R&D endowments at home driving R&D internationalisation

Evidence from the Italian business R&D survey

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Abstract

This study aims at unpacking the internal R&D determinants spurring a firm to invest in R&D abroad, that is owning R&D performing affiliates abroad. Differently from previous literature – mainly focusing on country level determinants as well as on motivations for the location choice of foreign R&D – we make a shift in the observation point. In particular, we dig deeper into the characteristics of firms' intra-mural R&D and the different types of R&D outsourcing to assess their association with R&D internationalisation. On the one hand, we account for the different types of R&D employees (share of researchers and technicians on R&D employees) and R&D performance (basic versus applied research; R&D performed in laboratories rather than in production facilities); on the other hand, we focus on a specific type of R&D outsourcing (to non-affiliated foreign partners, that is the "contract offshoring R&D"). The analysis is performed on the unbalanced panel of 33,476 observations referring to all Italian R&D performers over the 2003-2010 period. Our findings reveal that a more structured organisation of R&D at home (e.g. performing R&D in dedicated laboratories) and the propensity to outsource R&D to foreign non-affiliated partners are associated with a higher share of R&D internationalisation.

JEL-Code: F23, O32, O52

Keywords: R&D internationalisation; outsourcing R&D; firm-level R&D drivers

1) Introduction

The internationalisation of business research and development (R&D) has attracted the interest of leading scholars from around the mid-20th century to today (e.g. Hall, 2011). The reason for such persistent interest can be found in a growing empirical evidence about two key phenomena: firstly, the R&D expenditures of foreign affiliates have grown more rapidly, at global level, than domestic companies' R&D spending (OECD, 2008, 2011; Abramovsky et al., 2007), and secondly, such expenditures represent a remarkable share of national overall R&D budgets (Dachs et al., 2014). Interest in the topic has been newly triggered by new and diverging evidence found by recent studies (e.g. Laurens et al., 2015). Some studies reveal that the rate of R&D internationalisation was quite stable during the 1995–2005 period, while others show, for the same period, increased investment in outward R&D, at least in some countries (Iversen et al., 2016).

This difficulty in identifying clear trends in R&D internationalisation is mainly due to the limited availability of micro-level data concerning cross-border R&D expenditures (Dachs et al., 2014). This limitation has influenced empirical works on the topic in a twofold manner: on one hand, the relevant literature is based on either *ad hoc* surveys with a limited number of firms (Ambos and Ambos, 2011) or patent data (Belderbos et al., 2013), and, on the other hand, the theory has long been focusing on the trade-off between R&D investment at home or abroad as well as the presence of different R&D motivations (so called 'asset augmenting' versus 'asset exploiting') (Arvanitis and Hollestein, 2011; Kuemmerle, 1999; Patel and Pavitt, 1991; Pearce, 1999) and on the possible hollowing out effects of R&D investment abroad on the home country (Criscuolo and Patel, 2003). As a consequence, many analyses have been confined to a country level, trying to compare the characteristics of home and/or host countries as drivers of cross-border R&D investment (Patel and Vega, 1999; Le Bas and Sierra, 2002).

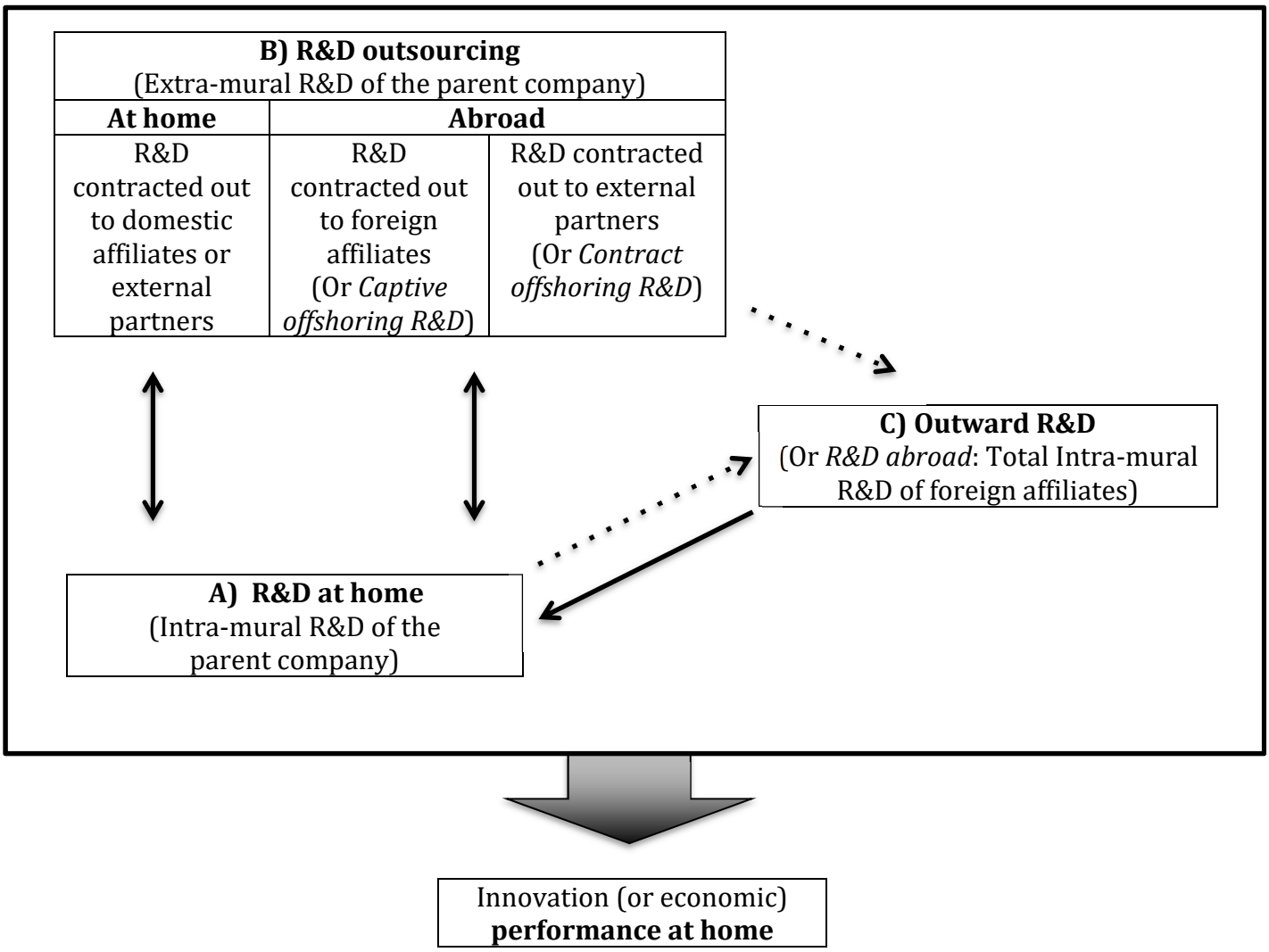
More recently, increased accessibility to firm-level data has allowed researchers to deepen the above-mentioned research questions (e.g. looking at the firm-level determinants of global R&D, as in Belderbos et al., 2013) as well as broaden them. In particular, many scholars have jointly

analysed the drivers of R&D outsourcing and offshoring (Martínez-Noya and García-Canal, 2011; Steinberg et al., 2017; Tamayo and Huergo, 2017).However, we point out that, in this stream of literature, when R&D is outsourced to a firm's foreign affiliates, scholars usually refer to it as 'captive offshoring R&D', and when R&D is outsourced to non-affiliated partners abroad, it is referred to as 'contract offshoring R&D'[1]. Thus, foreign affiliates have a dual nature: on the one hand, they can perform R&D as a result of a request (and funding) by a parent firm (termed 'captive offshoring R&D'), and on the other hand, they can undertake their own internal, self-funded R&D projects and provide other firms or institutions with R&D services on a market basis. This second nature is being neglected in studies looking only at R&D outsourced to foreign partners, which is just a subset of the whole R&D performed by a firm's foreign affiliates.

