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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) into the circle of the top R&D world investors, benefiting from performance gains in both financial and economic markets. We merge the European Industrial Research and Innovation Scoreboard with the fDi Markets dataset and find support for that. Increasing the number of FDI projects in R&D helps firms overcoming the discontinuities that, in the distribution of R&D expenditures, separate the largest R&D investors from those on their top. The same is true for the number of FDI projects in other economic activities, which are however less powerful than larger portfolios of international R&D projects in the pace they provide the status of top R&D spender. Furthermore, more FDI in R&D guarantee a safer status of this kind, as they increase the firm's capacity of resisting among the top R&D spenders, unlike FDI in general. Results obtained by
using the number of FDI projects in R&D are confirmed when their scale is considered. However, increasing their size is not enough for resisting the competition for a very top place in the R&D ranking. Policy implications about the support to R&D internationalization are drawn accordingly.

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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) into the circle of the top R&D world investors, benefiting from performance gains in both financial and economic markets. We merge the European Industrial Research and Innovation Scoreboard with the fDi Markets dataset and find support for that. Increasing the number of FDI projects in R&D helps firms overcoming the discontinuities that, in the distribution of R&D expenditures, separate the largest R&D investors from those on their top. The same is true for the number of FDI projects in other economic activities, which are however less powerful than larger portfolios of international R&D projects in the pace they provide the status of top R&D spender. Furthermore, more FDI in R&D guarantee a safer status of this kind, as they increase the firm's capacity of resisting among the top R&D spenders, unlike FDI in general. Results obtained by using the number of FDI projects in R&D are confirmed when their scale is considered. However, increasing their size is not enough for resisting the competition for a very top place in the R&D ranking. Policy implications about the support to R&D internationalization are drawn accordingly.

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

In the current global scenario, populated by Multinational Corporations (MNC) operating in an array of markets and technologies, innovation performances depend also and above all on the firms' capacity of sourcing knowledge internationally and of exploiting it in production activities on a worldwide basis. Foreign Direct Investments (FDI), mainly but not only in R&D, are crucial in this last respect. They allow firms to expand their markets, enter into global value chains, interact with foreign companies and labs, get embeddeded in the business and scientific communities of the host country, and thus tap into its set of knowledge and competencies (Maskell et al., 2007).

The motivations that lead firms to invest abroad have been receiving increasing attention in the extant literature (see Franco et al. (2010) for a critical review). The role of FDI driven by the search of new knowledge ("knowledge seeking" or "technology seeking" FDI (Cantwell, 1989)) has been singled out, especially through the internationalization of R&D activities.[1] Important results have been obtained about the impact of these FDI on the firm's innovative and economic performance (e.g. Subramaniam and Venkatraman, 2001; Penner-Hahn and Shaver, 2005). In particular, on the firm's capacity of gaining the technological leadership over its rivals on a worldwide scale. These analyses have mainly focused on the "outcome" of the race for the technological leadership, as it might be revealed by the patent specialization of the competing firms (e.g. Cantwell and Andersen, 1996). Conversely, little attention has been paid to the effect of FDI on the firm's capacity of outperforming the rivals in their R&D investments.[2] Furthermore, in those studies which have addressed the FDI-R&D relationship, *leaders* and *followers* have been distinguished on the basis of exogenously chosen statistical moments (e.g. mean and/or median) of their R&D intensity (e.g. Alcácer and Chung, 2007). In this way, firms with a higher (e.g. than the mean) R&D intensity are easily distinguished from those with a lower intensity among those which invest abroad, and scale effects can be comfortably ruled out from the analysis (e.g. by relating R&D to sales or employment). However, in so doing sight is unfortunately lost of two important issues: (i) the volume of the R&D expenditures firms can afford to invest in; (ii) the 'endogenous' thresholds that the identity and characteristics of the relevant players make emerge as necessary to overcome in order to stay among the leaders.

As we will claim in the following (Section 2), both of these aspects deserve special attention in addressing the issue at stake, as they represent a domain of competition from which firms can gain important increases of innovation and economic performance. Furthermore, as we will also argue, both can be positively affected by the firms' decisions to invest abroad, although to an extent which depends on the activities FDI occur in. Accordingly, they identify an additional sphere of activities on which internationalization policies can intervene in order to foster the firms' competitiveness.

In the application of the paper, we provide an empirical test of these arguments by

[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).

looking at the European Industrial and R&D Scoreboard, which maps a number of top R&D investors at the European and worldwide level on a yearly basis. More precisely, we merge subsequent releases of this Scoreboard among them and we integrate the resulting panel with fDi Market data, in order to see the role of FDI in enabling the firms to enter, and eventually stay, in the circle (market) of the top R&D investors. Drawing eclectically from the industrial organization literature, we model the competition for this circle through a sort of entry/exit model. The boundaries of this circle are first determined by looking at the distribution of the investment capacity companies reveal in R&D at the worldwide level. FDI are then plugged into the model among the explicatives that can account for the propensity firms have to entry in and exit from such a circle.

As the Scoreboard companies are typically large conglomerates, operating in several international markets, which together account for more than 80% of the total world R&D, their analysis represents a natural point of departure in searching for the circle of top R&D investors among them. 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".

The remainder of the paper is organised as follows. Section 2 illustrates the theoretical background and presents the main research hypothesis of the paper. Section 3 describes the model through which we test this hypothesis and the employed dataset. Section 4 discusses its results. Section 5 concludes and draws some policy implications.

2 Theoretical background

2.1 R&D leaders and R&D top spenders

The fact that firms compete also and above all through their innovations has attracted a lot of attention in economic and management studies, especially along the Schumpeterian tradition. A number of drivers have been identified for firms to emerge as technological leaders in their markets and to build up a competitive advantage on this leadership (Teece, 2006). The mastery of core capabilities – 'dynamic' ones, in particular (Teece and Pisano, 1994) – and the control of 'complementary assets' (Teece, 1986) – in marketing, distribution, and manufacturing, for example – have appeared crucial to complement what remains however the key innovation input: that is, the firm's capacity to invest in R&D. In strategic management and in business studies the debate on the firm's technological leadership has in fact evolved into that on the gains that R&D leaders have with respect to R&D followers. Drawing on and extending Caves and Porter (1977)'s conceptual framework, these advantages have been identified in a mix of (i)knowledge-spillovers, (ii) product differentiation, and (iii) economies of scope. In parallel, the economic literature on innovation races spurred by Reinganum (1985)'s work has shown that a larger R&D spending is a source of higher monopoly rents and future performance, although with different outcomes between incumbents and new entrants of a sector. Finally, in the accounting literature on R&D evaluation, R&D leaders have been found to earn significant future excess returns on the R&D followers, even aside from their use for risk compensation (Lev et al., 2006).[3]

In all of these studies, R&D leadership is captured by referring to some proxy of the firm's R&D intensity, like the ratio of R&D expenditure to sales, or to the market value of equity. As is well known, this is motivated by the intent of getting rid of size effects and focusing on the importance that R&D has with respect to the business scale of the firm. In this vein, large R&D spenders are those which invest the most of their resources in R&D, but not necessarily those which invest the largest amount of money in R&D, or in the largest R&D projects. However, being among the largest R&D spenders of an economic sector in absolute terms could be relevant too. On the one hand, on the stock market the scale of the firm's R&D expenditures has a signaling value of the firm's reputation and capacity of dealing with important technological breakthroughs, although in terms of market capitalization this is counter-balanced by the signaling of higher volatility of future earnings (Hall and Oriani, 2006; Cincera et al., 2009). In real 'markets', instead, targeting the group of the largest R&D spenders can increase the firm's probability to overcome sectoral thresholds in the relative expenditures, which make the R&D investment a "dilemma" (González and Pazó, 2004). Under a certain absolute level, the output effect of investing could in fact be not big enough to recover its costs, given the presence of indivisibilities of some R&D resources (*à la* Arrow) like: the fixed costs of research labs, the specialization required for an efficient team research work, and the pool of research projects for an adequate sharing of their risk. Furthermore, increasing the size of R&D investments above that of the majority of the 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).

