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On the R&D giants' shoulders: Do FDI help to stand on them?

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Abstract

The paper investigates the extent to which outward FDI affect the MNC's capacity of entering (and remaining in) the club of top R&D world investors, benefiting from performance gains in both financial and economic markets. By merging the European Industrial Research and Innovation Scoreboard with the fDi Markets dataset, we find supporting evidence. Increasing the number of FDI projects helps firms overcome the discontinuities that, in the distribution of R&D expenditures, separate the group of the largest world R&D investors from the top of them. The same is true for the number of FDI projects in R&D, which are also more important than greater FDI portfolios in becoming a top R&D spender. Furthermore, unlike FDI in general, more FDI in R&D guarantee firms to remain in this top club of firms as it increases their capacity of resisting competition for a place among the top R&D spenders. Results at the extensive margin (i.e. the number of FDI projects) are confirmed with respect to the scale of FDI projects (i.e. at the intensive margin). However, increasing their size is not enough to become one of the highest ranking R&D firms. Policy implications about the support to R&D internationalisation are drawn accordingly.

Keywords: Foreign Direct Investments (FDI), Multinational Corporations (MNC), Research & Development (R&D).

JEL codes: O32, F23, O33

Disclaimer

1 Introduction

In the current global scenario, populated by MNC operating in an array of markets and technologies, innovation performance depends largely on the capacity to source knowledge internationally. FDI, mainly but not only in R&D, are crucial in this respect. They allow firms to enter into global value chains, interact with foreign labs and companies, become embedded in the scientific and engineering community of the host country, and thus tap into its set of knowledge and competencies (Maskell et al., 2007).

FDI with the objective of "knowledge seeking" or "technology seeking" (Cantwell, 1989) have been receiving increasing attention in the growing literature on the internationalisation of R&D.[1] Significant work has been done related to the impact of FDI on the firm's innovative and economic performance (e.g. Subramaniam and Venkatraman, 2001; Penner-Hahn and Shaver, 2005). However, less attention has been paid to the effect of FDI on the competition for global technological leadership, in which MNC try to outperform their rivals also in their actual R&D investments.[2]

Scoreboard analyses of top R&D investors worldwide can provide an interesting account of this global competition, which justifies the focus of the present paper.[3] In financial markets, to be among the largest R&D spenders of an economic sector can increase investors' propensity to buy shares and reinforce the market value of R&D investments (Hall and Oriani, 2006). Indeed, top R&D spenders outperform their sectoral average in terms of market capitalisation (Cincera et al., 2009). In non-financial markets, entering the group of the largest R&D spenders can increase the firm's probability to overcome sectoral thresholds in relative expenditures, which makes investment in R&D a "dilemma" (González and Pazó, 2004). In this sense, the output return on investment could in fact not be enough to recover the costs, given the presence of indivisibilities of some R&D resources (á la Arrow) such as: the fixed costs of research labs, the specialisation required for efficient team research work, and the pool of research projects for an adequate sharing of their risk. Relatedly, increasing the size of R&D investments above that of the majority

[1] Among the several works on the trends and drivers of R&D internationalization, see Patel and Pavitt (1991); Granstrand et al. (1993); Cantwell and Piscitello (2000); Gammeltoft (2006); Kinkel and Som (2012); Castelli and Castellani (2013).

[2] Relevant exceptions are represented by Naghavi and Ottaviano (2009) and Belderbos et al. (2008).

[3] Examples are the European Industrial Research and Innovation Scoreboard and the UK R&D Scoreboard. Top R&D investors are also monitored by Forbes' "The World's Most Innovative Companies" and by booz&co.'s "The Global Innovation 1000".

of rivals can make R&D costs an effective barrier to entry, from which firms can benefit in a Schumpeterian fashion, when targeting a major (radical) process or product innovation (Mueller and Tilton, 1969).

This argument does not amount to suggesting that top R&D investors are necessarily the most innovative companies, as the results of R&D investments depend on their scale as well as their efficiency.[4] Nevertheless, successfully following the above competitive mechanisms can offer the firm large benefits from taking a technological lead. This motivates our focus on the top R&D spenders and on the role FDI can have in allowing firms to be among them.

Drawing eclectically from the industrial organization literature, we adopt a type of entry/exit model, with respect to a club of top R&D investors. The boundaries of this club are first determined by looking at the distribution of the investment capacity firms reveal in R&D worldwide. FDI is then introduced into the model among the factors that can account for the propensity firms have to entry and exit from such a club.

We estimate the previous model by using a panel of about 1,500 R&D investors, obtained by merging subsequent releases of the European Industrial Research and Innovation Scoreboard and by integrating it with data from the fDi Market dataset. As the firms included in our dataset are usually large conglomerates, operating in several international markets, which together account for more than 80% of total R&D worldwide, it is natural starting point in attempting to establish a group of top R&D investors.[5]

The rest of the paper is organised as follows. Section two illustrates the theoretical background and presents the main research hypothesis of the paper. Section three describes the model through which we test this hypothesis and the datasets employed. Section four discusses the results. Section five concludes and draws some policy implications.

[4] The last release of the "The Global Innovation 1000" (2013) actually finds that *"it is not how much companies spend on research and development that determines success. What really matters is how those R&D funds are invested in capabilities, talent, process, and tools"*.

[5] As much natural will be, in our future research agenda, the extension of this analysis to those companies that are out of the scoreboard domain, and which could eventually use their FDIs to arrive "at the foot of the R&D giants".