Instead, in our paper, the overall R&D activities by foreign affiliates are identified as the 'outward R&D' of the parent firm in the home country, thus signalling the key role of the parent firm in (a) establishing the foreign affiliate with R&D capacities and (b) supporting its further R&D activities. In figure 1, we provide a synthesis of the definitions given above.

[1] A complete overview of the different terminologies used in the R&D outsourcing/offshoring literature can be found in Steinberg et al. (2017) footnote 1, Brossard and Moussa (2016), figure 1.

Figure 1 – Theoretical framework in the current R&D outsourcing/offshoring debate



Note: continuous arrows represent research questions existing in literature; dotted arrows the neglected ones.

Source:Authors

A further point we note is that most of the studies aimed at explaining the role of R&D outsourcing and offshoring in firms' economic performance (or ability to innovate) do not use micro-data from business R&D surveys, but micro-data collected in innovation surveys like the EU Community Innovation Survey (CIS) or similar non-European surveys (e.g. Belderbos et al., 2015; Kotabe et al., 2007; Nieto and Rodriguez, 2011; Rahko, 2016; Tamayo and Huergo, 2017). Such innovation surveys make available to researchers information about a broad set of factors influencing innovation processes. However, a drawback of most of these studies is that they focus only on the

basic relationship between the level of R&D outsourcing and/or offshoring and the overall amount of innovation within the firm. Although this topic has been extensively scrutinised over the last few decades, our paper has a different aim. In fact, to the best of our knowledge, no paper analyses the role played by the organisation of internal R&D endowments, perhaps due to the lack of availability of business R&D micro-data in most countries, especially micro-data about outward R&D.

Therefore, our contribution to the literature is to reveal the extent to which R&D at home and R&D outsourcing abroad drive outward R&D (dotted arrows in figure 1), which is still largely unexplored. In particular, we are able to unpack the characteristics of the overall R&D activities, which so far have been operationalised only through aggregate measures of R&D intensity (e.g. Arvanitis and Hollestein, 2011) to see whether different combinations of R&D activities can result in different amounts of internationalised R&D.

Our empirical analysis is carried out using a novel database of Italian business R&D performers with data from the period 2003–2010, including detailed information about the amount of R&D undertaken by such firms in foreign locations (outward R&D). Relying on the variables available from the Italian R&D survey[2], we will disentangle both the internal R&D endowments of firms and their outsourcing strategies to test to what extent they are associated with outward R&D. We expect that some characteristics of **R&D at home** (e.g. that with a more structured organisation of internal R&D laboratories) and of **R&D outsourcing abroad** (e.g. that relying on external partners rather than affiliates) affect the propensity to invest in **outward R&D**.

The paper is structured as follows. Section 2 reviews the R&D internationalisation literature, focusing on firm-level drivers used in recent empirical studies. Section 3 presents the dataset used in this study and provides an overview of the patterns of Italian business R&D. Section 4 describes the empirical methodology, presents and comments on the results. Section 5 concludes.

[2] See Appendix B for a description of this survey.

2) Literature review and theoretical framework

2.1) R&D internationalisation from a country-level perspective

The key role of firms' internal technological endowments can be traced back to the first studies on internationalisation (e.g. Dunning, 1958; Hymer, 1960). Systematic analysis of R&D internationalisation dates back to the late 1970s and has been mainly focusing on US firms (e.g.; Lall, 1979; Mansfield, Teece and Romeo, 1979; Ronstadt, 1978). Relying on the key contributions of research in the 1990s comparing the R&D activities of home and host firms (Patel and Pavitt, 1991) and on novel taxonomies (Archibugi and Michie, 1995; Cantwell and Mudambi, 2005; Dunning and Narula, 1995; Kuemmerle, 1996), the empirical literature has started to analyse the motivations for performing R&D abroad. The debate has concentrated on the differences between the drivers of centrifugal and centripetal forces pulling R&D abroad. Related to the former category, there have been debates regarding the differences of 'exploiting' and 'augmenting' motivations to invest in R&D abroad.

Multinational enterprises (MNEs) have to meet two needs. First, they have to search for different types of knowledge to be incorporated in their country-level production processes in order to enhance their technological capabilities, for example by gaining access to localised knowledge spillovers (e.g. Ambos, 2005; Cantwell and Mudambi, 2005; Ghoshal and Bartlett, 1990; Gupta and Govindarajan, 1991;Narula and Zanfei, 2005). In this case, MNEs' strategy for R&D internationalisation is characterised by asset augmentation. Second, MNEs need to adapt foreign products to local tastes to more effectively serve customers' needs. They can do so by transferring to foreign affiliates those internal knowledge assets that were developed inside the parent firm but could be better exploited abroad (e.g. Ambos, 2005; Berry and Sakakibara, 2008; Cantwell 1995; Kuemmerle, 1997). This strategy focuses on asset exploitation.

The motivations behind centripetal strategies include the impossibility of segmenting some R&D activities and avoiding leakage of technological knowledge that is assumed to be a core asset of the

firm (e.g. Belderbos et al., 2008). This behaviour prevents the risk of significant knowledge spillovers, which jeopardise key knowledge assets. Two further points could be relevant when discussing centripetal forces. First, the coordination of a network of R&D plants abroad can be quite demanding and expensive. As underlined by Belderbos et al. (2013), these costs are closely related to the tacit nature of R&D, which makes face-to-face communication essential. A second point discussed by Belderbos et al. (2013), is that firms maintaining a certain amount of R&D at home can reinforce their deep roots in the innovation system of their home country, thus allowing for continuous interactions with domestic firms and universities and favouring faster innovation processes.

