Working Paper # 2014/12

COMPLEMENTARITY OF INTELLECTUAL CAPITAL AND R&D ACTIVITIES IN THE INNOVATION PROCESS: FIRM-LEVEL LONGITUDINAL ANALYSIS OF SPANISH MANUFACTURES

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UAM-Accenture Working Papers

ISSN: 2172-8143

Edited by: UAM-Accenture Chair on the Economics and Management of Innovation, Autonomous University of Madrid, Faculty of Economics

Editado por: Cátedra UAM-Accenture en Economía y Gestión de la Innovación

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Complementarity of intellectual capital and R&D activities in the innovation process: firm-level longitudinal analysis of Spanish manufactures

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Keywords: Intellectual capital, R&D activities, complementarity, innovation

Abstract

Most analysis of intellectual capital try to identify the role of variables related to the stock or flow of intangible assets in explaining innovation output. The problem of these models is that innovation output is usually measured as innovation performance (e.g. profits from innovation), which is the result not only of *choice* but also of *success*. In order to analyse the role of intellectual capital in the innovation process avoiding this problem, we assume that R&D activities and other intellectual capital variables such as human. structural and relational capital are all inputs of the same production plan, and analyse their complementarity within the innovation process. In this sense, the study of innovation process might focus on an input variable (i.e. R&D), reflecting an active attitude towards the attainment of innovations, and not merely success. In this paper, we start with the conventional analysis of investment in R&D to obtain the relation between R&D activities and intellectual capital as complementary movements to efficient production plans. Findings are consistent with the hypothesis that intellectual capital can be regarded complementary to R&D activities in innovation process.

Theoretical framework

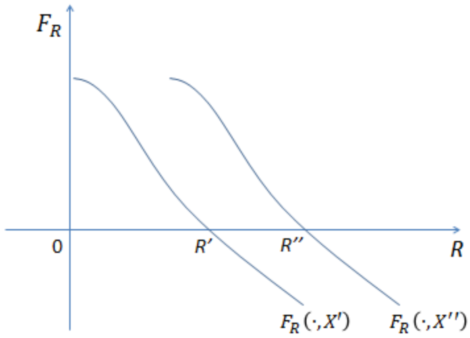
It is well known the basic approach to R&D investment from a micro-level perspective (Howe and McFetridge, 1976; David, Hall and Toole, 2000). The starting point is the assumption that the firm sorts the existing R&D projects hierarchically according to their expected returns, in order to start investing in those considered more profitable. The marginal profit of R&D activities for might be represented as a function involving marginal returns (MR) and marginal costs (MC), as presented in the following system of equation (1):

$$F(R,\boldsymbol{X},\boldsymbol{Z}) = MR(R,\boldsymbol{X}) - MC(R,\boldsymbol{Z}) \qquad (1)$$

where R is a scalar measure of R&D projects –as it is usual in conventional analysis, each project is implicitly taken as being finely divisible for expositional convenience-. The vectors **X** and **Z** capture other factors that might impact on the results of R&D activities, such as technological opportunities, state of demand, institutional factors, technology policy, conditions and expectations impacting on internal and external cost of funds, and other conditions affecting R&D performance (see David, Hall and Toole, 2000).

A competitive equilibrium requires that $F(R, \boldsymbol{X}, \boldsymbol{Z}) = 0$. Given this theoretical background, the "shift factors", **X** and **Z**, are assumed to displace de marginal profit function. Figure 1 shows this case, assuming that $F: \mathbb{R}^2 \to \mathbb{R}$. A shift in the use of input *X* from *X'* to *X''* generates new incentives to invest in R&D. The result is an increase of R&D activities of *R''*-*R'*.