From the previous considerations, a number of advantages can accrue to the top R&D investors. 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 – that is, 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 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).

While we claim that looking at top R&D spenders provides relevant information for detecting actual R&D leaders, we also cast some doubts on the methodological choice

[3] A different angle for the analysis of the firm's technological leadership is represented by those innovation studies which, instead of R&D and of its economic outcomes, look at patents and at the knowledge control that the specialization in some crucial fields allows to the firms for competing in their economic sectors in terms of innovations (Cantwell and Andersen, 1996).

that the extant literature makes for distinguishing them from the followers. In general, this is done by calibrating the distinction for the competitive forces operating within the industry and by referring to some kind of industry-adjusted R&D intensity. Firms whose R&D intensity is greater than (less than or equal to) that of the benchmark R&D intensity for the industry are classified as R&D leaders (followers). Different weighted and/or unweighted averages are considered as the benchmark (Lev et al., 2006; Alcácer and Chung, 2007). This approach enables one to retain the sector-specific nature of R&D leaders/followers (i.e. R&D followers of some sector could be leaders in another). However, it neglects that the race for R&D (and innovation) spans also across the boundaries of the firm's main economic activity. On the one hand, firms generally invest in a much wider spectrum of technologies than those which pertain to their production realm (Brusoni et al., 2001). On the other hand, the largest R&D expenditures are carried out by conglomerates which operate in a number of economic sectors, making the industry calibration of their R&D leadership even less accurate. The relative position that a firm reveals with respect to its world R&D rivals, rather than to industry rivals as such, could be equally important to ascertain its eventual R&D leadership. Furthermore, rather than identifying such a position through a standard and exogenously given momentum (e.g. the median of the ranking), it could be interesting to see whether the competition for the largest R&D investments endogenously determines some thresholds of expenditure, which some firms only can afford to overcome, thus emerging as leaders for the contingent distribution of expenditures that they identify. In so doing, the status of R&D leader is more directly related to the firm's capacity of outperforming its rivals in front of the 'R&D dilemma': that is, in accessing the 'club' of those R&D spenders which can bear the up-front costs for the most impacting R&D activities. As we will claim in the following, FDI can have a role in fostering such a capacity.

2.2 FDI and the competition for (higher) R&D expenditure

The relationship between FDI and R&D is a complex one. On the one hand, R&D activities can be claimed to provide firms with a number of advantages for becoming (more) multinational: both direct advantages, like those pointed out by the standard OLI (ownership, location, internationalization) paradigm (Dunning, 1977); and indirect ones, such as the R&D productivity premium that firms can exploit for investing abroad, pointed out by the new literature on heterogeneity in trade and FDI (Helpman et al., 2004). On the other hand, FDI can have an impact on the firm's R&D in turn, as is shown by the pivotal role of MNC in accounting for the volumes of R&D investments worldwide and for their internationalization (UNCTAD, 2005; UNESCO, 2010). This complexity makes the relationship at stake a dynamic interaction, with potential reverse causality, whose empirical analysis could be easily a source of endogeneity problems (Reeb et al., 2012).

Paying particular attention to this problem, in the paper we focus on the impact that FDI can have on the firm's level of R&D expenditure. Such an impact is apparently straightforward when we look at the international investments that the literature has called *knowledge* (or *technology*) *seeking* (Cantwell, 1989; Patel and Vega, 1999).

These are a specific version of the "strategic-asset-seeking" FDI identified by the seminal Dunning (1993)'s taxonomy and are mainly, though not exclusively, represented by *FDI in R&D* (Castelli and Castellani, 2013). Through these FDI, MNC can tap into the technological knowledge of the host country and catch-up with companies at the global frontier – when they actually lag behind (Pearce, 1999; Niosi, 1999) – but also sustain their eventual technological leadership by renewing their knowledge–base (Cantwell and Janne, 1999; Chung and Alcácer, 2002). "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). Accordingly, knowledge seeking can also occur between countries whose differences in technological levels and R&D intensity are small. For this reason, although the level of development of the host country keeps on differentiating their location choice and their impact (Hall, 2011), the analysis of the firm's portfolio of FDI in R&D can be of relevance even disregarding their destination, as we actually do in the paper.

The internationalization of R&D via FDI has received a lot of attention. Several studies have concentrated on the effects it has on the inventive capacity of the investing firms, for example in terms of patents production and/or citation (e.g. Penner-Hahn and Shaver, 2005; Criscuolo et al., 2005). Some other have focused on the effects that the internationalization of R&D has on the introduction of new innovative products (Subramaniam and Venkatraman, 2001; Naghavi and Ottaviano, 2009).[4]

The impact that the internationalization of R&D has on R&D expenditure as such has instead been less investigated. FDI in R&D have been shown to make this expenditure more geographically footloose, if not even to change the patterns of innovation specialization of the investing firms (Hall, 2011). More relevant for our research question is a different strand of literature, which has looked at the level of investments of MNC – especially compared to national firms – in both tangible and intangible assets, and in R&D in particular. The empirical evidence reported in this works show that multinational activities appear to increase the firm's propensity to invest in intangibles like R&D (Egger and Pfaffermayr, 2009) and their scale too. The possibility that FDI crowds out the firm's domestic expenditures in R&D is in general excluded (Desai et al., 2009). For a simple cost-benefit motivation, the decision to locate R&D abroad rarely implies the shut–down of a lab at home, and is rather accompanied by an expansion of the firm's R&D capacity (Hall, 2011). R&D investments carried out abroad can even have a "multiplier effect" with respect to that invested at home (Makino et al., 2002). This is particularly so in the case of technological leaders that, unlike laggards, engage

[4]In general, a positive innovation impact of the firm's R&D internationalization is not guaranteed and rather depends on a set of aspects. The complementarity between the technological base of the home and of the host country, the techno-economic characteristics (e.g. opportunity and appropriability conditions) of the industries in which they operate, the individual traits of the companies investing abroad, among which their capabilities of interacting and networking with the foreign providers, have appeared crucial (Chung and Alcácer, 2002; Song et al., 2011; Ambos, 2005; Piscitello and Santangelo, 2011)

in foreign R&D to capture a larger share of profits on the foreign market (Belderbos et al., 2008).

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 scale R&D investments, which could not be sub–divided to fit the capacity of the home labs (De Meyer, 1993; Chen and Chen, 1998). The internationalization of R&D could also be beneficial for running large multi–technology projects based on a multi-disciplinary kind of knowledge, which is 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).

On the basis of these arguments, our first research hypothesis is that FDI in R&D could help the investing firm to join the circle of the top R&D spenders, and possibly remain within it over time, benefiting from the advantages we have illustrated in the previous section.