However, the operationalisation of these concepts has been mainly explored at a country level, leaving firm-level determinants in the background. Most researchers have been searching for location-specific determinants, with initial studies focusing on a few developed countries, such as the US (Hedge and Hicks, 2008, among others) UK (Cantwell and Iammarino, 2000), Japan (Ito and Wakasugi, 2007) and continental European nations including Germany (Ambos and Ambos, 2011)[3]. The role played by the relative technological strengths and weaknesses of home and host countries is the crucial variable analysed (Le Bas and Sierra, 2002; Le Bas and Patel, 2005; Patel and Vega, 1999; Siedschlag et al. 2013)[4]. Therefore, even though studies on R&D motivation have proved to be important as they shed light on the basic reasons for which MNEs want to invest abroad in R&D activities, the role of internal R&D activities to drive such efforts remains unclear.

2.2) Firm-level analyses: identifying the characteristics of R&D performed at home

The main limitation of country-level data is that they can assess the dynamics of R&D outsourcing and offshoring only at an aggregate level. The balance of firms' R&D flows between home and host

[3] An extensive analysis of location factors for attracting R&D-intensive FDI can be found in OECD (2011).

[4] The country-level perspective has also been extensively used for a complementary type of analysis on the impacts of R&D internationalisation on home and host countries. For instance, Criscuolo (2009), starting from the idea that multinational corporations are actors that may influence the R&D endowments of a country to a large extent, looks for the reverse technology transfer effect influencing both the parent firm and other domestic firms via knowledge spillovers.

locations has been the main variable explored in the literature, and the explanatory variables are assumed to be dependent upon the characteristics of the investor and recipient countries. However, the characteristics of the R&D performed at home are highly heterogeneous across industries and firms.

The heterogeneity of R&D at home is increasingly attracting the attention of internationalisation scholars. R&D at home is usually found to be a positive driver of export propensity (e.g. in Nam and An, 2017) and of knowledge-seeking foreign direct investment (FDI, e.g. in Ambos and Ambos, 2011). Most of these studies, however, use the overall amount of R&D or the R&D intensity as an explanatory variable. A detailed analysis of internal R&D characteristics has been performed mostly in R&D management literature, including case studies and *ad hoc* surveys of limited firm samples (Florida, 1997; Haakonsson and Ujjual, 2015; Thursby and Thursby, 2006; Von Zedwitz and Gassmann, 2002).

Despite the data limitations, several studies highlight the analytical relevance of internal R&D breakdown. Belderbos et al. (2013), examining a sample of 156 firms located in Europe, the US and Japan from 1995 to 2002, identify several firm-level determinants of home/host R&D balance. Their main findings show that a persisting home bias in R&D is affected by the organisation of R&D in large R&D laboratories (Belderbos et al., 2013). Performing R&D at home in laboratories rather than in productive facilities thus has a negative association with R&D internationalisation. However, as suggested by Sachwald (2004), setting up R&D laboratories implies that a firm has decided to face high sunk costs and long-term commitment in R&D activities. In other words, it is a sign that R&D is an important component of the firm's strategy. From this viewpoint, performing R&D in dedicated laboratories might be associated with a higher ability to manage complex R&D networks, thus leading to a higher propensity to internationalise R&D. Firms undertaking R&D at home in productive facilities might be characterised by more informal R&D, and thus it is less likely that they will engage in R&D internationalisation.

Another frequent breakdown of internal R&D deals with the characteristics of R&D employees. Erken and Kleijn (2010) find that the level of human capital, added value of foreign affiliates and stock of private R&D are the main variables explaining cross-border knowledge flows. The different types in which human capital in R&D can be divided such as researchers, technicians and supporting staff, is found by Lin (2014) to have an impact on a measure of industrial performance. Teirlinck and Spithoven (2013) find that R&D outsourcing and cooperation among Belgian SMEs are affected by internal R&D personnel requirements. In particular, a higher share of researchers is associated with more R&D outsourcing. However, the authors do not investigate whether this phenomenon only occurs domestically or abroad as well. We claim that a higher share of researchers comprising R&D personnel at home might have an ambiguous association with R&D internationalisation. On the one hand, having more researchers might signal that the most structured and advanced R&D performers at home are also more likely to internationalise R&D. On the other hand, a higher share of researchers at home might highlight that firms are keeping relevant research in their home country and thus are less interested in delocalising strategic assets abroad.

A third type of internal R&D breakdown is due to distinctions of different types of R&D: basic research, applied research, and experimental development. Bertrand and Mol (2013) find that performing basic R&D at home is positively associated with propensity to outsource R&D, both at home and abroad. Shimizutani and Todo (2008) carry out an empirical analysis of Japanese foreign affiliates with R&D projects abroad, finding that the intensity of R&D at home is associated with the probability to undertake only the development (and design) phases of R&D abroad, not research (basic or applied). On the contrary, studying 170 European and US technology-intensive firms, Martínez-Noya et al. (2013) find a positive association between the outsourcing of basic research and the performance of these outsourcing agreements. Overall, we expect a negative association of basic research at home with R&D internationalisation. Indeed, a high share of basic research is the typical signal that firms are engaged in very strategic type of R&D at home, thus diminishing the probability that they will offshore R&D.

2.3) The recent debate on contract versus captive R&D offshoring

Researchers are increasingly exploring the role played by two types of external investment in R&D: the share of R&D outsourced by a firm to its foreign affiliates (termed 'captive R&D offshoring') and that outsourced to non-affiliated foreign partners (termed 'contract R&D offshoring'). These studies usually jointly analyse the drivers of R&D outsourcing and offshoring or test their role in fostering firms' innovativeness. For instance, Nieto and Rodriguez (2011) find that offshoring to foreign affiliates has a higher impact on Spanish firms' innovativeness than outsourcing to non-affiliated foreign partners. Similar results, although focused on SMEs' growth as a dependant variable, were found by Rodriguez and Nieto (2016). Brossard and Moussa (2016) analyse the innovation output of French R&D firms, dividing their R&D outsourcing into four categories: onshore affiliate external R&D, offshore affiliate external R&D, onshore non-affiliate R&D and offshore non-affiliate external R&D. They find that onshore non-affiliate external R&D has a negative impact on innovativeness, but no significant complementarity appears between internal R&D and the other three types of R&D outsourcing (Brossard and Moussa, 2016). Steinberg et al. (2017) study a panel of German R&D performers, finding the following: contract R&D offshoring has a higher impact on innovativeness than captive R&D offshoring when the degree of R&D offshoring is limited; for higher degrees of R&D offshoring, captive is preferable to contract R&D offshoring; and for both types, the link between R&D offshoring and innovation performance is leveraged by higher degrees of intra-mural R&D intensity.

Other studies focus on the drivers for outsourcing domestically rather than abroad (that is, offshoring). Bertrand and Mol (2013) find that, in France, both the antecedents and impact of R&D outsourcing differ if the partners are domestic or foreign. In particular, offshore outsourcing is positively affected by the R&D intensity of the firm that, in turn, also positively benefits the rate of product innovation at home. Using a survey on EU and US firms, Martínez-Noya and García-Canal (2011) find that the patenting activity of firms at home is a stronger driver than R&D budget at

home of both domestic and offshore outsourcing. Using the same dataset, Martínez-Noya et al. (2012) distinguish between developing and developed countries as recipients of R&D offshoring, finding that the former are chosen primarily for their labour costs, while the latter are chosen for knowledge-seeking motivations. A similar result is found by Cincera et al. (2014): the low cost of researchers is a key driver for attracting foreign R&D by EU multinational firms, but only when they target emerging countries (e.g. China and India).