Figure 1. *The effect of "shift factors" in the marginal profit*



If we assume that output of R&D activities is a function with strictly decreasing returns of scale for each input, and a maximizing profit behavior, then we can interpret the relation between R&D activities and other inputs as a function[1]:

$$R = R(\boldsymbol{X}, \boldsymbol{Z}) \quad (2)$$

Even though our aim is to analyze the relevance of certain inputs of the innovation process, from equation (2) it can be seen that our analysis include an input as dependent variable, i.e. R&D activities, rather than output variables, such as innovation performance (which is a typical choice in specialized literature). As it has been pointed out by Arqué-Castells (2013), the advantage of using input variables is that they differ from output variables in the sense that they reflect an active attitude towards the attainment of innovations, and are not directly mixed with demand conditions for innovation as is the case of variables such as "sales". Equation (2) unambiguously relates (at least theoretically) R&D activities with the rest of inputs, because these relations come from the fact that they are all part of the same production plan, and not because an unclear causal link with success.

Specialized literature usually uses a linear function case for equation (2) to establish the relation between R&D and other relevant factors (taking observed values, or its logarithmic transformation), generally using regression or panel data analysis.

[1] By the implicit function theorem, we have that $R = R(\boldsymbol{X}, \boldsymbol{Z})$ will exists if $\partial F(R, \boldsymbol{X}, \boldsymbol{Y})/\partial R \neq 0$. It is easy to show that decreasing returns of scale guarantee that $\partial F(R, \boldsymbol{X}, \boldsymbol{Y})/\partial R < 0$, since $\partial MR(R, \boldsymbol{X})/\partial R < 0$, and $\partial MC(R, \boldsymbol{Y})/\partial R > 0$. It would be possible to obtain the relation between R and the other input variables using this theorem, but as far as we know there are no reasonable assumptions surrounding the sign of $\partial F(R, \boldsymbol{X}, \boldsymbol{Y})/\partial X_i$ for (as there is with $\partial F(R, \boldsymbol{X}, \boldsymbol{Y})/\partial R < 0$, assuming decreasing returns). These are exactly the relations estimated by the model proposed in this paper.

Now, let us return to the question of the "shift variables" that we should consider to explain the engagement in R&D activities. Probably, the most studied one is public funding for R&D, and previous studies have shown a positive correlation between public R&D contracts and grants, and private R&D investment. Intellectual property rights (e.g., patents, trademarks, etc.) is also a typical control variable, since it is expected that it affects the appropriability of R&D outcomes, encouraging R&D activities. Other relevant variables in the literature are the size of the firm, sales, sector of activity, market concentration (usually measured by Herfindahl index), activities in international markets, other expenses for innovative activities, etc. Taking into account the specialized literature on management, we are interested in expanding this set of variables by including factors related with the stock and management of intellectual capital.

Intellectual capital and R&D activities

The concept of intellectual capital or intangible assets is relatively new in the economic literature, and if refers to those non-physical assets with three core characteristics: they are a source of probable future economic benefits, have no physical embodiment and, to some extent, may be retained and managed by companies (OCDE, 2011:16).

Although at some point the concept of intangible asset has been primarily related to R&D and intellectual property rights (such as patents and trademarks), the extension of innovative activities to other areas beyond the purely technological ones has expanded the concept. Nowadays it is widely accepted that intellectual capital consists of three elements: human capital, structural capital and relational capital (Cañibano et al., 2002).

Specialized literature has highlighted the effect on innovation performance of *human capital* (Marvel and Lumpkin, 2007; De Winne and Sels, 2010); *structural capital* –especially the case of managerial flexibility, and organizational learning capacity (Huchzermeier and Loch, 2001; Levardy and Browning, 2009) –; and *relational capital* –particularly networks for innovation (Reagans and Zuckerman, 2001; Czarnitzki and Ebersberger, 2007; Cuervo and Asakawa, 2010).

We propose to analyse the effects of intellectual capital inputs on innovation process, through its relation with the degree of engagement of the agent with R&D activities. In the case of human capital, we consider the qualification of employees and the existence of training activities. Intellectual property rights and *managerial flexibility* (Bamel, et al., 2013) are our variables for structural capital. Finally, the existence of a formal network of external partners will indicate, in our work, the presence of relational capital management.