2 Theoretical background

The relationship between FDI and R&D has been widely investigated by different research streams in international business studies. An extensive review of them is out of this paper's scope, but some of their elements are worth recalling as they represent the background to the issue at stake. A first relevant insight comes from the literature on FDI motivations and, in particular, on so-called "knowledge (or technology) seeking" (Cantwell, 1989). In addressing our research question, it should be noted that recent studies have shown that, not only can FDI help technology laggards catching-up with companies at the global frontier; allowing their home countries to narrow technology-gaps. Increasingly, they represent also a strategy through which technology leaders can try to stay ahead, by renewing their innovation capacity with knowledge diverse from that of their home base (Cantwell and Janne, 1999; Chung and Alcácer, 2002). R&D offshoring has become a channel though which companies compete for acquiring innovative competencies at the global level (Lewin et al., 2009).[6] Accordingly, knowledge seeking can also occur between countries whose differences in technological levels and R&D are small. This makes the analysis of the firm's FDI portfolio relevant for its inspection, and for its impact on R&D, somehow irrespectively from the characteristics of the host country.[7]

A second set of background arguments concerns the impact of FDI, possibly driven by knowledge seeking, on firms' innovation. The majority of the literature has concentrated on the effect on the inventive capacity of the investing firms, pointing to an increase in their patents production and/or citation (e.g. Penner-Hahn and Shaver, 2005; Criscuolo et al., 2005). Other works have looked at how the internationalisation of R&D interacts with the business processes through which firms introduce new innovative products (Subramaniam and Venkatraman, 2001; Naghavi and Ottaviano, 2009), finding more puzzling results. In general, a positive innovation impact of the firm's internationalisation is not guaranteed and rather depends on a set of factors. The complementarity between the technological base of the home and of the host country, the

[6] "Home-base augmenting" MNC, which tap into new knowledge abroad to develop technologies and products that serve, not only the host market, but also the home and the global ones, are becoming the new typology with respect to the traditional "home-base exploiting" ones (Cantwell and Mudambi, 2005; Ambos et al., 2006).

[7] Of course, these characteristics are relevant to ascertain the actual extent to which FDI are driven by other motivations than knowledge seeking, such as the reduction of production and/or R&D costs, or the adaptation of products and services to the local markets. The location of foreign facilities is in fact crucial for its detection (Kuemmerle, 1999). However, to start with we will leave out the host country issue and dedicate to it in our future research.

techno-economic characteristics (e.g. opportunity and appropriability conditions) of the industries in which they operate, the individual traits of the companies investing abroad including their capabilities of interacting and networking with the foreign providers, appear the most significant (Chung and Alcácer, 2002; Song et al., 2011; Ambos, 2005; Piscitello and Santangelo, 2011). Furthermore, the specific innovation realm in which FDI (in R&D) can impact needs to be distinguished.

More relevant for our investigation is a third stream of literature, which has looked at the level of investments of MNC, when compared to national firms, with respect to both tangible and intangible assets, like R&D. Empirical evidence does not support the hypothesis of a possible crowding-out of FDI on the firm's domestic activities (Desai et al., 2009). On the contrary, multinational activities appear to increase the firm's propensity to invest in intangible assets (Egger and Pfaffermayr, 2009), which leads to our research hypothesis. We claim that, not only can FDI crowd-in the firm's investments in R&D, but they can also help it in joining the club of the largest R&D investors, providing it with a number of advantages. First of all, the largest R&D investors can be expected to have a wider and more diversified knowledge-base, through which they will have the chance of dealing with a larger portfolio of innovation projects: with higher opportunities of risk pooling, although with a more demanding organisational governance (Gerybadze and Reger, 1999; Mikkola, 2001). Second, their capacity of scanning, accessing and combining external knowledge sources - in brief, the second face of their "large R&D" (Cohen and Levinthal, 1990) - could be arguably larger too, with higher chances of managing research cooperation in an open-innovation fashion (Enkel et al., 2009). Finally, their research projects are presumably of a larger than average scale, with higher opportunities of international economies of scale and a higher capacity of overcoming the up-front fixed costs and the indivisibilities from which path-breaking innovations are usually affected, especially in certain sectors (Godoe, 2000; Cohen, 2010). Our main research hypothesis is that FDI, and FDI in R&D in particular, can affect the chance firms have to climb the ladder of the most highly investing R&D companies, and to benefit from the advantages outlined above. At the outset, as we said, the internationalisation of R&D is a way through which MNC can "augment", rather than simply "exploit", their knowledge base and that of their countries. As some recent evidence has shown, although with some important country and sector specification, the subsidiaries of MNCs can receive more than what they give in terms of knowledge (Singh, 2008). Providing it is directed towards an "exploration", rather than "exploitation", this kind of learning (á la March) from the R&D carried out abroad can have a "multiplier effect" with respect to that invested at home (Makino et al., 2002).

More concretely, setting a network of R&D centers and subsidiaries in different locations, and connecting them through proper network linkages and technologies, can be the key for a company to pursue large innovation investments, which could not be sub-divided to fit the capacity of the home labs (De Meyer, 1993; Chen and Chen, 1998). The internationalisation of R&D could also be beneficial for running large multi-technology and -disciplinary projects, which are usually geographically dispersed/distributed and can thus only be tapped into different country and/or region-specific innovation systems (Gerybadze and Reger, 1999; Gassmann and Von Zedtwitz, 1998)

Overall, our research hypothesis appears theoretically supported to be tested empirically, the methods of which we outline in the next section.