Arvanitis and Hollenstein (2011) have shed further light on the different drivers for investment in R&D abroad. Their analysis, based on a firm-level panel dataset for Switzerland, highlights the relevance of the ownership advantage which appears to be far greater than the relevance of the locational advantage (even though the relative importance of each of them may vary according to the motives for foreign R&D investments). However, within the large number of the explanatory variables used by the authors, only two directly concern R&D: the share of R&D per employee and its persistence over time. Any other variable is only connected to firms' innovation strategy and external linkages in a generic way (e.g. use of R&D cooperation or outsourcing).

Tamayo and Huergo (2017), by studying data about the firms included in the Spanish PITEC database from 2004 to 2010, compare the determinants of R&D offshoring by considering whether there are significant differences between independent firms and firms belonging to a group. This study focuses on several technological variables, including international technological cooperation, total expenditure on R&D and patent applications. They find a difference between independent firms and affiliates only in their marginal effects. This paper also uses aggregate measures of R&D endowments, such as R&D employment and continuous R&D.

Overall, the mentioned literature has identified the two relevant drivers of R&D internationalisation: on the one hand, the breakdown of internal (intra-mural) R&D by its main characteristics, and on the other hand, the role of outsourced R&D abroad and its composition in captive and contract offshore R&D. It is worth to mention that the role of both drivers in

determining the balance between firms' R&D performed at home or abroad (dotted arrows in figure 1) has been neglected so far in the economic literature.

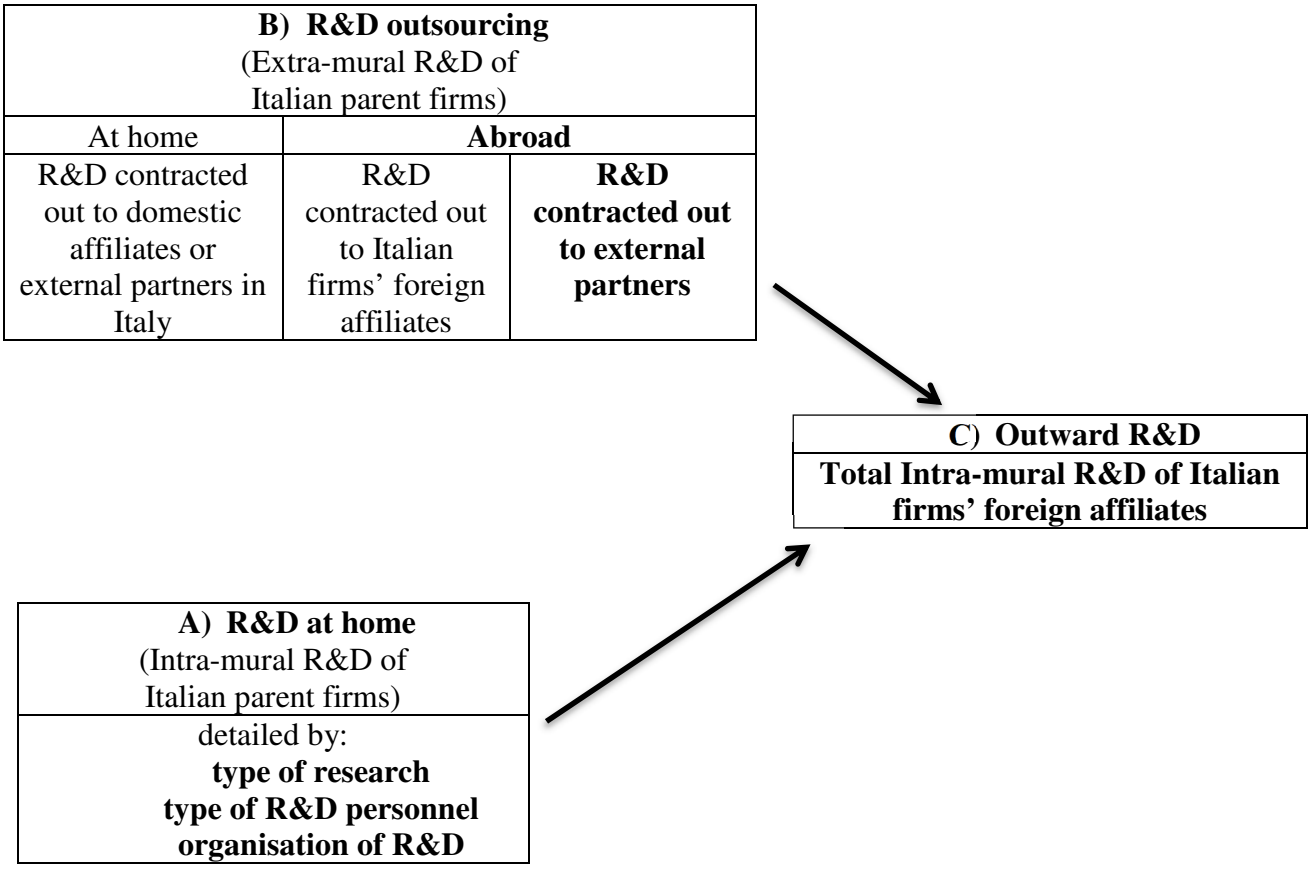
There is an empirical reason for this neglect. In all studies, R&D internationalisation has only been measured in terms of R&D outsourcing abroad. Indeed, so-called 'captive R&D offshoring' is just part of a wider phenomenon. It describes the aspects of R&D performed by foreign affiliates and *funded* by the parent company (or by its affiliates at home). However, foreign affiliates' R&D can be funded partially by the affiliate itself (self-funding) or by other external parties, including private firms and public administrations [5]. Therefore, summing up these funds to those eventually outsourced by the mother company, the value of foreign affiliates' R&D (termed 'outward R&D') can be higher than captive offshore R&D.

This distinction produces a corollary: in order to increase their multinational experience (Castellani and Zanfei, 2002), some firms might use a softer form of R&D internationalisation – R&D outsourcing abroad, to affiliates or not – to more capably manage a larger network of foreign affiliates performing R&D. Since captive R&D offshoring can partially overlap outward R&D, it cannot be an appropriate proxy to measure this association. On the contrary, we claim that the contract R&D offshoring (R&D contracted out to non-affiliates abroad) is a valuable proxy to test this association.

In figure 2, we recall the theoretical framework presented in figure 1 and make explicit the directions for the empirical tests described in section 4. Although we have a broad idea of the trends on R&D internationalisation, we have no ex ante expectations on how intra-mural (block A) and extra-mural (block B) variables area associated with outward R&D (block C). Within this paper, we explore R&D internationalisation with a double novelty: on the one hand, we make use of a systematic question on outward R&D asked to all R&D performers in the Italian R&D survey; on the other hand, we break the internal R&D variable down into its main components, as shown in figure 2. An explanation of variables is provided in section 3.