Data and methodology

To test for the relation of intellectual capital and R&D activities, we use panel data, from the Spanish Community Innovation Survey Information, of 1852 manufacturing firms for the period 2003 to 2011. Because the goal is to analyse complementary between intellectual capital and R&D, the firms of the sample are those who declare R&D activities in at least one year in 2003-2011.

As is conventional in specialized literature, we use a linear specification for Equation (2). The focus of the test is the relevance of the set of parameters related to intellectual capital, since this will suggest the existence of a complementary path between intellectual capital and R&D activities in the innovation process.

Results

The main findings of this analysis are consistent with the hypothesis that intellectual capital variables are related with R&D activities (Table 1). Both variables of human capital (PhD employees, and training) are significant. These results might imply a positive relation between qualification of labor and absorption capacities. Between these two variables, having PhD employees showed a more intense relation with R&D.

In the case of structural capital, intellectual property rights are positively related with R&D, consistently with preceding empirical evidence. Managerial flexibility, measured by the introduction of innovation in management or new commercial techniques, showed also a high relation with R&D activities.

Table 1

Random-effects tobit regression
Sample: 1852 firms from industrial sector; years 2003, 2005, 2008-2011. (N=11112)
Dependent variable: Investment in R&D activities (log.)

Explanatory variables	***Coef.***	***t-stat.***
Control variables		
Const.	5.365	3.5
Size (log.)	0.345	4.5
Sales per employee (log.)	0.048	0.5
Market concentration	-0.294	-2.2
International market	1.675	7.0
Public grants for R&D (log.)	0.186	16.5
Contracts for R&D with public sector (log.)	0.041	1.7
Other expenses for innovation activities (log.)	0.154	16.0
High-tech technology sector	2.622	7.1
Medium-high technology sector	1.716	6.5
Low technology sector	0.424	1.4
Time-effects for 2005	-3.286	-12.4
Time-effects for 2008	-3.481	-13.4
Time-effects for 2009	-3.846	-14.6
Time-effects for 2010	-4.150	-15.7
Time-effects for 2011	-4.288	-16.2
Intellectual capital variables		
PhD employees	2.456	14.5
Training	0.367	2.7
Intellectual prop. rights (patents, trademarks, etc.)	1.291	10.6
Innovations in management and procedures	1.246	11.1
New commercial techniques for product positioning	0.525	1.7
Vertical collaboration	0.651	4.6
Horizontal collaboration	0.619	3.1
Collaboration with private research organizations	0.085	0.5
Collaboration with public research organizations	0.546	3.9
Likelihood-ratio (χ^2)	2379.4	
Prob > χ^2	0.0000	

Finally, regarding relational capital, the collaboration with clients and suppliers (vertical), with competitors or firms of the same sector of activity (horizontal), and with public research centers, exhibit a significant relation with R&D as well.

With the exception of the variable “Sales per employee”, all control variables of the model behave as expected. First, we can see that R&D spending is a matter of size. Consistently with previous literature, the relation between R&D and market concentration (measured by Herfindhal index) is negative and significant. Participation in international markets also has a high correlation with the dependent variable. As expected, public grants and contracts for R&D, and other innovation expenditure (such as external R&D, equipment and software, external knowledge, etc.) are directly related with internal R&D expenditure. Perhaps, the only “surprise” is that productivity (measured by the ratio of sales per employee) showed no significant correlation in the model.

Discussion

The aim of this research is to show the relevance of intellectual capital management on innovation process. A very simple (conventional) framework analysis is used to study this relevance not on innovation performance, but on the level of engagement of the agent with R&D activities. Although the use of this framework in the context of intellectual capital studies is relatively new, it has received several criticisms in other contexts (such as innovation studies). Clearly, the research agenda is to test this relation with more complex models that allow defining trajectories of our relevant variables, to test possible interactions.

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