An impact on the global competition for the R&D leadership can also be expected from FDI in other activities than R&D, such as manufacturing activities as such, if not even service ones (e.g. marketing). In these cases the channels through which FDI can increase the scale of the firm's operations in R&D is less direct, but still arguable. First of all, FDI could matter in this respect when they are *resource seeking*, that is driven by the MNC's search for particular types of resources that are not available at home, in absolute terms or at convenient relative prices (Dunning, 1993). Even when we leave apart those technological and innovation management capabilities that fall more naturally in the knowledge seeking category (Franco et al., 2010), other international resources can in fact represent crucial complementary assets for the implementation of large R&D projects by MNC. This is particularly evident with respect to skilled labor, which represents a crucial 'asset' that R&D intensive multinationals 'seek' for implementing their innovation projects into economic activities on a global scale (Zanfei, 2000). Similarly, in order to move along the innovation value-chain, the firm's R&D could be in need of natural resources available in the international markets (think about pharmaceutical and electronic MNC in need of chemicals and semiconductors, respectively), and for whose acquisition transaction costs and incomplete contracts might make international trade (e.g. in the form of outsourcing) inconvenient.

FDI in non-R&D activities can magnify the scale of the MNC's R&D expenditure also when they are driven by a *market seeking* motivation (Dunning, 1993), a reason that can also drive FDI in R&D and that amplifies their role for the issue at stake. In general, a number of the international investments that MNC carry out, especially in manufacturing, are driven by their search for host markets of greater dimensions and/or host markets of a special appeal in order to: interact with key foreign suppliers and customers, prevent potential competitors from entering, and supplying adjacent markets with goods and services ('export-platform' FDI (Ekholm et al., 2003)). In the former case, these FDI can provide the MNC with economies of scale that could lower the production costs of the outcomes of their R&D projects and overcome eventual indivisibilities for doing that. In the latter case, instead, the commercialization of the MNC's R&D outcomes could be facilitated by economies of scope accruing by the exploitation of country-differences in consumer tastes and supply capabilities.

This last set of arguments leads us to our second research hypothesis, which is twofold. First of all, we expect that the firm's capacity of joining and resisting the competition for the largest R&D volumes is significantly affected by its FDI in non-R&D activities. Secondly, we expect that this effect will be lower than that of FDI in R&D (our previous hypothesis) for the reasons we have implicitly addressed in our discussion. In brief, non-R&D FDI have a less direct link with the firm's R&D expenditures than R&D ones, as they refer to assets and markets which are complementary (and in some cases even conditional) to its inventive activities. Furthermore, unlike non-R&D ones, FDI in R&D could simultaneously work for both knowledge and market (if not even, resource) seeking and thus have an amplified impact on the MNC's R&D.

3 Empirical application

3.1 R&D and FDI company data

The data used for the empirical application comes from two sources. On the one hand, R&D investments have been drawn form 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 the world business R&D expenditure, that the Institute of Prospective Technological Studies (IPTS, Joint Research Centre, European Commission) carries out annually since 2004. In particular, company level data have been drawn for the R&D investments, and for other accounting variables, of the top 1,500 R&D investors over the period 2004-2011.

Scoreboard information have been matched with data from a second source, that is fDi Markets, by fDi Intelligence (The Financial Times Ltd). The database tracks cross-border greenfield investments, covering all sectors and countries worldwide since 2003. In particular, from the database information has been drawn on FDI projects classified by investment activities (e.g. R&D, manufacturing, sale and marketing) and on their capital expenditure (*Capex*).[5]

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

[5] 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 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.

retained for the empirical application. As Table 1 shows, in-between 2003 and 2012, these top R&D spenders have invested in 33,572 FDI projects. The largest number of them has been initiated in manufacturing (37.6%), followed by sales and marketing (14.6%), and then R&D (11.7%), pointing to a pattern of internationalization of economic activities that is quite well known (e.g. Karabag et al., 2011).

Table 1: Distribution of FDI projects per economic activities

FDI Activity	# of Projects	%
Manufacturing	12,612	37.6%
Sales, Marketing Support	4,909	14.6%
Research & Development	3,918	11.7%
Retail	2,795	8.3%
Logistics, Distribution Transportation	1,808	5.4%
Business Services	1,655	4.9%
Headquarters	1,290	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	33,572	

Although lower than in manufacturing and marketing/sales, the share of projects in R&D is not negligible. It should also be retained that, for the sake of our empirical application, among these we have also considered the projects that fDi Markets classifies as "Design, Development & Testing" projects as distinguished from "Research & Development". This is an empirical choice made by other studies using the current database, and motivated by the fact that knowledge sourcing opportunities may arise at different stages of the research and development/deployment chain of the innovative companies. A finer analysis of the R&D projects mapped by fDi Markets has revealed among them the presence of foreign R&D labs that carry out local *development* activities, and even *adaptation* activities of products and technologies to local customers, in addition to pure *research* labs (D'Agostino and Santangelo, 2012). Still, the inclusion of FDI in design, development and testing helps us in retaining further learning processes that occur on the basis of research, trials-and-errors and feed-backs at lower stages of the innovation chain. One should just think of the case of software companies, for which the research and the testing of the product is nearly indistinguishable.

3.2 The circles of the top R&D investors

Looking for a threshold to identify the circle of the top R&D investors at the worldwide level is not an easy task. The IRI Scoreboard already identifies a threshold with this aim, but it simply sets it up exogenously with a fixed number of companies, with respect to which it carries out the analysis over time. Apart from being exogenous, the same threshold has appeared to separate from the non-Scoreboard ones a number of companies whose innovative behavior and economic performance is far from homogeneous. Kancs and Siliverstovs (2012), for example, have recently shown that the relationship between R&D expenditures and productivity growth of the Scoreboard companies is actually non-linear. Namely, 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 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 climbed, 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 year (2011) (Figure 1) confirms this expectation (the distribution for the others years is almost identical). The level of R&D expenditure "increases" at an increasing pace approaching the top of the ranking. The relationship between the companies ranking position and their R&D expenditure appears exponential, with the latter that starts to break off around the 500^{th} rank position and takes then off around the 250^{th}. In other words, in correspondence of these two positions the R&D rate of change along the ranking increases steeply, suggesting these to be the most important posts (not to say discontinuities) for leaders to let the followers at a safer distance.

It should be noticed that, while the 250^{th} cut-off is actually close to the average of the R&D distribution (reached by the 265^{th} position), generally used in the literature for discriminating R&D leaders from the followers, the 500^{th} one appears more selective than the median position (the 750^{th}), also used for the same scope. In order to test whether the thresholds emerged from the data are more informative than the standard ones, we have thus regressed the R&D growth rates along the sample ranking against a dummy for each of 'our' candidate positions and for the average and the median ones. Table 2 compare the relative R^2 and F statistics, revealing that, in both cases, our thresholds explain a larger part of the variance of the R&D growth rates and provide a better fit to the data we are analyzing. Accordingly, the 250^{th} and the 500^{th} positions have been chosen as boundaries of the (two) circle(s) of top R&D investors we are looking for.