[5] The share of R&D performed by foreign affiliates *not* on behalf of the mother company can be linked to the wider concept of affiliates' autonomy (Hedlund, 1979).

Figure 2 – Theoretical framework and empirical tests in this paper



Source: Authors

3) Sample Characteristics: Internationalisation Strategies and Descriptive Statistics used for the Analysis

3.1) Patterns of Italian R&D internationalisation strategies

The firm-level data used for this empirical analysis were collected by the Italian Statistical Institute (ISTAT) through its annual business R&D survey. This survey, which has been conducted since 1963, is a census-based survey targeting all potential R&D-performing firms that are active in the country. Data collection includes information about many features of firms' internal R&D processes, ranging from the quantity of resources invested in R&D projects (e.g. R&D expenditure and number of R&D employees) to more qualitative evidence, like the location of R&D activities in

a region and the finalisation of research activities (including basic and applied research as well as experimental development).

A key feature of this dataset is the availability of firm-level data on outward *R&D*, which is R&D investment by foreign affiliates of Italian R&D performers. This allows for identification of three complementary strategies a firm can implement in order to achieve its research objectives[6]:

A) Internal (intra-mural) R&D expenditure.

B) Outsourcing R&D projects to other national or foreign performers (i.e. extra-mural R&D).

C) Co-investing in R&D carried out by foreign affiliates (identified by statisticians as the above-mentioned outward *R&D*).

We highlight this particular feature of the dataset because, as pointed out in the literature review, very little evidence is available about the combination of internal R&D performance and R&D outsourcing with outward R&D; most business R&D surveys at the international level, unlike the Italian R&D survey, do not ask firms about the R&D activities undertaken by foreign affiliates.

As shown in figure 3, almost one fifth of the total R&D investment by Italian firms is outsourced (2010 data), and about 16% of the external investment in R&D is devoted to foreign affiliates. In addition, figure 3 shows that R&D outsourced to foreign affiliates is just a portion of the whole R&D undertaken by these affiliates.

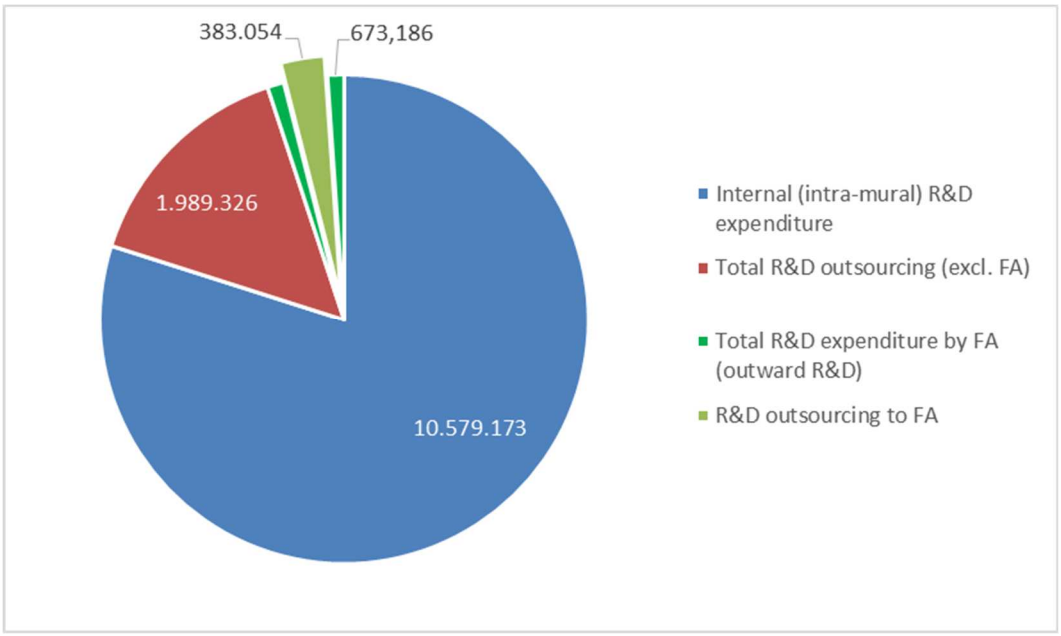
A key point of this study is that, when investigating a firm's R&D strategy, both its roles as a R&D performer and a R&D funder have to be taken into consideration. Combination of internal R&D performance and R&D outsourcing (which display a 3:1 ratio in figure 3) is a common pattern among firms investing in research. However, the role of a R&D funder is not limited to R&D outsourcing. The decision of allowing foreign affiliates to undertake R&D by using their own self-funds is dependent on the R&D internationalisation strategy of the parent firm as well. Neglecting this part of R&D (the darker green in figure 3) would imply an underestimation of firms' internationalisation scope.

[6] The following three blocks reflect those of figures 1 and 2, and are linked to research questions in literature, as recalled in section 2.

Figure 3 – Main components of the R&D internationalisation strategy by Italian firms.

R&D expenditure in 2010 (figures in thousand euros).

To be noted that 'Total R&D expenditure by Foreign Affiliates (FA)' is partially including 'R&D outsourcing to FA'.



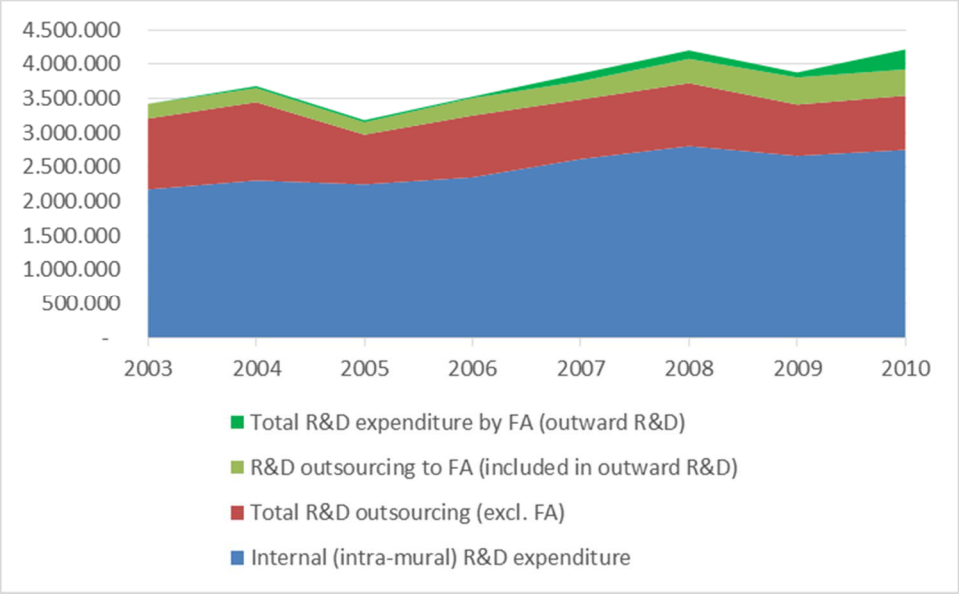
Source: Authors' elaboration on Italian R&D survey

Relying upon the rich evidence made available by the Italian R&D survey, an unbalanced panel with 39,152 observations corresponding to 13,675 R&D-performing firms with at least one observation in the period from 2001 to 2010 has been assembled. Information on the outward R&D of such firms – defined as R&D expenditure by their foreign affiliates – is also available, but only for the sub-period from 2003 to 2010. Figure 4 shows that the total amount of outward R&D by Italian firms has been increasing in the observed period.