3 Empirical application

3.1 R&D and FDI company data

The data used for the empirical analysis comes from two sources. On the one hand, R&D investments have been drawn from the EU Industrial R&D Investment (IRI) Scoreboard (http://iri.jrc.ec.europa.eu). This is a scoreboard analysis of top R&D investors across the world, representing more than 80% of world business R&D expenditure, which has been carried out annually since 2004 by the Institute of Prospective Technological Studies (IPTS, Joint Research Centre, European Commission). Specifically, company level data is taken for R&D investments as well as other accounting variables, of the top 1,500 R&D investors over the period 2004-2011.

Scoreboard information has been matched with data from a second source; fDi Markets by fDi Intelligence (The Financial Times Ltd). The database tracks cross-border green field investments, covering all sectors and countries worldwide since 2003. Specifically, data on FDI projects classified by investment activities (e.g. R&D, manufacturing, sale and marketing) and on their capital expenditure (*Capex*) has been used.[8]

[8] It should be noted that for a number of projects the Capex is estimated. The algorithm to fill Capex missing information works as follow: it first looks at projects in the same country/sector/activity with actual Capex data and then removes the smallest and largest 5% of projects in order to create an estimation dataset. If there are less than 5 projects in this dataset, then the algorithm switch to regional data (i.e. North America in the case of projects in

In performing the merge between the two datasets, the FDI projects carried out by the subsidiaries of a certain MNC have been assigned to the relative parent company. In so doing, 1,150 scoreboard companies have been identified in fDi Markets and thus retained for the empirical application. As Table 1 shows, between 2003 and 2012, these top R&D spenders have invested in 33,572 FDI projects. The largest number has been in manufacturing (37.6%), followed by sales and marketing (14.6%), and R&D (11.7%), confirming a well documented pattern of internationalisation of economic activities (e.g. Karabag et al., 2011).

Table 1: Distribution of FDI projects per economic activities

FDI Activity	# of Projects	%
Manufacturing	12612	37.6%
Sales, Marketing Support	4909	14.6%
Research & Development	3918	11.7%
Retail	2795	8.3%
Logistics, Distribution Transportation	1808	5.4%
Business Services	1655	4.9%
Headquarters	1290	3.8%
ICT Internet Infrastructure	794	2.4%
Maintenance Servicing	671	2.0%
Electricity	631	1.9%
Customer Contact Centre	564	1.7%
Education Training	542	1.6%
Extraction	509	1.5%
Technical Support Centre	340	1.0%
Shared Services Centre	297	0.9%
Construction	162	0.5%
Recycling	75	0.2%
Total	33572	

Although lower than in manufacturing and marketing/sales, when compared to the subsequent activities, the share of projects in R&D is not negligible. It should also be noted that, in the empirical analysis, we have also considered among the R&D ones, the projects that fDi Markets classifies as "Design, Development & Testing". This is an empirical choice made by other studies using the current database, and motivated by the fact that knowledge sourcing opportunities

Canada); if there are still less than 5 projects, then the algorithm switch to global data (this would only be the case for rare combinations of sector/activity). Where the Capex is known, the algorithm uses the estimation dataset to look at the average ratio of Capex and complete the gaps. These estimates are generally pretty accurate as the ratios in a given combination of country/sector/activity are pretty standard. If the Capex is unknown, the algorithm uses the average values of the dataset.

may arise at different stages of the research and development/deployment chain of the innovative companies. Limiting the set of relevant projects to those that, according to the Oslo Manual (2005), involve some elements of "basic research" would arguably have neglected an important dimension of the issue at stake.[9]

3.1.1 The club of the top R&D investors

Finding a threshold to identify the club of top R&D investors at the worldwide level is not an easy task. The IRI Scoreboard does identify a threshold, but this is only established exogenously by the fixed number of companies analysed over time. Furthermore, this threshold appears to separate from the non-Scoreboard ones a number of companies whose innovative behaviour and economic performance is far from homogeneous. Kancs and Siliverstovs (2012), for example, have recently shown that the relationship between R&D expenditure and productivity growth of the Scoreboard companies is actually non-linear. They find that the impact of R&D on productivity growth becomes significantly positive only after a certain critical mass of R&D is reached.

This kind of evidence, which is consistent with the theoretical premises of endogenous growth theories,[10] seems to suggest that the ladder of companies that the Scoreboard identifies is not that smooth in terms of levels of investments. On the contrary, even when its 1,500th step has been reached, further steps might emerge along the ladder, whose height (size) can create discontinues in benefiting from them. The distribution of the R&D expenditure of the Scoreboard companies against their ranking position in the latest available data (2011) confirms this expectation (Figure1).[11]

The level of R&D expenditure "rises" at an increasing pace approaching the top of the ranking. The relationship between the companies ranking position and their R&D expenditure even appears to be exponential. R&D expenditures start to break off around the 500th rank position

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[9] One should just think of the case of software companies, for which the research and the testing of the product is nearly undistinguishable.

[10] According to the relative models, the productivity of R&D investment may be sensitive to the level of technological sophistication (R&D investment in the past) in two opposite ways, depending on the elasticity of productivity with respect to the knowledge stock. If this elasticity is positive, it means that prior R&D investment increases the current productivity (namely, the "standing on shoulders"' effect); whereas, when the R&D elasticity is negative, prior research has discovered the ideas which were easiest to find (the "fishing out" effect), new ideas are much more difficult to discover, and a further increase in productivity becomes arduous. Interactions between the two forces may result in non-linear R&D productivity relationship.

[11] The distribution for the others years is almost identical.

and then take off around the 250th position. In brief, being at the top it is not for everyone. Quite pragmatically, this statistical analysis suggests that these thresholds can be used to establish our (two) club(s) of top R&D investors.

