Gonzalez, 1999). One of the activities related to the management of intangible assets includes the protection of a firm's new knowledge from imitation by using formal rights known as intellectual property rights (IPRs) which include industrial designs, trade secrets, patents and trademarks. They grant firms temporary private monopoly rights over their innovations, in this way preventing imitation by rivals during the period of their temporary monopoly (Ernst, 1995). Despite small and medium enterprises (SMEs) are often regarded as important innovators in the economy, SMEs are often viewed as being disadvantaged in their ability to apply for and use patents (Jensen and Webster, 2006) despite the literature presents evidence of the increasing use of IPRs, in general, (Hanel, 2006; Greenhalgh*et al.*, 2001) and of patents, in particular, by SMEs (Hughes and Mina, 2010). Italian SMEs also appear to show a similar trend, with patenting activity increasing from 2002 to 2011.[1]

The impact of patents on SMEs performance, including the impact of their quality, deserves further investigation because this issue has not been addressed in great detail, as some authors recently recognised (i.e. Mendonca*et al.*, 2004; Rogers *et al.*, 2007). The use of a set of quality-indicators to make patent data more representative of innovation is beginning

[1]Our elaboration from EPO data: http://www.epo.org/about-us/statistics.html.

to gain acceptance (Ejermo, 2009), because the economic value of patents is skewed (Scherer and Harhoff, 2000), and only a small percentage of patents are truly valuable. The present analysis aims to test the influence not only of the number of patents but also of patent quality on SMEs performance in the mechanical industry.

Section 2 presents an analysis of the literature on the impact of patents and patent quality on SMEs performance and concludes with the hypotheses. Section 3 describes the methodology, and section 4 discusses the results and presents the conclusions and suggestions for further research.

Literature review and hypothesis

A *patent* is an exclusive right given by law to inventors to make use of and exploit their inventions for a limited period. Data related to patents are often used to proxy innovative ideas (i.e. Griliches, 1990; Lanjouw and Schankerman, 2004) and, as a consequence, to test the impact of the innovation and patents on firm performance. The literature on this topic is diverse and presents conflicting results. Some studies found that patents do not have any impact on firm performance when measured in terms of the return on assets (ROA), sales growth and market value (i.e. Griliches*et al.*, 1991; Kretschmer and Soetendorp, 2001) or that they are negatively associated with performance (Artz*et al.*, 2010). Instead, other papers found a positive and significant relationship between patents and firm performance (i.e. Teece, 1998; Ernst, 1995, 2001;Hall *et al.*, 2005; Chen and Chang, 2010).

Previous articles (i.e. Thwaites, 1982; O'Mahony, 1998) mainly focused on the manufacturing industry as a whole, while other authors concentrated their analyses on certain industries and countries with the aim of testing industry- and country-specificity. Concerning the mechanical sector, Ernst (2001) found evidence of increased sales with a time lag of two to three years after the patent priority year in the German machine tool industry.

To the best of our knowledge, few empirical studies have specifically investigated the impact of patenting activities on SMEs performance (see Greenhalgh and Rogers, 2007). In the pharmaceutical industry, Demirel and Mazzucato (2012) found a positive relationship between R&D productivity and firm growth only for small pharmaceutical firms. Furthermore, most of the studies on this topic (i.e. Del Monte and Papagni, 2003; Rogers *et al.*, 2007) were not industry specific and employed different innovation proxies (i.e. R&D on sales, propensity to innovation, product innovation). Based on these considerations, we formulated the first hypothesis.

H1: The number of patented inventions is not associated with SMEs performance in the mechanical industry.

A patented invention refers to a patent family comprising all patents (patented in more than one country) protecting the same invention disclosed by a common inventor (OECD, 2009).

The number of patents has often been used as an indicator of R&D output and innovation, but it cannot take into account the entire and precise R&D capabilities of companies (Chen and Chang, 2010) and it does not always measure the value of innovation accurately (Bloom and van Reenen, 2002). For this reason, aspects related to patent quality should be taken into account to better investigate the relationship between patents and firm performance.