Figure 4 – Trends in R&D expenditure by Italian firms with international R&D activities

Figures in thousand euros at current prices, years 2003-2010.

To be noted that 'Total R&D expenditure by FA' is partially including 'R&D outsourcing to FA'.



Source: Authors' elaboration on Italian R&D survey

R&D outsourcing to foreign affiliates (light green area in figure 4) is a main component of the total R&D expenditure by the same foreign affiliates (dark green area). When considering the subset of Italian R&D performers engaged in at least one of these two R&D internationalisation activities, there is clear evidence that foreign affiliates are playing an increasing role in supporting their parent firms' R&D strategies. This phenomenon, at least in Italy, is still empirically unexplored, with the exception of preliminary evidence in Cozza and Zanfei (2014), who nevertheless were focusing on a different research question. Although the country is not a leader in R&D globalisation, Italy can provide interesting insights into this topic.

Outward R&D activities, as shown in figure 4, are on the rise, increasing at the remarkable (compound) rate of 19% per year during the 2003–2010 period. It has to be stressed that most outward R&D is concentrated in a few countries, with the sum of the first four target countries (Brazil, Germany, France and the US) accounting for more than two-thirds of the total outward R&D expenditure in 2010.

Two main limitations of this approach have to be mentioned. First, there are only 720 observations of Italian firms with outward R&D, referring to 269 Italian firms surveyed between 2003 and 2010. Second, since outward R&D is reported only by respondents performing R&D in Italy, the ISTAT dataset potentially excludes those firms that perform R&D *only* abroad[7].

3.2) Descriptive statistics of variables used in the econometric analysis

The current availability of Italian firm-level R&D data makes it possible to develop an original approach in identifying those Italian firms investing in outward R&D, not only in terms of structural features (e.g. firm size, group structure, industry) but rather in terms of R&D-related dimensions (number of R&D employees, type and organisation of R&D). This information has been codified as a set of variables in order to compare outward R&D investors with the group of 'non-outward R&D investors', that is, firms investing in R&D only at home (including both internal R&D performance and domestic outsourcing). A descriptive analysis of the dataset can give some preliminary answers about a few well-established issues on R&D internationalisation.

In parallel with the description of the theoretical framework, it has to be pointed out that the potential for R&D globalisation by Italian firms has not yet been fully exploited, mostly because of the small average size of Italian R&D performers. Indeed, outward R&D investments, mostly by large firms, were only around 6% of the total domestic R&D expenditure by Italian firms in 2010. Firms investing in outward R&D accounted for only 2% of the total number of R&D performers in Italy but more than 22% of the total internal R&D expenditure in 2010.

Also, the structure of the Italian business sector should not be neglected when interpreting this evidence. On the one side, the polarisation between a high number of SMEs, often operating in low-tech industries (both in manufacturing and services), and a low number of large enterprises which concentrate most of the technological potential of the country industrial structure, is a factor

[7] Controls performed on other sources suggest that 17 observations we deleted from the sample were from such a case. We therefore run our regressions with 703 positive observations.

affecting the innovation capacity of the Italian business sector as a whole[8]. On the other side, it influences Italian globalisation dynamics: as a result, a limited number of large enterprises performing R&D at home and abroad can shape the degree of R&D internationalisation of the country.

Additional information about the peculiar features of R&D performed by globalised firms can be drawn from the distribution of the R&D workforce in terms of occupation and from the finalisation of R&D activities. By comparing, for instance, the ratio between researchers and technicians involved in R&D projects (figure 5 and table 1), it can be pointed out that technicians, on average, outnumber researchers, especially in globalised firms. This is not surprising as far as business R&D facilities are concerned, where R&D is mostly carried out with a short- to medium-term perspective and focuses on the actual application of R&D results. This pattern is confirmed by the data on R&D finalisation, highlighting the role of applied research versus basic research efforts.

Figure 5 – Comparing R&D personnel in firms investing and not investing in outward R&D.
Researchers and technicians engaged in basic and applied research, years 2010.

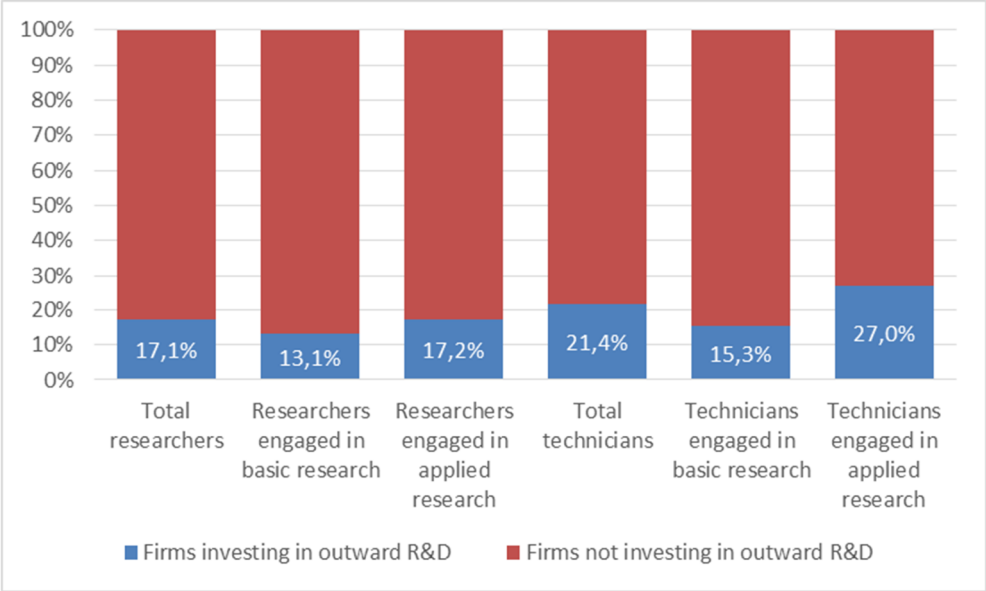


Table 1 – Descriptive statistics about R&D personnel in terms of type of research
(number of individuals engaged in R&D from 2003 to 2010)

Variable	Mean	Std. Dev.	Min	Max
Total researchers	7.71367	45.7296	0	1322.8

[8] See Hall et al. (2009), Iammarino et al. (2009), Bonaccorsi and Perani (2014).