Let us observe that the thresholds at word actually discriminate our Scoreboard companies in a way which is consistent with our theoretical premises. At first, Table 3 shows that the identified groups actually concentrate the bulk of the R&D expenditure, both at the beginning and at the end of the retained 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 we consider the top 500, the share over the total R&D expenditures raises up to about 82%, with a concomitant decline in the median value (366). Com-

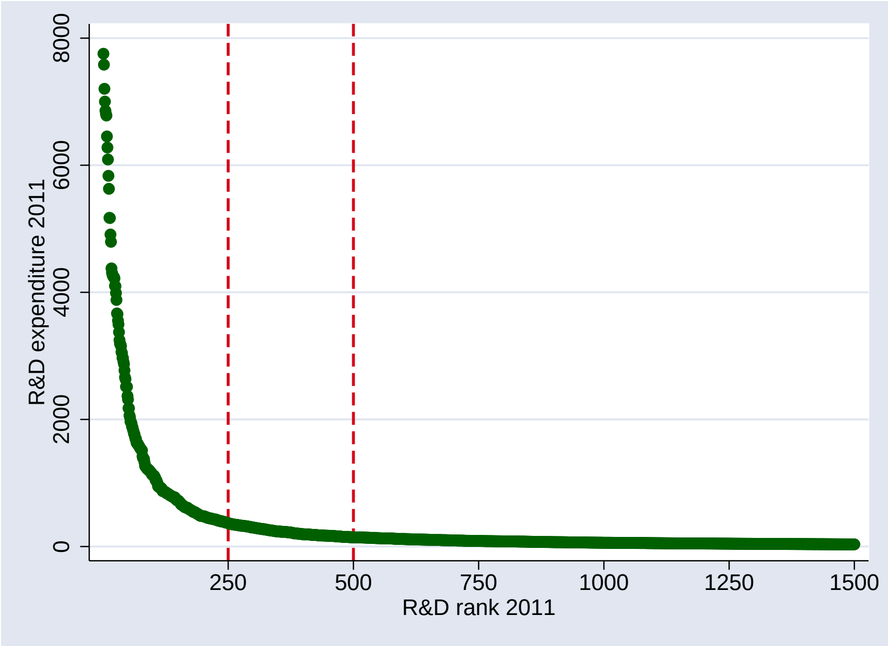

Figure 1: Ranking and R&D expenditures

Table 2: Testing the thresholds on R&D growth-rates along the ranking

	250th		Average (265th)	500th		Median (750th)
Threshold	0.0104***		0.0099***	0.0065***		0.0047***
	(0.000)		(0.000)	(0.000)		(0.000)
R-squared	0.270	>	0.260	0.171	>	0.101
F-test	553.7	>	525.5	309.1	>	167.7

panies below the 500 ranking position display on average a much lower level of R&D expenditure. Similar patterns can be observed in 2004 (our first year sample period), when R&D expenditures were even more concentrated.

More relevant is the fact that in 2011, for which we were able to obtain reliable figures only[6], the market capitalization per employee (*MktCap/Emp*) of the (median) Scoreboard companies increases in moving up along 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, when a company is a top spender, investors are inclined 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 top

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

Table 3: 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
Top 500	442,433	82.4%	885	366	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
Top 500	295,672	91.1%	676	243	-	0.020	0.236
Other (501 - 1500)	28,843	8.9%	23	17	-	0.014	0.187
Whole sample	324,514		184	28	-	0.016	0.202

circles in the ladder show better performances than (that of the) followers in terms of two variables usually taken to account for the impact of innovation on the firm's competitive advantage over the rivals (e.g. Nakao, 1993) – that is, operating profit per employee (*OpProf/Emp*) – and on the (labor) productivity of its economic activities (e.g. Ortega-Argilés et al., 2011) – that is, net sales per employee (*Sales/Emp*). These advantages are consistent with those we have hypothesized in Section 2.1.

3.3 Entry-exit and the top R&D circles: model and econometric strategy

In order to model the company's entry and exit with respect to the top circles of the R&D ladder, we draw eclectically on previous studies in industrial organization which address a similar competitive dynamics with respect to markets with different structures and degrees of firm heterogeneity (e.g. Lieberman, 1989; Armstrong and Porter, 2007). For each company $i = 1, \ldots, N$, at time $t = 1, \ldots, T$, we accordingly define entry and exit as the outcome of a Markov process, where $y_{it} = 1$ indicates that the company has a level of R&D spending sufficiently high to be in the ladders' circle, and $y_{it} = 0$ otherwise. The conditional distribution of company's i R&D expenditure, assumed independent across firms, is then given by:

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

where $\pi_{i,v|u}$ is the probability of a transition from the state $u = 0, 1$ at time $t - 1$ to the state $v = 0, 1$ at time t.[7]

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

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

By imposing that $\boldsymbol{\beta}_{00} = 0$ and $\boldsymbol{\beta}_{11} = 0$, 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:

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

and the probabilities of crossing the threshold:

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

Once 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 retrieve both robust standard errors and estimates of the between-model covariances of the parameters, and thus to test for differences (in the absolute values of the parameters) in the two equations. For those covariates that provide a significant contribution in explaining both the entry and exit dynamics, we will test whether they exert symmetric effects on the two processes.

In order to test our research hypothesis, we plug in vector $\mathbf{x}$ the company's involvement in outward FDI projects. As a first step to attenuate the problem of endogeneity that could affect the use of FDI as a regressor for entry/exit in the R&D circles, we take stock of the dynamic nature of our data and introduce a time-lag between the latter and the former. In this way, we factually prevent a reverse causality from belonging to the circles to investing abroad. In order to avoid losing and excessive number of observations, we assume that one year of time could be enough for an FDI project to have an effect on the R&D expenditure of the investing firm, and thus refer to FDI at time $t - 1$ for entry and exit at time t. The green-field nature of the FDI projects collected in the fDi Market database, whose implementation presumably urges a more prompt and substantial injection of fresh R&D resources than a M&A project, makes this 'early' impact hypothesis not so prohibitive to support. Of course, other sources of endogeneity could still remain, that only randomised controlled experiments could

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

satisfactorily solved Reeb et al. (2012). As we will say in the following, in the absence of a suitable counter-factual group, we will resort to the more standard, tough imperfect, technique of controlling for other variables and sources of unobserved heterogeneity in the relationship at stake.

The previous methodology is applied in three Models. In Model 1, we assume that the probability that a company i enters in (Model 1.1), and exits from (Model 1.2), the circle at time t, $\pi_{i,t(1|0)}$ ($\pi_{i,t(0|1)}$) is affected by the number of its FDI projects in R&D at time $t-1$ ($FDIrd_{t-1}$). In so doing, we aim at testing our first research hypothesis (see Section 2.2) by referring to the firm's capacity of setting up and managing knowledge-seeking investments on an international basis, irrespectively from their actual size. In the case in which these projects are also dispersed on a geographical basis – an aspect that is out of the paper's scope – this capacity would also reflect an extensive strategy of internationalization of the focal firm. Alternatively, that is even with an appreciable geographical concentration, the same variable could be taken to account for an intensive strategy, but of cumulative and incremental internationalization through a series of diverse research projects. In both cases, the variable at stake would signal a 'numerous' (possibly frequent) resort to international markets for R&D, from which the learning effects we addressed in Section 2.2 would arguably follow.

In Model 2, the firm's probability of entering in (Model 2.1) and exiting from (Model 2.2) the identified circles at time t is explained by adding to $FDIrd_{t-1}$ the number of FDI projects it has carried out in non-R&D activities ($FDInrd_{t-1}$). In so doing, we aim at testing our second research hypothesis (see Section 2.2), still by referring to the advantages that a copious (and eventually geographically dispersed) resort to international markets could have for R&D vs. non-R&D activities.

Finally, in Model 3 the same logic is repeated (entry in Model 3.1, exit in Model 3.2), by replacing $FDIrd_{t-1}$ with the total capital expenditure in R&D projects by company i at time $t-1$ ($FDIrdexp_{t-1}$). This constitutes a further test of our first research hypothesis, of which it could represent a sort of robustness check. The internationalization of R&D is here addressed with respect to the amount invested in the relative projects, rather than their number. In this way, the learning effects that can accrue from economies of scale in research can be better disentangled from those possibly related to economies of scope, which the number of projects in Model 1 captures. In order to focus on this last aspect, the number of FDI in activities other than R&D ($FDInrd_{t-1}$) is just used as control for the internationalization degree of the focal firm.