In his broad analysis of the literature about patent quality, van Zeebroeck (2011) described the five most classical indicators of patent quality: forward citation counts, grant outcomes, scope, renewals and opposition incidences. Van Zeebroeck and van

Pottelsberge(2011) added another variable, the number of inventors, to indicate the research effort made to design the invention.

Some studies have employed these indicators of patent quality to shed light on the relationship between the patenting activity of firms and their performance and to determine whether owing high-quality patents could positively influence firm performance. In these studies, scholars selected one of two approaches to measure patent quality: separate indicators or a composite index.

Using the first approach, Lerner (1994) reported a positive and sizable correlation between the average scope of firms' patents, measured in terms of the number of IPCs, and the market value of the firms. Ernst (2001) found that patent filings at the EPO had a positive impact on the firms' sales, and Hall*et al.* (2005) showed that citation-weighted patent stocks are more highly correlated with market value than patent stocks themselves and that this is mainly due to the high valuation placed on firms that hold very highly cited patents.

Using the second approach, Lanjouw and Schankerman (2001) found a positive correlation between the patent quality index, comprising the number of claims, forward and backward citations and the size of the patent families, and firm value. Drawing on the ability of patent quality to be approximated with sufficient reliability by combining different indicators, Chen and Chang (2010) tested the influence of the quality of patents on the market value of firms in the U.S. pharmaceutical industry employing four complementary patent-quality indicators derived from previous studies:their results indicate that the relative patent position of a company in its most important technological field and patent citations of a company are positively associated with its market value, while theHerfindahl–Hirschman Index of the company's patents, as well as the revealed technology advantageof a company in its most important technological field, are negatively associated with its market value (Chen and Chang, 2010).

The number of papers is quite limited, and they mainly focus on large U.S. firms and the market value is the most common dependent variable. To the best of our knowledge, no study has specifically considered SMEs belonging to a specific manufacturing industry.

Based on the general evidence that most studies that correlated patent quality with market value or sales of firms find a positive relationship between these two constructs, we formulated the second hypothesis.

H2: High-quality patented inventions are positively associated with SMEs performance in the mechanical industry.

Research design and data collection

We identified a panel data set of 217 Italian SMEs operating in the Venice-Padua mechanical district, in the North-Eastern region of Italy, which has a leading position in the manufacturing industry, and patenting activity in the sector has shown an increasing trend during the last years.[2]

In this study, SMEs performance, the dependent variable, was proxied by firm sales, similarly to several previous works (i.e. Ernst, 2001; Bloom and van Reenen, 2002). The sample mainly comprises small firms (turnover less than 10 million euros) and a few medium-sized companies (turnover between 10 and 50 million euros).

In the first step of our study, we used the yearly number of patent families as the independent variable to count the number of patented inventions generated from the innovation activities, in accordance with previous studies (i.e. Harhoff *et al.*, 1999; Belderbos*et al.*, 2010). To best reflect the time of origin of the invention, we used the earliest priority year as the reference date.

[2]Our elaboration from EPO data: http://www.epo.org/about-us/statistics.html.

In the second step of our analyses, we employed different single indicators of patent quality as independent variables in our regressions: the presence of at least one EPO patent filing among the members of the family ('EPO Filing'), the number of received citations ('Fwd. Cit.'), the number of family members ('Fam. Memb.') and the number of inventors ('Inventors'). Information on claims, renewals and IPC codes were missing for many Italian patent documents. Furthermore, there was no information on the number of oppositions and litigation cases.

Our use of lagged variables is based on the assumption that the moment of first priority filing for a new invention is coincident with the start of its actual implementation and the corresponding product development (when worthy). However, the final commercialisation of the products that exploit the new invention requires a longer time (Ernst, 2001). Previous literature suggests that a lag of up to four years can be assumed in the mechanical industry (i.e.Griliches*et al.*, 1991; Ernst, 2001).