Total technicians	9.70629	67.7223	0	6559
Researchers involved in basic research	0.67933	7.37041	0	768
Researchers involved in applied research	3.95281	28.9512	0	1184
Technicians involved in basic research	0.67571	9.89005	0	900.3
Technicians involved in applied research	4.49674	48.596	0	5325.2

Source: Authors' elaboration on Italian R&D survey

Along with R&D outsourcing, the acquisition of external R&D services aimed at integrating internal competences with additional knowledge from external sources can also be taken into consideration. Most of the R&D outsourced by Italian R&D-performing firms comes from other firms, not research institutions, such as universities or public R&D laboratories (figure 6 and table 2). This is quite peculiar and proves that firms are more likely to look for support from other domestic firms because of the advantages of geographical contiguity.

When comparing firms performing R&D only in Italy and firms investing in outward R&D, the latter features a strong orientation to combine outward R&D with outsourcing (or extra-mural) R&D expenditures. By considering all the recipients of extra-mural R&D expenditure (i.e. the external providers of R&D services), globalised firms, as already mentioned, show a very high propensity to employ R&D services from affiliated firms both in Italy and abroad (around 50% of the total R&D expenditure in both cases). This effort to source knowledge and research services also from foreign sources is reinforced by the use of non-affiliated foreign firms and foreign institutions as additional providers of R&D services (both of which contribute around 40% of the total extra-mural R&D expenditure).

Figure 6 – Comparing R&D outsourcing in firms investing and not investing in outward R&D.
R&D outsourcing (extra-mural expenditure), year 2010.

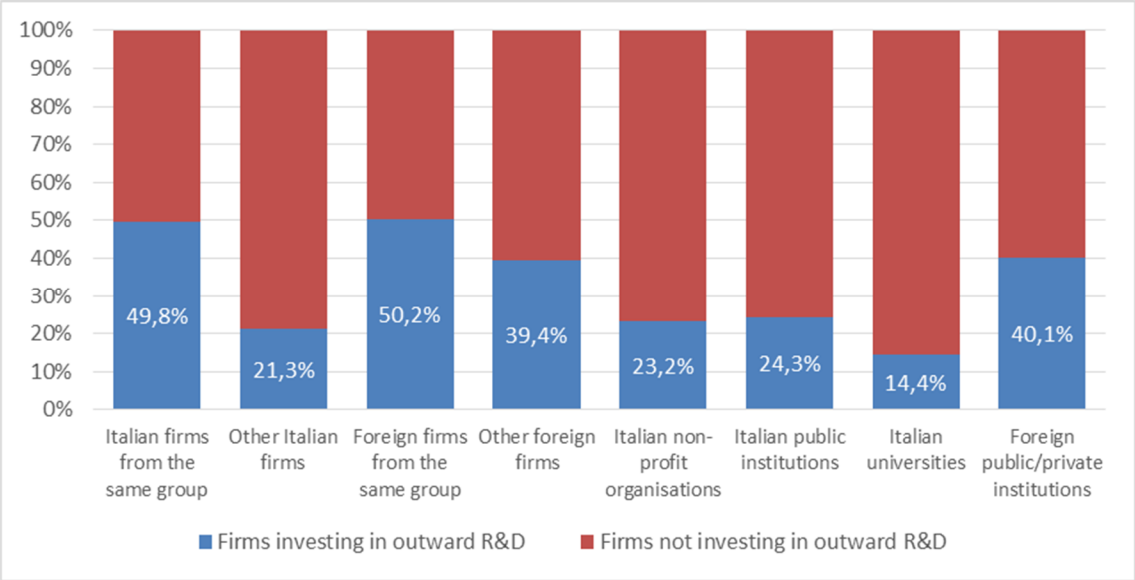


Table 2 – Descriptive statistics on total R&D outsourcing by Italian R&D-performing firms
(data on external R&D funding in thousands of euros, years 2003 to 2010)

Variable	Mean	Std. Dev.	Min	Max
Italian firms from the same business group	111.9807	3723.678	0	300676
Other Italian firms	134.0615	3682.484	0	440374
Foreign firms from the same business group	67.2159	1310.571	0	65795
Other foreign firms	62.9696	1209.208	0	75137
Italian non-profit organisations	16.67938	285.3435	0	18000
Italian public institutions	7.339945	198.5676	0	16014
Italian universities	16.20937	448.6038	0	64241
Foreign public/private institutions	6.479	252.4239	0	26674
Total R&D outsourcing	422.9354	7655.2	0	656019

Source: Authors' elaboration on Italian R&D survey

In Table 3 we present some basic descriptive statistics of the variables as they are built and used in the estimation of the models. The general picture that emerges from the data about our sample, is that of a type of firm doing R&D abroad, that is characterized not by a high level of technological intensity with respect to its internal R&D resources, but by a high propensity to make R&D that is market driven.

Table 3 – Descriptive statistics of variables

Variable	Description	Observations	Mean	Std. Dev.	Min	Max
RDout	Share of outward R&D expenditure on total amount of R&D	33476	0.005326	0.046879	0	0.944882
log_empl	Log of the number of employees	33476	3.956244	1.650884	-0.28768	11.0121
log_pat	Log of the number of patents per year	33476	0.155046	0.526956	0	7.60589
log_RDempl	Log of the number of R&D employees (f.t.e.)	33476	1.794254	1.322066	-2.30259	8.988758
labs	Dummy = 1 if a firm has either a R&D divisional lab or R&D central lab	33476	0.272315	0.445158	0	1
structure	Dummy = 1 if a firm has either a project or production structure	33476	0.888547	0.314697	0	1
tech_x	Share of the number of technicians on total R&D employees (f.t.e.)	33476	0.464052	0.326384	0	1
research_x	Share of the number of researchers on total R&D employees (f.t.e.)	33476	0.341703	0.30982	0	1
applied	Share of the number of researchers devoted to applied research on total R&D employees	33476	0.157736	0.25232	0	1
basic	Share of the number of researchers devoted to basic research on total R&D employees	33476	0.029244	0.114772	0	1
log_extramural_tot	Log of total extra-mural R&D	33476	1.071058	2.153961	0	13.39394
extra_ita	Expenditure funding R&D performed by Italian partners over total amount of R&D extra-mural	33476	0.209397	0.399458	0	1
extra_for	Expenditure funding R&D performed by non-affiliated foreign firms and institutions over total amount of R&D extra-mural	33476	0.020534	0.121696	0	1

4) Econometric analysis and results

4.1) Methodology

Our dependent variable is the share of R&D expenditure in a foreign country compared to the sum of domestic and foreign R&D expenditures. This variable is bounded between 0 and 1 with a very high amount of observations (as we have only 703 positive outward R&D values) that are clustered around 0. For this reason, we first employ a Tobit model with pooled observations. That is, we hypothesise that the zero realisation represents a corner solution as y = 0 represents a choice of the firm.