In all the three Models we have to retain that, in addition to FDI projects, the process of entry/exit with respect to the circle of top R&D investors could be affected also by other variables, which should enter the $\mathbf{x}$ 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 not unambiguous (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 organization 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) among the R&D ladders 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).

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

In general, estimation results provide us with support to our research hypotheses. However, important and interesting specifications emerge across the two considered circles of top R&D spenders and across the three models.

Our first research hypothesis about the role of FDI in R&D (Section 2.2) gets confirmed when we look at the lower in rank of the two circles (Table 4). A larger number of international R&D projects significantly increases the firm's probability of entering into the group of the top 500 R&D spenders (Model 1.1). Furthermore, it significantly reduces the risk of exiting from the same group in the aftermath of the same projects (Model 1.2).[8]

This is a first interesting result, which adds new evidence on the advantages that companies can have by seeking knowledge internationally and/or by looking for the development and/or adaptation of their research on a global scale. On the one hand, through these international activities firms can afford to pursue the largest R&D investments at the worldwide level, and to compete for the markets and technologies which require such a large R&D involvement: for example, because of the presence of up-front fixed costs and indivisibilities. On the other hand, drawing more extensively than the other R&D giants on international markets for their R&D activities, firms are also able to renew their knowledge base and to better resist the competition for the technological leadership at stake.

Looking at the first circle of top R&D spenders, our second research hypothesis gets confirmed only partially. On the one hand, the access to the group of the 500 largest R&D investors is also helped by FDI projects in activities other than R&D (Model 2.1), although with a low significance and size. Moreover, the size of the coefficient for R&D FDI does not change with respect to Model 1.1. This is a second interesting result of our application, which points to a possible role of 'complementary' international activities

[8] As reported at the bottom of the estimation tables, tests on the coefficients prevent us from retaining as significant apparent differences between those for entry and exit.

to R&D ones for firms to reach the leadership for the largest R&D investments: investing abroad in search of resources and/or markets might provide firms with an R&D advantage, even when this occurs in other activities than R&D. The degree of internationalization 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 a larger scale of R&D investments in order to exploit them.

On the other hand, a greater internationalization of activities other than R&D does not help the R&D giants to resist the competition for the same leadership, as the number of FDI projects in R&D instead keeps on doing (Model 2.2). While a wider access to research-based knowledge sources at the global level helps the leaders to stay in the top-500 circle, a larger number of international activities *per se* does not guarantee safer positions in it. Once they got in the circle, companies need to resort to more research-related international strategies for resisting the competition of the new large-R&D comers. This result supports the second part of our second research hypothesis, which is also confirmed by the size of the coefficients in Model 2.1. As expected, a larger portfolio of international R&D projects helps more than a larger portfolio of other international economic activities in climbing the R&D ladder. As we argued in Section 2.2, the former provides more direct and extensive advantages in terms of R&D expenditure than the latter.

Table 4: Top 500 estimations

	Entry 500 (1.1)	Exit 500 (1.2)	Entry 500 (2.1)	Exit 500 (2.2)	Entry 500 (3.1)	Exit 500 (3.2)
$FDIrd_{t-1}$	0.5185***	-0.5990***	0.5271***	-0.5415***		
	(0.184)	(0.218)	(0.169)	(0.207)		
$FDInonrd_{t-1}$			0.0501*	0.0199	0.0512*	0.0197
			(0.028)	(0.027)	(0.029)	(0.029)
$FDIrdexp_{t-1}$					0.0115***	-0.0214**
					(0.004)	(0.010)
$Log(Emp)$	0.6673***	-0.7844***	0.6303***	-0.7131***	0.6480***	-0.7173***
	(0.120)	(0.163)	(0.116)	(0.137)	(0.117)	(0.139)
$OpProf$	0.0001***	-0.0001	0.0001**	-0.0001	0.0001**	-0.0001
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
Age	0.0000	-0.0016	0.0005	-0.0015	0.0005	-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	-9.1097***	-8.7567***	-8.7680***	4.0037**	-8.9274***	4.0019**
	(1.750)	(1.895)	(1.223)	(1.601)	(1.239)	(1.618)
Observations	3,899	3,899	3,899	3,899	3,899	3,899
Pseudo R-squared*	0.182	0.198	0.184	0.199	0.158	0.155
Coefficient tests						
FDI projects in R&D: $\lvert entry \rvert = \lvert exit \rvert$	*0.08 (0.7779)*		*0.01 (0.9571)*			
FDI capex in R&D: $\lvert entry \rvert = \lvert exit \rvert$					*0.79 (0.3733)*	
Employees: $\lvert entry \rvert = \lvert exit \rvert$	*0.33 (0.5642)*		*0.21 (0.6448)*		*0.15 (0.7031)*	

*Robust standard errors in parentheses - *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$ - Pseudo R-squared from the original logit regressions*

In this last respect, let us also observe that, as Figure 2 shows, the estimated probabilities of *entering* in the circle of the top 500 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 lowest numbers of projects, revealing a kind of logistic distribution. Conversely, the estimated probabilities of joining the same group increase much more smoothly, with the increase in the number of non-R&D FDI (lower part of the figure). As we said, unlike a knowledge-seeking driven, a general internationalization strategy, whose knowledge outcome can be only indirectly functional to R&D investments, appears less powerful in guaranteeing the status of top spenders.

Still with respect to the first of the two thresholds (Table 4), our research hypotheses are supported also when the scale of the international R&D activities of the sampled firms is retained, instead of their number. Once we control for their internationalization degree in other activities ($FDInrd$), the firms with the largest international projects in R&D ($FDIrdexp$) get similar gains than those with the most numerous ones: the probability of joining the top 500 increases (Model 3.1), as well as that of remaining among them (Model 3.2). This is a third interesting result of our application, which suggests an additional and possibly more expected channel through which the internationalization of R&D can help the firms compete for the leadership in the volumes of R&D expenditure: that is, through the benefits of economies of scale at the global level. While Models 1 and 2 tell us that a pervasive strategy of knowledge/technology seeking could be enough for climbing the R&D giants' shoulders, irrespectively from the size of the projects and thus possibly with the benefits of economies of scope, Model 3 tells us that the intensity of the R&D internationalization also matters. As we said, setting in motion international 'innovative' projects of larger amounts could actually enable companies to overcome the indivisibilities that often prevents them from implementing R&D investments.

The previous results are nearly completely confirmed when we look at the R&D spenders' dynamics with respect to the upper in rank of our two thresholds, that is the 250^{th} position (Table 5). Increasing the number of FDI in R&D appears a significant strategy for gaining (Model 1.1) and maintaining (Model 1.2) the access to the very top of the worldwide ranking in terms of R&D expenditure. As Figure 2 (upper part) shows, and as expected, reaching this upper circle through R&D internationalization is more difficult than reaching the lower circle, at least for the companies with a smaller portfolio of R&D projects: the first part of the blue sigmoid is shifted downward with respect to the green one. Still, setting FDI in R&D projects at work helps with that. Along with evidence on the 500^{th} position, this result provides a general support to our first research hypothesis: knowledge/technology seeking international activities can have a significant impact on the companies' R&D volumes of expenditure.