We also controlled for firm size, as suggested by most empirical studies on firm performance and innovation (i.e. Chang *et al.*, 2012; Lin and Chen, 2005). We determined SMEs size based on the firms' total assets. As the raw data are skewed, we log transformed all the variables.

The dataset was built by matching different data sources: patent data were drawn from Thomson Innovation, and economic information was collected from AIDA.

Data analysis and findings

In line with previous studies, we propose an approach that uses cross-sectional time series regression to investigate the relationship between patents and SMEs performance proxied by sales which is the dependent variable in our panel data. A fixed-effect model[3] was used to remove all between-firm variance and thus control for any time-invariant unobserved heterogeneity among the firms (Ernst, 2001; Chang *et al.*, 2012).

The following panel models were employed to estimate the impacts on the performance of the firm:

(1) $\text{Sales}_{i,t} = \beta_0 + \beta_1 (\text{Number of patented inventions}_{t-\tau}) + \beta_2 (\text{Assets of firm}_{i,t}) + \text{Error term}$

(2) $\text{Sales}_{i,t} = \beta_0 + \beta_1 (\text{Indicator of patent quality}_{i,t-\tau}) + \beta_2 (\text{Count of patented inventions}_{t-\tau}) + \beta_3 (\text{Assets of firm}_{i,t}) + \text{Error term}$

where i= 1,2…,N is the company identifier, t = 1,2…, T is the number of time periods, β_0 is the intercept and β_j is the regression coefficient. Each of the equations (eq. 1 and eq. 2) corresponds to six models, with the different lags between the performance of the firm and the patenting activities defined as τ = 0,1,…4.

Table I contains the correlation coefficients related to the variables included in the model. Among the independent variables, 'EPO Filing', 'Fwd. Cit.' and 'Fam. Memb.' report correlation levels, while the 'Inventors' variable does not. The first three variables are associated with patent quality expressed in terms of its value, whereas the fourth variable is linked to patent quality as determined by the complexity of the invention (van Zeebroeck and van Pottelsberghe de la Potterie, 2011).

[3]All our analyses were carried out using Stata 11.2 software for statistical data analysis. We tested the assumption in each regression model by performing the Hausman Test,which is used to decide between a fixed or a random effect.

Table 1. Correlation matrix for the independent variables used in the empirical analyses

	Variable	**1**	**2**	**3**	**4**	**5**	**6**
1	No. inventions	1.000					
2	EPO Filing	-0.007	1.000				
3	Fwd. Cit.	-0.058	0.560*	1.000			
4	Fam. Memb.	-0.100	0.620*	0.531*	1.000		
5	Inventors	0.069	0.065	0.048	-0.036	1.000	
6	Assets	0.242*	0.333*	0.144*	0.121	0.073	1.000

*Level of significance < 0.05

For these reasons, they were included in the regression models one at a time, following the first of the two approaches we identified in the analysis of the literature.
Table II reports the results of the tests on the impact of the number of patented inventions on sales by controlling for the assets of the company. H1, which predicts no impact of patents on SMEs performance, was supported for sales without any difference related to the time lag. The control variable, total assets, which is a proxy for the size of the firm, was positively related to firm performance.

Table 2. Panel data regression results. Test of the impact of the number of patented inventions on sales when first priority filings are in the same year or in each of the previous five years. The number of observations is not always the same due to missing data

VARIABLES	**(1) Model**	**(2) Model**	**(3) Model**	**(4) Model**	**(5) Model**	**(6) Model**
No. inventions	0.022					
	(0.033)					
No. inventions [t-1]		0.029				
		(0.032)				
No. inventions [t-2]			-0.003			
			(0.032)			
No. inventions [t-3]				0.021		
				(0.032)		
No. inventions [t-4]					0.023	
					(0.033)	
No. inventions [t-5]						0.025
						(0.035)
Assets	0.640***	0.640***	0.640***	0.639***	0.639***	0.583***
	(0.020)	(0.020)	(0.020)	(0.020)	(0.020)	(0.023)
Constant	3.182***	3.187***	3.188***	3.192***	3.191***	3.667***
	(0.170)	(0.170)	(0.170)	(0.170)	(0.170)	(0.196)
Observations	1,795	1,795	1,795	1,795	1,789	1,591
R^2	0.389	0.389	0.389	0.389	0.388	0.314
adj R^2	0.312	0.312	0.312	0.312	0.311	0.214

Standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.10

As discussed in the previous section, the second hypothesis further investigated the relationship between the quality of the patented inventions and SMEs performance by including a set of variables in our econometric models that are proxies of patent quality, instead of using only the number of patented inventions. Each equation tested the impact of the independent variables, the number of patented inventions and one of the four proxies of patent quality on SMEs performance (‘EPO Filing’, ‘Fwd. Cit.’, ‘Fam. Memb.’ and

‘Inventors’ respectively), controlling for firm size. Moreover, the four models were replicated with different time lags between SMEs performance and the independent variables, from no lag to four years’ lag. The results of the regression were significant only when considering a lag of four years (see Table III). The coefficients of the proxies of quality were all positively correlated with SMEs performance when the number of inventions was included and the size of the firm was taken into account. Thus, H2 was confirmed, but only with a specific time lag between patents and SMEs performance.

Table 3. Panel data regression results. Test of the impact of the quality of the patented inventions, proxied by four different variables, on sales (including the number of patented inventions and controlling for firm size); 4 years lag

VARIABLES	**(1) Model**	**(2) Model**	**(3) Model**	**(4) Model**
EPO Filing [t-4]	0.123**			
	(0.052)			
Fwd. Cit. [t-4]		0.056**		
		(0.027)		
Fam. Memb. [t-4]			0.047**	
			(0.023)	
Inventors [t-4]				0.171**
				(0.086)
No. inventions [t-4]	-0.042	-0.018	0.001	-0.034
	(0.098)	(0.098)	(0.098)	(0.098)
Assets	0.655***	0.655***	0.662***	0.626***
	(0.061)	(0.061)	(0.062)	(0.061)
Constant	3.260***	3.259***	3.165***	3.531***
	(0.556)	(0.560)	(0.569)	(0.559)
Observations	201	201	201	201
R^2	0.502	0.497	0.496	0.495
adj R^2	0.156	0.147	0.145	0.144

Standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.10

Discussion and conclusion

The aim of this paper was to investigate the impact of innovation, proxied by patented inventions, on SMEs performance. To do this, we used a fixed-effect, cross-sectional time-series regression model on a panel dataset of Italian SMEs in the period ranging from 2002 to 2010. In addition to controlling for the count of patented invention, we introduced patent quality indicators because the number of patents cannot accurately describe the R&D capabilities of companies (Chen and Chang, 2010). Moreover, it has been proven that the economic value of patents is skewed (Scherer and Harhoff, 2000). Therefore, only a small percentage of patents is truly valuable. Using quality indicators associated with patents improves the accuracy of the measure of innovation and provides a more complete and reliable picture of the innovative activity of a firm.

The results show that if we proxy innovation using only the number of patented inventions, it seems not to have any impact on SMEs performance. However, if we use

quality indicators related to ‘EPO Filing’, ‘Fwd. Cit.’, ‘Fam. Memb.’ and ‘Inventors’ to obtain more precise information on the examined patented inventions, innovation then has an impact on the subsequent SMEs performance, with a time lag of four years. This could be explained by delayed introduction of higher quality technological innovations to the market caused, for example, by technological complexity, administrative circumstances or greater initial market resistance (Ernst, 2001).

Our results show also that for SMEs, there is a positive relationship between patent quality and firm performance. This is in accordance with the findings of previous studies which considered mainly large pharmaceutical firms (Lerner, 1994; Chen and Chang, 2010). However, the analyses on the different time lags reveal some interesting findings since the number of inventions are not correlated with performance while their quality is significantly and positively correlated.