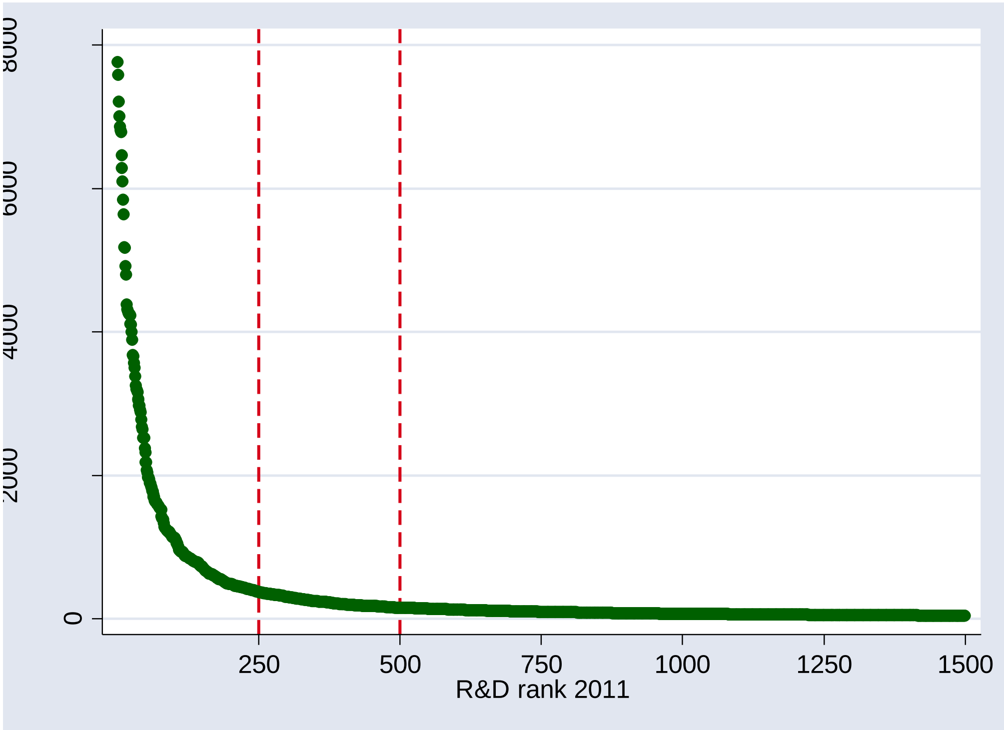

Figure 1: Ranking and R&D expenditures

Further analysis would of course be needed to ascertain whether being part of the "club(s)" actually gives these companies a significant comparative advantage over the outsiders. Such an analysis - which we postpone to our future research agenda - will have to consider different realms of outcomes variables (for example, profitability and innovativeness, in addition to productivity), which presumably will result in different sets of thresholds that would then be compared. For the time being, let us observe that the thresholds identified actually discriminate our Scoreboard companies in a way which is consistent with our theoretical premises. First, Table 2 shows that the identified groups actually concentrate the bulk of the R&D expenditure, both at the beginning and at the end of the time period. In 2011, the top 250 companies carried out about 72% of the total R&D expenditure, with a median value of 854 millions. When considering the top 500, the share over the total R&D expenditures increases to about 82% with a concomitant decline in the median value (366). Companies below the 500 ranking position display on average a much lower level of R&D expenditure.

Table 2: R&D distribution and descriptive statistics by ranking groups (Million Euros)

	R&D expenditure	Sample %	Mean	Median	Median	Median	Median
2011	*(total)*	*R&D*	*R&D*	*R&D*	*MktCap/ Emp*	*OpProf/ Emp*	*NSales/ Emp*
Top 250	384,927	71.7%	1,540	854	0.333	0.035	0.318
250-500	57,506	10.7%	230	220	0.253	0.023	0.259
Others (501-1500)	94,648	17.6%	40	29	0.227	0.015	0.222
Whole sample	537,081		189	38	0.241	0.017	0.235
2004	*(total)*	*R&D*	*R&D*	*R&D*	*MktCap/ Emp*	*OpProf/ Emp*	*NSales/ Emp*
Top 250	264,590	81.5%	1,058	469	-	0.027	0.281
250-500	31,082	9.6%	124	117	-	0.020	0.236
Others (501-1500)	28,843	8.9%	23	17	-	0.014	0.187
Whole sample	324,514		184	28	-	0.016	0.202

Similar patterns can be observed in 2004 (our first year sample period), when R&D expenditures were even further concentrated. More relevant is the fact that in 2011, the only year for which we were able to obtain reliable figures[12], the market capitalization per employee (MktCap/Emp) of the (median) Scoreboard companies increases when moving up the ladder (top 250: 0.33; top 500: 0.25; other companies: 0.23). This confirms the prize of R&D market value already found by Cincera et al. (2009) and the argument according to which, being a company top R&D spender, spurs the investors to discount a positive relation between higher R&D capital and subsequent stock returns (Lev and Sougiannis, 1996).

Quite interestingly, in both 2004 and 2011, the (median) R&D investors of the higher clubs in the ladder show better economic performances, both in terms of operating profit per employee (OpProf/Emp) and of net sales per employee (Sales/Emp), still pointing to the advantages we have hypothesized in Section 2.

[12] For 2004 we do not have enough available data on market capitalization to calculate representative figures.