The entry/exit dynamics with respect to the higher 250 spenders also support our second research hypothesis, about the role of FDI in activities other than R&D. Once more, the support is partial and limited to the access to this higher group (Model 2.1), which is significantly fostered by resource/asset and market seeing FDI ($FDInrd$), but to a lesser extent than by knowledge/technology seeking ones ($FDIrd$). Also in this

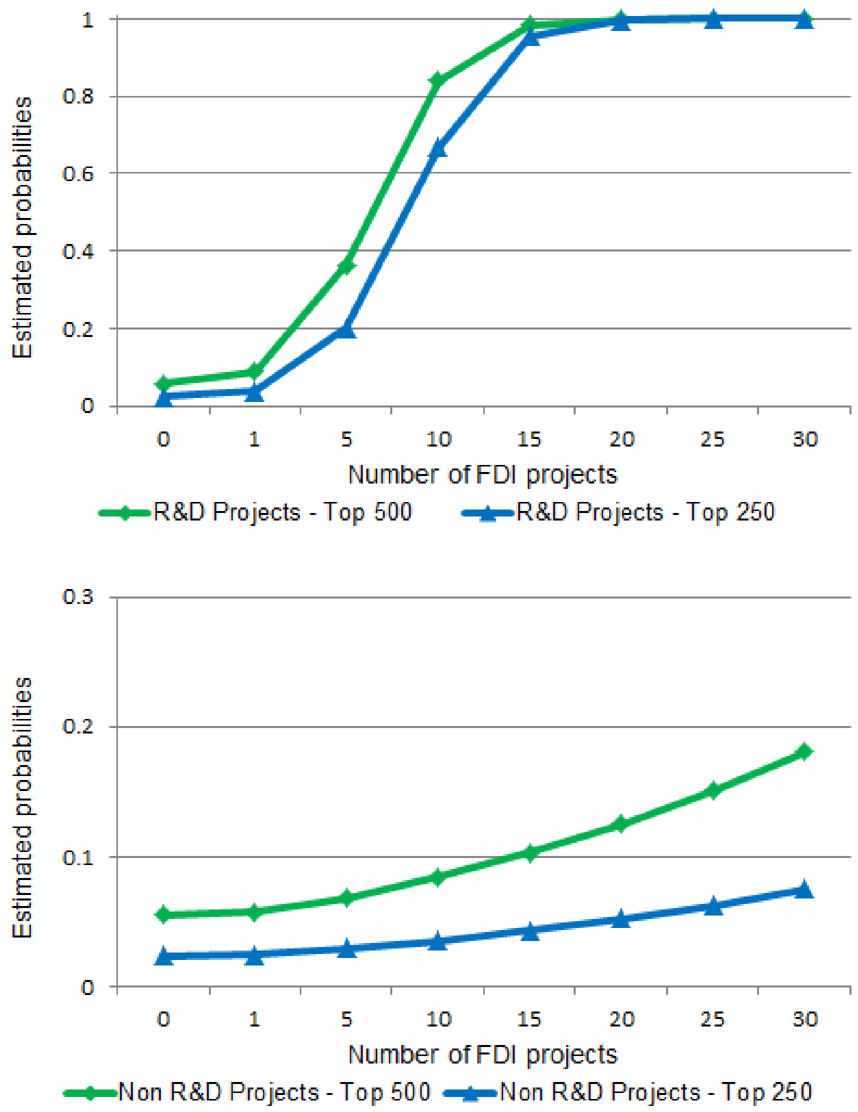

Figure 2: Estimated probabilities of entering in the top 500 & 250 circles

case, the comparison between the upper and lower part of Figure 2 (blue lines) suggests that widening the portfolio of non-R&D international projects increases the entry-probabilities in the group much more smoothly than widening that of R&D projects. Furthermore, the same internationalization strategy is much less powerful than that of targeting the top 500. The blue line stands quite below the green line in the lower part of the figure. Quite interestingly, the divide between the two curves is larger than in the upper part of the same figure, suggesting that the 'escalating power' of non-R&D FDI gets more substantially exhausted than that of R&D FDI.

Our second research hypothesis is instead not confirmed when we look at the exit dynamics from the group of the top 250. Similarly to the top 500, a generic increase of the internationalization degree of the sample companies is not enough (significant) for protecting them against the competition of new large R&D comers, which apparently requires more research-based international activities (Model 2.2).

An important element of variation with respect to the previous circle emerges when we consider the size of the international R&D activities of our firms ($FDIrdexp$). On the one hand, as in the previous case, larger FDI in R&D makes entry in the top 250 circle easier (Model 3.1). On the other hand, unlike the previous case, bigger international projects in R&D do not make the top 250 more 'sticky' (Model 3.2). Once this part of the R&D 'iceberg' is reached, economies of scale in research stop constituting a reliable safeguard against the risk of following down from it. At the same level, it is only an extensive (or incrementally intensive) internationalization of R&D, possibly more inclined to a diversication mode, that can help in staying within the group.

In concluding, some interesting results emerge from the controls used in the estimations. First of all, as expected, larger firms are more prone to make the investigated shifts along the R&D ladder. Conversely, the smaller ones are more inclined to exit from the R&D circles at stake, pointing to an interesting extension of the hypothesis of the "liability of smallness" in industrial dynamics. No significant effect is instead found for the extension of the "liability of newness" to our realm. The coefficients attached to the variable *Age* are not statistically significant (a part from one case at 10%): once the effects of the other variables are taken into account, a company's age does not contribute to explaining its capacity of climbing the R&D giants' shoulders. In this specific realm, the higher opportunities which are usually recognized to younger firms in industrial dynamics do not seem to matter. Entry-in and exit-from the R&D circle does not seem an issue of industrial demography. Finally, the companies' profitability has a significant effect on the probability to enter into the top 500th circle, and the same holds true, for the probability of staying in the more restricted 250th one. The availability of internal financial resources, by relaxing the financial constraints that companies' may face when investment decision are taken, could explain the further result. As for the second, an expectedly higher financial performance of the top 250 might make the availability of cash-flows less important for R&D investment decisions. However, more cash-flow could be needed to keep an open window on the new opportunities in the market.

Table 5: Top 250 estimations

	Entry 250 (1.1)	Exit 250 (1.2)	Entry 250 (2.1)	Exit 250 (2.2)	Entry 250 (3.1)	Exit 250 (3.2)
$FDIrd_{t-1}$	0.6334***	-0.3882**	0.5644***	-0.3591**		
	(0.178)	(0.158)	(0.168)	(0.153)		
$FDInonrd_{t-1}$			0.0463*	-0.0030	0.0508*	-0.0117
			(0.026)	(0.048)	(0.028)	(0.048)
$FDIrdexp_{t-1}$					0.0129***	-0.0057
					(0.004)	(0.006)
$Log(Emp)$	1.0037***	-0.5507***	0.9037***	-0.5493***	0.9281***	-0.5816***
	(0.178)	(0.213)	(0.140)	(0.190)	(0.142)	(0.197)
$OpProf$	0.0001	-0.0001*	0.0001	-0.0001**	0.0001	-0.0001**
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
Age	0.0057*	0.0036	0.0030	0.0023	0.0030	0.0025
	(0.003)	(0.004)	(0.002)	(0.004)	(0.002)	(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	-12.2994***	-7.8428***	-12.5526***	3.3187	-12.7608***	3.5489
	(2.129)	(2.797)	(1.512)	(2.231)	(1.546)	(2.288)
Observations	3,899	3,899	3,899	3,899	3,899	3,899
Pseudo R-squared	0.268	0.194	0.269	0.194	0.232	0.159
Coefficient tests						
FDI projects in R&D: $\|entry\| = \|exit\|$	*1.06 (0.3033)*		*0.81 (0.3670)*			
Employees: $\|entry\| = \|exit\|$	*2.67 (0.1025)*		*2.25 (0.1333)*		*2.04 (0.1530)*	

*Robust standard errors in parentheses - *** p < 0.01, ** p < 0.05, * p < 0.1 - Pseudo R-squared from the original logit regressions*

5 Conclusions

In a global scenario, innovation competition also entails struggling for the leadership in 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.