Our results are not completely in accordance with those of Ernst (2001) who focused on the German machine tool industry between 1984 and 1992, but we need to take into account that different times, geographical areas and sizes of firms have been considered. That study reported that the number of national patent applications has a positive influence on subsequent sales increases, with a time lag of two to three years after the year of priority and that EPO applications have a lag of three years.

In contrast, our analyses show that the number of patented inventions has no influence on subsequent sales, regardless of the time lag, and that the presence of a European patent application has a positive impact on subsequent sales with a time lag of four years and that such a lag is confirmed by all the quality indicators applied in our analysis. A possible explanation is that the SMEs in our sample are less skilled in making effective use of the patent system, thus demanding protection also for lower quality inventions, which have no impact on firm performance, as has been suggested in some studies (i.e. MacDonald, 2004). However, higher quality innovations protected through patents appear to have a positive effect on sales with a four years’ lag, which is longer than that suggested in previous literature (Griliches*et al.*, 1991; Ernst, 2001) that focused more on medium and large companies. The results suggest that SMEs generally require a longer time to exploit a valuable invention, consistently with their financial and production capabilities.

Furthermore, the first part of our findings, referring to the impact of the number of patented inventions on SMEs performance, could be explained by considering the work of Griliches (1990) who asserted that a patent is often taken out for reasons other than directly benefitting a firm economically, for instance, to block competition. De Rassenfosse (2010) recently expanded on this idea, stating that a large majority of SMEs file patents to protect against imitation by competitors. He further stated that while SMEs in the U.S. license a high share of their patent portfolio, European SMEs face much greater difficulties in respect to patent registration and patent portfolio protection, suggesting inefficiencies in the European market for technology. MacDonald (2004) concluded that there is no foundation for the idea that patents have a positive effect on the performance of SMEs. However, this conclusion might not apply, *ceteris paribus.* Our analysis shows that if SMEs own quality patents, which cover a valuable innovation, such patents can enhance their performance.

These results have useful implications both for empirical studies using patent data and for management practice. In relation to empirical studies, this study confirms that patent quality indicators could provide a more complete picture of the relevant innovative activity of a firm. Thus, we agree with Ejermo (2009) who stated that systematic empirical study using patent data as a proxy for innovation should make some adjustments for patent quality. Moreover, there is little in the literature on the relationship between patents and SMEs performance.

In relation to management implications, as patenting is costly, and SMEs face resource constraints, they should have a policy on patents to take account of situations where there is an important innovation. Otherwise, they risk having to pay for a large patent portfolio without reaping any reward in terms of economic performance. Having a policy in place on patenting will enable SMEs to benefit from patenting, even if this requires them having to pay much more attention to the type of patents they file. Filing a smaller number of patents for particularly valuable innovations could be more productive in terms of the performance of the firm. From this perspective, SMEs might benefit from initiatives aimed at improving the company's awareness of IP in terms of the quality of the patent, the evaluation of the technology and the management of the IP.[4]

This study is one of the first attempts to shed light on the relationship between IPRs and the performance of SMEs considering quality indicators. Our paper has some limitations which could be addressed in future studies.

First, our study sample focused only on Italian SMEs. This could be extended to include SMEs from other regions/countries. Second, we examined only the situation in the mechanical industry. It would be useful to determine whether our findings are generalizable to other industries, with a single industry considered each time to provide focus and to reduce error variance. Third, not all possible quality indicators were collected, for example, the number of claims or the related opposition cases, because these data were unavailable for our sample. Lastly, a qualitative approach could be used to discover whether any other variables influence the relationship between innovation, proxied by patent data, and SMEs performance.

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[4]By way of example, in recent years, the European Commission haslaunched several projects to help SMEs to improve their knowledge and management of IP rights (based on the document COM, 2008). A detailed list is available on the official website of the Directorate General 'Enterprise and Industry': (http://ec.europa.eu/enterprise/policies/innovation/policy/intellectual-property/index_en.htm).

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