3.12 The club of top R&D investors

We model the company's entry into and exit from the clubs of the R&D ladders as a Markov process. For each company $i = 1; \ldots ;N$, at time $t = 1; \ldots ; T$, we define the outcome of this process as $y_{it} = 0;1$, where $y_{it} = 1$ indicates that the company has a level of R&D spending sufficiently high to be in the ladders' club, and $y_{it} = 0$ otherwise. The conditional distribution of company's i R&D expenditure, assumed independent across firms, is then given by:

$$\pi_{i,v|u} = P(y_{it} = v \mid y_{it-1} = u) \tag{1}$$

where $\pi_{i,v|u}$ is the probability of a transition from the state $u = 0;1$ at time $t\text{-}1$ to the state $v = 0; 1$ at time t.[13]

Let us define $x_i \equiv (1; x_{i1}; \ldots ; x_{ip})'$ as the vector of p covariates for the i-th company, which affect the transition from state u to state v, and let $\beta_{uv} \equiv (\beta_{0uv}; \beta_{1uv}; \ldots ; \beta_{puv})'$ be the vector of parameters for the same transition. The transition probabilities in terms of conditional probabilities as functions of covariates x are:

$$\pi_{i,v|u}(\boldsymbol{x}) = P(y_{it} = v \mid y_{it-1} = u, \boldsymbol{x}) = \frac{\exp(\beta_{uv}'\boldsymbol{x}_{it})}{\sum_{uv}\exp(\beta_{uv}'\boldsymbol{x}_{it})} \tag{2}$$

By imposing that $\beta_{oo} = 0$ and $\beta_{11} = 0$, the transition probability from being below the threshold and staying below (and being and staying above) the threshold the next period can be written as:

$$\pi_{i,v=u}(\boldsymbol{x}) = \frac{1}{1 + \sum_{u \neq v}\exp(\beta_{uv}'\boldsymbol{x}_{it})} \tag{3}$$

and the probabilities of crossing the threshold:

$$\pi_{i,v\neq u}(\boldsymbol{x}) = \frac{\exp(\beta_{uv}'\boldsymbol{x}_{it})}{1 + \sum_{u \neq v}\exp(\beta_{uv}'\boldsymbol{x}_{it})} \tag{4}$$

After conditioning on the covariates, the transition probabilities are assumed to be independent across companies and time, and we can retrieve both the transition matrix and the impact of the FDI determinants via maximum likelihood.

More precisely, we estimate a system of two logistic regressions, one for the *entry* and the other for the *exit* process, via Seemingly Unrelated Estimation (SUE). This approach allows us to

[13] Note that $\sum_{v=0,1}\pi_{i,v|u} = 1,\ u = 1{,}0.$

retrieve both robust standard errors and estimates of the between-model covariance of the parameters, and thus to test for differences (in the absolute values of the parameters) in the two equations. In brief, we can properly test whether our covariates exert symmetric effects on the *entry* and *exit* dynamics we are considering.

In order to test our research hypothesis, we plug in vector x the company's involvement in outward FDI projects. In particular, we do that by estimating three models. In Model 1, we assume that the probability that a company i enters in (exit from) the club at time t, $\pi_{i,t(1|0)}$ ($\pi_{i,t(0|1)}$), is affected by the total number of FDI projects that it has carried out at time t - 1 ($FDItot_{t-1}$). In so doing, we want to investigate whether the level of internationalisation that the companies acquire by setting up green-field projects abroad, irrespectively from the activity for which this is done[14], provide them with an additional amount of knowledge, resources and/or market opportunities, through which they can access the R&D ladders club, if they were out of it; or eventually avoid exit from the club, if they were already part of it. In this last respect, it should be noted that the dynamic nature of this (and of the other) model allows us to address a possible problem of reverse causality in the issue at stake, as the level of companies' R&D investments can equally work well as a driver for their FDI decisions in search of new knowledge, rather than resulting from them (Faeth, 2009).

In Model 2 we consider among the relevant predictors the number of FDI projects of company i at time t - 1 in R&D activities ($FDIrd_{t-1}$). In so doing, we aim at testing more directly whether the role of knowledge-seeking that R&D offshoring has been found to have is able to impact on the entry-exit dynamics we are considering. In particular, by focusing on the simple number of FDI projects in R&D, we address their role of knowledge-seeking at the extensive margin, as it can accrue to the firm by sourcing, with a larger number of projects, a larger number of countries/regions, or a larger number of providers in the same locations.

Finally, in Model 3 the logic is repeated, by introducing the total capital expenditure in R&D projects by company i at time t - 1 ($FDIrdexp_{t-1}$), side by side with the total number of FDI projects. In such a way, the role of knowledge-seeking enabled by FDI is addressed at the intensive margin, looking at the impact that the scale of the firm's international projects and the learning effects that are connected to it have on the entry/exit dynamics at stake.

[14] As we said, in this first exercise, we also investigate this irrespectively from the host country of FDI.

In addition to FDI projects, the process of entry/exit with respect to the club of top R&D investors could of course also be affected by other variables, which should enter the **x** vector too. First of all, companies might climb up and down the R&D ladder depending on their availability of financial resources to invest in R&D, providing an interesting opportunity for testing a relationship on which the evidence is still ambiguous (Hundley et al., 1996). In this vein, the operating profit of the firms (*OpProf*) is considered among the regressors of all the previous three models.