The internationalization of R&D through FDI can help in this respect, as multinational projects of this kind enable companies to access new knowledge sources for their technologies. Although less directly, an impact on the firm's capacity to compete for the circles of the top R&D expenditure worldwide can also be expected by other international activities, through which MNC can search for markets and resources for implementing their larger R&D projects.

Our application to the companies of the European Scoreboard of Industrial Research and Innovation generally confirms these hypothesis, shedding new lights on the innovation advantages of internationalization. FDI in R&D give a significant and positive contribution to climbing on the R&D giants' shoulders: a contribution that also passes through the economies of scale that large R&D international projects entail, but which is not necessarily related to that, as a large portfolio of projects of this kind can work equally well. To be sure, only the latter guarantees to the investing firm to keep their leadership in R&D expenditure against competition, while the former stops working when the very top of the worldwide ladder is reached. The benefits of international economies of scope could work better than those of economies of scale in this last respect.

Quite interestingly, also FDI projects in activities other than R&D could have a role in supporting the firms in the international technological competition at word. As expected, their impact is lower than that of FDI in R&D for accessing the top R&D circles, while it even vanishes with respect to the firm's capacity of resisting the competition of the new R&D comers. Still, this is an important result, with a first relevant policy implication. Supporting the internationalization of companies through outward FDI could have a side-effect on their R&D capacity and eventually also a domestic innovation impact. Not only can it increase the domestic investments of MNC in R&D, as the extant literature has found. But it can also help the firms to reach a critical R&D mass, which the literature has shown important for their investments to be positively evaluated by the financial markets and to be used in high-scale intensive projects with larger economic returns.

Another set of policy implications is connected to the results about the role of FDI in R&D. First of all, while R&D offshoring could possibly have the drawbacks that the literature has pointed to – for example, the risk of loosing core-competencies and of international knowledge leakage – by helping firms source R&D knowledge internationally (for example, through initiatives of international knowledge transfer and/or qualified labor mobility and exchanges of researchers), policy makers can provide them with important opportunities. On the one hand, they could help companies in affording those critical levels of R&D investments from which the most path-breaking innovation outcomes often follow, with the biggest economic returns. On the other hand, supporting the internationalization of R&D, though mainly in terms of wider projects portfolios, policy makers could provide firms with a longer temporal window among the top R&D spenders, allowing them for longer opportunities to exploit the acquired knowledge into successful innovations.

Of course, the paper is not free of limitations, which future research on the topic will try to address. First of all, the empirical application does not make use yet of information on the geographical location of the host countries, which would make the identification of the FDI motivations more accurate. A similar improvement could be obtained by further disaggregating the activities other than R&D that have been internationalized by the sample firms. In terms of methodology, the set of research hypotheses we have put forward could be enriched in future by putting more micro-structure on the used entry–exit model.

References

Alcácer, J. and W. Chung (2007). Location strategies and knowledge spillovers. *Management Science 53*(5), 760–776.

Aldrich, H. and E. R. Auster (1986). Even dwarfs started small: Liabilities of age and size and their strategic implications. *Research in organizational behavior 8*, 165–198.

Ambos, B. (2005). Foreign direct investment in industrial research and development: A study of German MNCs. *Research Policy 34*(4), 395–410.

Ambos, T. C., B. Ambos, and B. B. Schlegelmilch (2006). Learning from foreign subsidiaries: An empirical investigation of headquarters' benefits from reverse knowledge transfers. *International Business Review 15*(3), 294–312.

Armstrong, M. and R. Porter (2007). Empirical models of entry and market structure. In *Handbook of Industrial Organization – Volume 3*, pp. 1845–1886. North-Holland.

Belderbos, R., E. Lykogianni, and R. Veugelers (2008). Strategic R&D location by multinational firms: spillovers, technology sourcing, and competition. *Journal of Economics & Management Strategy 17*(3), 759–779.

Brusoni, S., A. Prencipe, and K. Pavitt (2001). Knowledge specialization, organizational coupling, and the boundaries of the firm: why do firms know more than they make? *Administrative science quarterly 46*(4), 597–621.

Cantwell, J. (1989). *Technological Innovation and Multinational Corporations.* Basic Blackwell.

Cantwell, J. and B. Andersen (1996). A statistical analysis of corporate technological leadership historically. *Economics of Innovation and New Technology 4*(3), 211–234.

Cantwell, J. and O. Janne (1999). Technological globalisation and innovative centres: the role of corporate technological leadership and locational hierarchy. *Research Policy 28*(2), 119–144.

Cantwell, J. and R. Mudambi (2005). MNE competence-creating subsidiary mandates. *Strategic Management Journal 26*(12), 1109–1128.

Cantwell, J. and L. Piscitello (2000). Accumulating technological competence: its changing impact on corporate diversification and internationalization. *Industrial and Corporate Change 9*(1), 21–51.

Castelli, C. and D. Castellani (2013). The internationalisation of R&D: sectoral and geographic patterns of cross-border investments. *Economia e Politica Industriale 1.*

Caves, R. and M. Porter (1977). From entry barriers to mobility barriers: conjectural decisions and contrived deterrence to new competition. *Quarterly Journal of Economics 91*, 241–262.

Chen, H. and T.-J. Chen (1998). Network linkages and location choice in foreign direct investment. *Journal of International Business Studies 29*(3), 445–467.

Chung, W. and J. Alcácer (2002). Knowledge seeking and location choice of foreign direct investment in the united states. *Management Science 48*(12), 1534–1554.

Cincera, M., R. Ortega-Argilés, and P. Moncada-Paternò-Castello (2009). The performance of top R&D investing companies in the stock market. Technical report, IRI, JRC-PTS Working Paper.

Cohen, W. M. (2010). Fifty years of empirical studies of innovative activity and performance. *Handbook of the Economics of Innovation*, 129–213.

Cohen, W. M. and D. A. Levinthal (1990). Absorptive capacity: a new perspective on learning and innovation. *Administrative Science Quarterly 35*(1), 128–152.

Criscuolo, P., R. Narula, and B. Verspagen (2005). Role of home and host country innovation systems in R&D internationalisation: a patent citation analysis. *Economics of Innovation and New Technology 14*(5), 417–433.

D'Agostino, L. M. and G. D. Santangelo (2012). Do overseas R&D laboratories in emerging markets contribute to home knowledge creation? *Management International Review 52*(2), 251–273.

De Meyer, A. (1993). Management of an international network of industrial R&D laboratories. *R&D Management 23*(2), 109–120.

Desai, M. A., C. F. Foley, and J. R. Hines Jr (2009). Domestic effects of the foreign activities of us multinationals. *American Economic Journal: Economic Policy 1*(1), 181–203.

Dunning, J. (1977). *Trade, Location of Economic Activity and the Multinational Enterprise: a search for an eclectic approach.* London, Macmillan.

Dunning, J. (1993). *Multinational Enterprises and the Global Economy.* Harlow: Addison-Wesley.

Egger, P. and M. Pfaffermayr (2009). Multinationals have higher domestic investments than national firms. Technical report, Leverhulme Centre for Research on Globalisation and Economic Policy (GEP), University of Nottingham.