Further explanatory variables emerge by drawing eclectically on industrial organisation also for the determinants it has found for firm entry and exit with respect to "standard" markets. First of all, the capacity (incapacity) of being (staying) high on the R&D ladder could depend on the firm's size, with the possibility of extending to this realm the evidence of a "liability of smallness" (Aldrich and Auster, 1986; Honjo, 2000). Accordingly, the natural logarithm of the company's employees (*Log(Emp)*) is inserted among the controls. In the same vein, the age of the firm (*Age*) could affect its potential of scaling up the thresholds of the R&D worldwide ranking, as well as the risk of falling below them over time: the equivalent of a "liability of newness" becomes thus interesting to test (Stinchcombe, 1965; Geroski, 1995). All of these firm-specific controls help us in attenuating a problem of self-selection that could emerge when we consider that, following and extending the seminal contribution by Melitz (2003), FDI are mainly a prerogative of the most productive firms. A series of dummies complete the list of controls, in order to take into account industry, country and time specificities. As we said, in order to overcome potential endogeneity problems, all the variables apart from *Log(Emp)* and *Age*, and of course the dummies, enter into the model with a year lag.

4 Results

The estimation results provide us with large support to our research hypothesis, with respect to both the top 500 (Table 3) and the top 250 R&D investors (Table 4). Furthermore, they show some interesting specificities in its empirical analysis.

First of all, and consistently with the arguments discussed in Section two, the coefficients attached to $FDItot_{t-1}$ are statistically significant and positive in explaining the *"entry"* process for both the cut-offs, in Model 1. A larger number of FDI projects gives companies an advantage in reaching the largest volumes of innovative efforts. The degree of internationalisation that firms acquire by setting up new subsidiaries abroad, irrespectively from their dedication to innovation-related activities, apparently increases their set of knowledge and market opportunities, to the point of spurring a shift to larger scale R&D investments in order to exploit them.

It should be noted that, by referring to the number of projects, rather than to their amount, the effect that FDI exert on R&D investments in Model 1 should be deemed an "extensive", rather than an "intensive" internationalisation effect. In other words, entry into the top R&D clubs seems to require (benefit from) a larger "portfolio" of international activities.[15] The company ranking 500th in 2011 has an R&D expenditure of about 145 million Euros, suggesting that the majority of world firms are more likely to experience an "*entry* type mechanism". This should however be confirmed with other samples and specifications, which could allow us to determine a general R&D threshold level.

Model 1 provides another interesting result. With respect to both the considered thresholds, a larger number of FDI projects does not help companies to retain their status in the top R&D clubs. Once they enter, companies need to follow further strategies, in addition/alternatively to internationalisation for resisting competition of newcomers. Possibly, FDI are less important than other domestic activities when attempting to exploit the opportunities provided by internationalisation.

[15] Further work on the geographical and sectoral diversification of this portfolio is required to support this interpretation and is on our future research agenda.

Table 3: Top 500 estimations

	Entry 500 (1)	Exit 500 (1)	Entry 500 (2)	Exit 500 (2)	Entry 500 (3)	Exit 500 (3)
FDItot*t-1*	0.0799***	-0.0259			0.0759***	-0.0006
	(0.029)	(0.045)			(0.029)	(0.043)
FDIrd*t-1*			0.5185***	-0.5990***		
			(0.184)	(0.218)		
FDIrdexp*t-1*					0.0087**	-0.0232**
					(0.004)	(0.012)
OpProf	0.0001***	-0.0001	0.0001***	-0.0001	0.0001***	-0.0001
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
Log(Emp)	0.6316***	-0.8216***	0.6673***	-0.7844***	0.6174***	-0.7830***
	(0.119)	(0.164)	(0.120)	(0.163)	(0.119)	(0.164)
Age	-0.0008	-0.0013	0.0000	-0.0016	-0.0006	-0.0015
	(0.002)	(0.003)	(0.002)	(0.003)	(0.002)	(0.003)
Sector dummies	*Included*	*Included*	*Included*	*Included*	*Included*	*Included*
Year dummies	*Included*	*Included*	*Included*	*Included*	*Included*	*Included*
Country dummies	*Included*	*Included*	*Included*	*Included*	*Included*	*Included*
Constant	-8.7672***	-7.4524***	-9.1097***	-8.7567***	-8.6178***	-7.3412***
	(1.706)	(1.929)	(1.750)	(1.895)	(1.720)	(1.945)
Observations	3,899	3,899	3,899	3,899	3,899	3,899

Robust standard errors in parentheses - *** $p<0.01$, ** $p<0.05$, * $p<0.1$

Model 2 shows that climbing the identified R&D ladder is also helped by increasing the number of FDI projects in R&D, and with a much larger impact than FDI projects in general. What is more, and as expected, this latter kind of multinational projects appears more powerful in gaining firms the status of top 250 and 500 R&D spender. As Figure 2 shows, the estimated probabilities of entering the two clubs sharply increase with the number of R&D projects (upper part of the figure), and approach a certainty kind of outcome (that is a unitary probability) already for the companies with the lower numbers of projects of this kind in the distribution.

Table 4: Top 250 estimations

	Entry 250 (1)	Exit 250 (1)	Entry 250 (2)	Exit 250 (2)	Entry 250 (3)	Exit 250 (3)
FDItot*t-1*	0.0937***	-0.0343			0.0833**	-0.0193
	(0.032)	(0.046)			(0.033)	(0.052)
FDIrd*t-1*			0.6334***	-0.3882**		
			(0.178)	(0.158)		
FDIrdexp*t-1*					0.0104**	-0.0052
					(0.005)	(0.007)
OpProf	0.0001*	-0.0001*	0.0001	-0.0001*	0.0001	-0.0001*
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
Log(Emp)	0.9211***	-0.5861***	1.0037***	-0.5507***	0.9104***	-0.5754***
	(0.176)	(0.220)	(0.178)	(0.213)	(0.179)	(0.220)
Age	0.0039	0.0047	0.0057*	0.0036	0.0045	0.0042
	(0.004)	(0.004)	(0.003)	(0.004)	(0.004)	(0.004)
Sector dummies	*Included*	*Included*	*Included*	*Included*	*Included*	*Included*
Year dummies	*Included*	*Included*	*Included*	*Included*	*Included*	*Included*
Country dummies	*Included*	*Included*	*Included*	*Included*	*Included*	*Included*
Constant	-11.2761***	-9.0246***	-12.2994***	-7.8428***	-11.2742***	-8.0397***
	(2.138)	(2.899)	(2.129)	(2.797)	(2.174)	(2.919)
Observations	3,699	3,699	3,699	3,699	3,699	3,699

Robust standard errors in parentheses - *** p<0.01, ** p<0.05, * p<0.1

Conversely, the estimated probabilities of climbing the two ladders increase much more smoothly, with the increase in the number of general FDI (lower part of the figure). As we said, unlike a knowledge-seeking driven, a general internationalisation strategy, whose knowledge outcome can be only indirectly functional to R&D investments, appears less powerful in guaranteeing the status of top spenders.

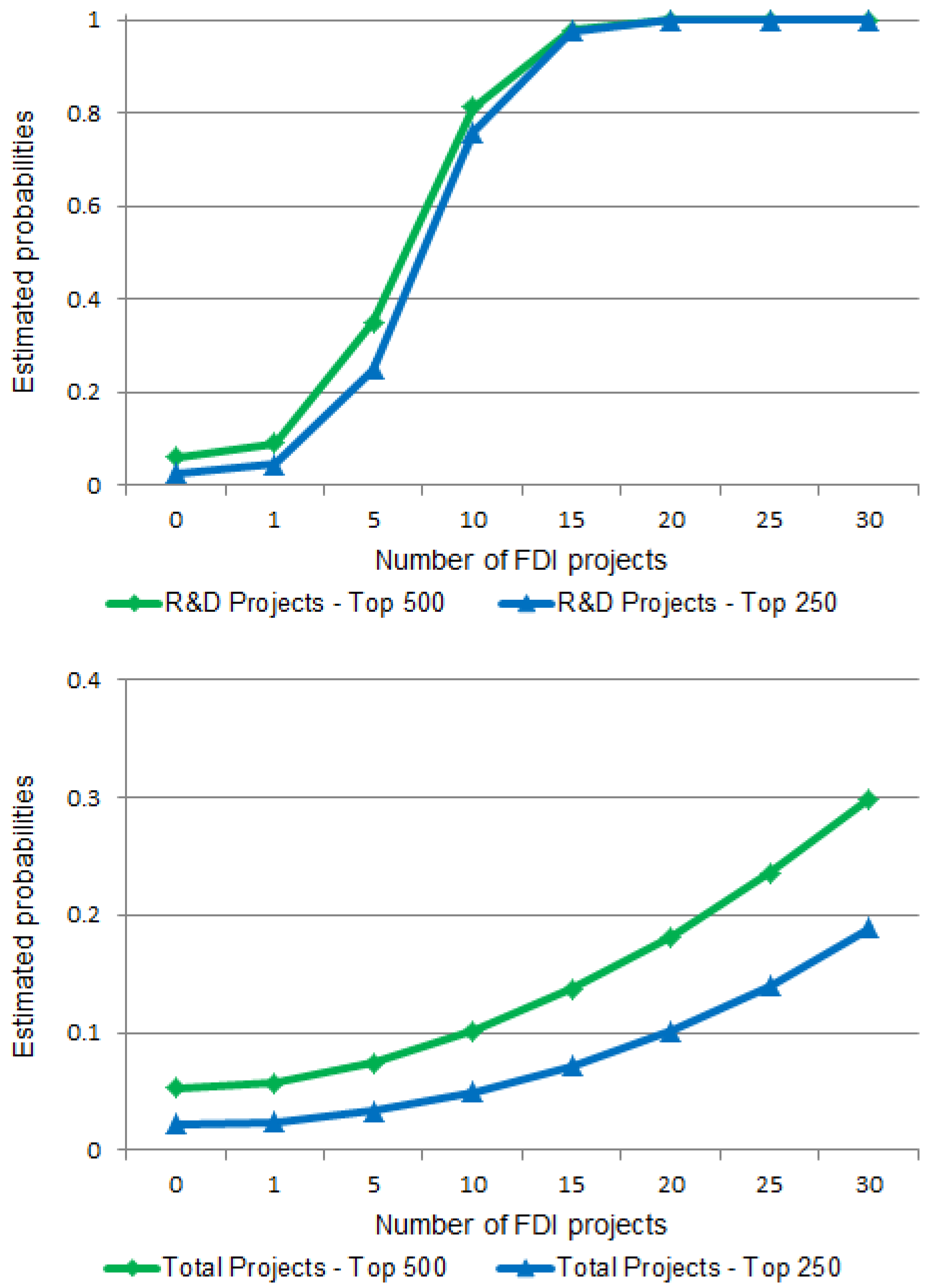

Figure 2: Estimated probabilities of entering in the top 500 & 250 clubs

Another important difference with respect to Model 1 has to do with the probability of exiting from the club of top R&D spenders. Unlike for FDI in general, not only does this increase their propensity of climbing the highest steps of the R&D worldwide ladder. This time, a wider access to research-based knowledge sources at the global level also helps the leaders to stay in the club.[16] In other words, when compared with greater FDI portfolios in the magnitude and pace of general FDI projects, a larger set of international R&D activities seems to guarantee safer positions in the competition for the largest innovative efforts.