Ekholm, K., R. Forslid, and J. R. Markusen (2003). Export-platform foreign direct investment. Working Paper 9517, NBER.

Enkel, E., O. Gassmann, and H. Chesbrough (2009). Open R&D and open innovation: exploring the phenomenon. *R&D Management 39*(4), 311–316.

Franco, C., F. Rentocchini, and G. Vittucci Merzetti (2010). Why do firms invest abroad? An analysis of the motives underlying foreign direct investments. *ICFAI Journal of International Business Law IX*(1-2), 42–65.

Gammeltoft, P. (2006). Internationalisation of R&D: trends, drivers and managerial challenges. *International Journal of Technology and Globalisation 2*(1), 177–199.

Gassmann, O. and M. Von Zedtwitz (1998). Organization of industrial R&D on a global scale. *R&D Management 28*(3), 147–161.

Geroski, P. A. (1995). What do we know about entry? *International Journal of Industrial Organization 13*(4), 421–440.

Gerybadze, A. and G. Reger (1999). Globalization of R&D: recent changes in the management of innovation in transnational corporations. *Research Policy 28*(2), 251–274.

Godoe, H. (2000). Innovation regimes, R&D and radical innovations in telecommunications. *Research Policy 29*(9), 1033–1046.

González, X. and C. Pazó (2004). Firms' R&D dilemma: to undertake or not to undertake R&D. *Applied Economics Letters 11*(1), 55–59.

Granstrand, O., L. Håkanson, and S. Sjölander (1993). Internationalization of R&D: a survey of some recent research. *Research Policy 22*(5), 413–430.

Hall, B. H. (2011). *The internationalization of R&D.* UNU-MERIT, Maastricht Economic and Social Research and Training Centre on Innovation and Technology.

Hall, B. H. and R. Oriani (2006). Does the market value R&D investment by European firms? evidence from a panel of manufacturing firms in France, Germany, and Italy. *International Journal of Industrial Organization 24*(5), 971–993.

Helpman, E., M. J. Melitz, and S. R. Yeaple (2004). Export versus FDI with heterogeneous firms. *American Economic Review*, 300–316.

Honjo, Y. (2000). Business failure of new firms: an empirical analysis using a multiplicative hazards model. *International Journal of Industrial Organization 18*(4), 557–574.

Hundley, G., C. K. Jacobson, and S. H. Park (1996). Effects of profitability and liquidity on R&D intensity: Japanese and US companies compared. *Academy of Management Journal 39*(6), 1659–1674.

Kancs, d. and B. Siliverstovs (2012). R&D and non-linear productivity growth of heterogeneous firms. EUR - Scientific and Technical Research Reports JRC77247, European Commission, Joint Research Centre, Institute for Prospective Technological Studies.

Karabag, S. F., A. Tuncay-Celikel, and C. Berggren (2011). The limits of R&D internationalization and the importance of local initiatives: Turkey as a critical case. *World Development 39*(8), 1347–1357.

Kinkel, S. and O. Som (2012). Changing patterns of R&D relocation activities in the course of the global economic crisis. Technical report, DRUID summer conference, June 2012.

Lev, B., S. Radhakrishnan, and M. Ciftci (2006). The stock market valuation of R&D leaders. Technical Report 2451/27475, NYU Working Paper.

Lev, B. and T. Sougiannis (1996). The capitalization, amortization, and value-relevance of R&D. *Journal of accounting and economics 21*(1), 107–138.

Lieberman, M. B. (1989). The learning curve, technology barriers to entry, and competitive survival in the chemical processing industries. *Strategic Management Journal 10*(5), 431–447.

Makino, S., C.-M. Lau, and R.-S. Yeh (2002). Asset-exploitation versus asset-seeking: Implications for location choice of foreign direct investment from newly industrialized economies. *Journal of International Business Studies 33*(3), 403–421.

Maskell, P., T. Pedersen, B. Petersen, and J. Dick-Nielsen (2007). Learning paths to offshore outsourcing: from cost reduction to knowledge seeking. *Industry and Innovation 14*(3), 239–257.

Mikkola, J. H. (2001). Portfolio management of R&D projects: implications for innovation management. *Technovation 21*(7), 423–435.

Mueller, D. C. and J. E. Tilton (1969). Research and development costs as a barrier to entry. *The Canadian Journal of Economics/Revue canadienne d'Economique 2*(4), 570–579.

Naghavi, A. and G. Ottaviano (2009). Offshoring and product innovation. *Economic Theory 38*(3), 517–532.

Nakao, T. (1993). Market share, advertising, R&D, and profitability: an empirical analysis of leading industrial firms in Japan. *Review of Industrial Organization 8*(3), 315–328.

Niosi, J. (1999). The internationalization of industrial r&d: from technology transfer to the learning organization,. *Research Policy 28*, 107–117.

Ortega-Argilés, R., L. Potters, and M. Vivarelli (2011). R&D and productivity: testing sectoral peculiarities using micro data. *Empirical Economics 41*(3), 817–839.

Patel, P. and K. Pavitt (1991). Large firms in the production of the world's technology: an important case of "non-globalisation". *Journal of International Business Studies 22*(1), 1–21.

Patel, P. and M. Vega (1999). Patterns of internationalisation of corporate technology: location vs. home country advantages. *Research Policy 28*(2), 145–155.

Pearce, D. (1999). Decentralised r&d and strategic competitiveness: globalised approaches to generation and use of technology in multinational enterprises (mnes). *Research Policy 28*, 157–178.

Penner-Hahn, J. and J. M. Shaver (2005). Does international research and development increase patent output? An analysis of Japanese pharmaceutical firms. *Strategic Management Journal 26*(2), 121–140.

Piscitello, L. and G. Santangelo (2011). Does R&D offshoring displace or strengthen knowledge production at home? Evidence from OECD countries. In F. J. Contractor, V. Kumar, and S. K. Kundu (Eds.), *Global Outsourcing and Offshoring: an Integrated Approach to Theory and Corporate Strategy.* Cambridge University Press.

Reeb, D., M. Sakakibara, and I. P. Mahmood (2012). From the editors: Endogeneity in international business research. *Journal of International Business Studies 43*(3), 211–218.

Reinganum, J. F. (1985). Innovation and industry evolution. *Quarterly Journal of Economics 100*, 81–99.

Song, J., K. Asakawa, and Y. Chu (2011). What determines knowledge sourcing from host locations of overseas R&D operations?: A study of global R&D activities of Japanese multinationals. *Research Policy 40*(3), 380–390.

Stinchcombe, A. (1965). Social structure and organizations. *The Handbook of Organizations, J. March, editor*, 142–193.

Subramaniam, M. and N. Venkatraman (2001). Determinants of transnational new product development capability: Testing the influence of transferring and deploying tacit overseas knowledge. *Strategic Management Journal 22*(4), 359–378.

Teece, D. and G. Pisano (1994). The dynamic capabilities of firms: an introduction. *Industrial and Corporate Change 3*(3), 537–556.

Teece, D. J. (1986). Profiting from technological innovation: Implications for integration, collaboration, licensing and public policy. *Research policy 15*(6), 285–305.

Teece, D. J. (2006). Reflections on profiting from innovation. *Research Policy 35*(8), 1131–1146.

UNCTAD (2005). *World Investment Report. Transnational Corporations and the Internationalization of R&D.* New York, Geneva.

UNESCO (2010). *Science and Technology Statistics.* UNESCO Institute of Statistics.

Zanfei, A. (2000). Transnational firms and changing organization of innovative activities. *Cambridge Journal of Economics 5*, 515–554.