The results of Model 2 are mainly confirmed when the intensity of the companies' involvement in R&D offshoring is considered, as we do in Model 3. Entering the club of both the top 500 and 250 R&D investors appears also *(but not only!)* a question of "scale" of international R&D projects. As expected, setting in motion "innovative" projects of larger amounts contributes to placing the relative MNC among the R&D giants of the world. According to our arguments in Section 2, R&D offshoring of a large scale could actually enable companies to overcome the indivisibilities that often prevent them from implementing R&D investments. *FDIrdexp* also helps in decreasing the probability of exiting from the R&D circle, but with an interesting variation with respect to the previous case.[17] While the size of FDI projects in R&D makes the belonging to the top 500 more "sticky", this is not the case for that of the top 250. Once this top of the R&D "iceberg" is reached, only a strategy of "extensive" knowledge seeking, more inclined to a diversification mode, can help in not falling back. Conversely, a "simple" increase of the scale of international R&D activities does not constitute a reliable safeguard against it.

In conclusion, some interesting results emerge from the controls used in the estimations. First of all, as expected, larger firms are more prone to make the shifts investigated along the R&D ladder. Conversely, the smaller ones are more inclined to exit from the R&D clubs in question, pointing to an interesting extension of the hypothesis of the "liability of smallness". No significant effect is instead found for the extension of the "liability of newness" to our framework. The coefficients attached to the variable *Age* are not statistically significant (apart from one case at 10%): once the effects of the other variables are taken into account, the companies' age does not contribute to explaining their capacity to climb onto the R&D giants' shoulders. In this specific context, the greater opportunities which are usually recognised to younger firms in industrial dynamics do not seem to matter. Entry-in and exit-from the R&D club does not seem an issue of industrial demography. Finally, the companies' profitability has a significant (though marginal) effect on the probability to enter into the top 500 club, and the same holds true, but with a low statistical significance (10%), for the probability of staying in the more restricted 250 one. The

[16] The test on the relative coefficients shows that, in spite of their apparent difference, FDI in R&D impact on entry and exit to the same extent.

[17] Also in the present case, the impacts on entry and exit are not significantly different between them.

availability of internal financial resources, by relaxing the financial constraints that companies' may face when investment decision are taken, could explain this further result.

5 Conclusions

At the global level innovation competition also entails competing for large R&D investments on a worldwide scale. Climbing the ladder of the world R&D spenders can help firms to pool the risks of different research projects and/or overcome the indivisibilities that affect the use of R&D resources, especially in the discovery of path-breaking, brand new products and processes. This is particularly relevant for the case of European companies, which are often excluded from this game, because of their small average-size and their not very high-tech specialisation pattern.

Internationalisation through FDI, and R&D offshoring in particular, can help in this respect, as they enable companies to access new markets and knowledge sources. By extending the extant literature on the relationship between FDI and R&D, our application to the companies of the European Scoreboard of Industrial Research and Innovation largely confirms this hypothesis. FDI give a significant and positive contribution to climbing on the R&D giants' shoulders, and this contribution appears more powerful in terms of pace in the case of FDI in R&D. Furthermore, in the case of R&D only, and relatively more at the extensive margin, FDI also provide help in remaining at the top and resisting competition from newcomers.

Interesting policy implications can be drawn from these results. First, supporting the internationalisation of companies through outward FDI has an important side-effect on their R&D capacity, which could also have a domestic innovation impact. Not only can it increase the domestic investments of MNC in R&D, as the literature has found. But it can also help the firms to reach a critical mass for their R&D investments to be positively evaluated by the financial markets and to be used in high-scale intensive projects with larger economic returns. Second, while R&D offshoring could possibly have the drawbacks that the literature has pointed to - for example, the risk of losing core-competencies - by helping firms source R&D knowledge internationally, policy makers can provide them with a longer time window among the top R&D spenders, giving them longer opportunities to exploit the acquired knowledge into successful innovations. Last but not least, the support to an extensive, rather than intensive, internationalisation strategy of the firms - such as the one offered by widening the spectrum of geographical markets in which they can encounter favourable conditions to expand - appears in general more effective in guaranteeing them a permanent status of top R&D spender.

In conclusion, we should once more stress that, by climbing (and staying) on the R&D giants' shoulders, companies will not be necessarily more innovative, or more productive, as further research should be carried out in this direction. However, the effect that FDI and R&D offshoring have on the firms' capacity of acquiring a higher profile of R&D investors should be carefully considered. The delocalisation of R&D might move the "brain" of European companies elsewhere, but in such a way its working capacity could increase substantially. The relative outcomes could increase and, with proper policy interventions, also directed to sustain smarter patterns for growth according to the Europe2020 objectives.

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Title: On the R&D giants' shoulders: Do FDI help to stand on them?

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Abstract

The paper investigates the extent to which outward FDI affect the MNC's capacity of entering (and remaining in) the club of top R&D world investors, benefiting from performance gains in both financial and economic markets. By merging the European Industrial Research and Innovation Scoreboard with the fDi Markets dataset, we find supporting evidence. Increasing the number of FDI projects helps firms overcome the discontinuities that, in the distribution of R&D expenditures, separate the group of the largest world R&D investors from the top of them. The same is true for the number of FDI projects in R&D, which are also more important than greater FDI portfolios in becoming a top R&D spender. Furthermore, unlike FDI in general, more FDI in R&D guarantee firms to remain in this top club of firms as it increases their capacity of resisting competition for a place among the top R&D spenders. Results at the extensive margin (i.e. the number of FDI projects) are confirmed with respect to the scale of FDI projects (i.e. at the intensive margin). However, increasing their size is not enough to become one of the highest ranking R&D firms. Policy implications about the support to R&D internationalisation are drawn accordingly.

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