The limitation of this model recognised by the literature is that all zero values are considered to be originated by the same process that generates positive and, in our case, continuous values. For this

reason, as a robustness check, we employ for the main specifications of the benchmark model the double hurdle model, which was first proposed by Cragg (1971). We estimate the model using independent and homoscedastic error terms: it is as if we had two equations and combined a Probit and a Tobit estimator. It can be considered a sort of bivariate model because of the separation of the two processes (Blundell and Meghir, 1987). In our case, the two hurdles that need to be overcome in order to carry out outward R&D are the factors that determine the probability that a firm is part of the zero class. The first is whether the firm is willing to have a certain amount of outward R&D presence abroad and, if the firm clears the first hurdle, the second is whether the firm is able to invest a non-zero amount in R&D abroad. Following the theoretical framework developed in the previous sections, the variables that are suitable to separate the two processes are firm size and the amount of extra-mural R&D. We consider the drivers identified in section 2 as those that are most relevant to clearing the second hurdle. As in the original model (Cragg, 1971), we consider the errors to be jointly normal and independent.

4.2) Results

Table 4 shows our benchmark estimates. We first run a model considering only aggregated R&D variables, and then we run five different models in order to progressively capture more specific features of both internal R&D endowments and outsourcing strategies. In all of these regressions, we include sector and year dummies to account for a possible common effect on sectors and years.

Table 4 – Benchmark estimates

Variables	(1)	(2)	(3)	(4)	(5)	(6)
log_empl	0.0971***	0.112***	0.113***	0.108***	0.134***	0.135***
	(0.0101)	(0.00759)	(0.00757)	(0.0104)	(0.00766)	(0.00765)
log_pat	0.0824***	0.0870***	0.0866***	0.0906***	0.102***	0.102***
	(0.0119)	(0.0113)	(0.0113)	(0.0116)	(0.0109)	(0.0108)
log_RDempl	0.0559***			0.0731***		
	(0.0103)			(0.0103)		
labs		0.204***	0.204***		0.214***	0.215***
		(0.0234)	(0.0234)		(0.0236)	(0.0237)
structure		0.0321	0.0318		0.0340	0.0324
		(0.0312)	(0.0312)		(0.0318)	(0.0318)
tech_x		0.145***			0.142***	
		(0.0510)			(0.0503)	
research_x		0.152***			0.155***	
		(0.0551)			(0.0546)	
applied			0.0779**			0.0722*
			(0.0395)			(0.0400)
basic			-0.0300			-0.0409
			(0.0983)			(0.0990)
log_extra-mural_tot	0.0427***	0.0447***	0.0446***			
	(0.00368)	(0.00355)	(0.00356)			
extra_ita				0.0719***	0.0693***	0.0690***
				(0.0230)	(0.0227)	(0.0227)
extra_for				0.558***	0.564***	0.562***
				(0.0462)	(0.0456)	(0.0458)
Constant	-2.123***	-2.275***	-2.170***	-2.200***	-2.338***	-2.228***
	(0.126)	(0.132)	(0.125)	(0.133)	(0.138)	(0.132)
Observations	33,476	33,476	33,476	33,476	33,476	33,476

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

We note that firm size plays a significant role in all models, confirming the well-established expectation that larger firms are more likely to perform R&D abroad. An interesting result is that the number of patents is always positive and significant, indicating that more innovative firms will be willing, under some circumstances, to bring their innovativeness out of their home countries' borders. This means that firms that patent more, being able to codify and make results from their R&D investments exchangeable, are expected to have more exchanges with foreign partners or customers.

Overall, R&D internationalisation is more likely to occur when firms at home are large, file more patents and basically are R&D-intensive (in terms of both intra-mural and extra-mural R&D). In the first column of Table 4 we see that both the number of R&D employees and the total amount of extra-mural R&D are in fact highly positive and significant. This is also in line with the theoretical framework outlined above. We move forward by disentangling our internal R&D variable to fully capture the drivers of R&D internationalisation. In column (2) of Table 4, we show that outward R&D is associated with the undertaking of internal R&D in laboratories, rather than in production plants. As anticipated in section 2, we interpret this result in the sense that performing R&D in the framework of application-oriented R&D projects or as an ancillary function in production plants is a type of R&D activity with a shorter time-frame and less likely to be internationalised. Even though from our descriptive statistics we have found a key role of technicians in fostering Italian business R&D, we find no difference between relying on a higher share of researchers or technicians as R&D employees (Table 4, column 2).

A further type of R&D employees' breakdown is shown in column (3) of Table 4. In this case, researchers devoted to basic research can be distinguished from those working on applied research. Only applied research is positively and significantly (at the 5% level) associated with outward R&D. We conclude that firms more involved in applied research are also more likely to internationalise their R&D. Carrying out basic research inside the firm has several benefits, such as the ability to be the first to master a new technology and, as a consequence, be a leader in a specific technological market (e.g. Cohen and Levinthal, 1989; Rosenberg, 1990). However, it can also have some disadvantages, such as the possibility of losing mastery over a technology that is difficult to appropriate (Higon, 2016) when delocalising research laboratories abroad.

In columns (4), (5) and (6) of Table 4, in line with our theoretical discussion, we are considering a breakdown of our further R&D variable: R&D outsourcing. More specifically, we check whether outsourcing R&D to other partners in Italy and to other (non-affiliated) partners abroad has any

correlation with outward R&D[9]. Column (4) of Table 4 shows that both components are positive and significant. We conclude that being involved in R&D outsourcing is a positive driver of R&D internationalisation, as found in previous literature. However, we build upon the literature finding that experience of the international market of R&D services is a key component of outsourcing R&D to non-affiliated partners abroad. This is in fact quite a challenging option as partners are simultaneously outside firm and geographical boundaries. Firms that are devoting a share of their R&D budget to foreign non-affiliated partners are expected to be able to identify the best options to establish R&D performing affiliates around the world. In addition, the experience in trading R&D services with R&D partners abroad increases the probability that firms will encourage an 'open' attitude by their foreign affiliates in order to broaden their network of potential partners and customers. For example, if an Italian MNE outsources R&D to a US non-affiliated partner, it might be expected to support the co-operation of such R&D provider with its US affiliates, which are geographically closer to the external partner, thus in a better position to exploit the potential for sharing projects and competences in a network perspective. However, we cannot explore this concept with the data used in this paper and thus leave it for future research.

Finally, in columns (5) and (6) of Table 4, we report the complete models as well as the breakdown of both intra-mural and outsourced R&D. The signs and significance of all variables are confirmed.

The results of the estimations carried out using the double-hurdle model (which are presented in appendix) are robust.[10] In particular, we note that size and outsourced R&D always positively affects the probability that the firm will overcome the first hurdle. This means that if a firm is bigger and outsources more R&D abroad, the probability that it will decide to invest a non-zero amount in R&D abroad is positive. The double hurdle model results confirm what was found by the benchmark model regarding the main variables of interest: that both technicians and researchers

[9] R&D outsourced to foreign affiliates (or captive offshore R&D) is excluded in econometric test for endogeneity reasons.

[10] We provide estimations of the models considering the unpacking of both intra-mural and outsourced R&D.

have a positive and significant effect on the amount of outward R&D as well as researchers devoted to applied and basic research have different impacts (see Table A1, Appendix A).

As we think that our results are still too aggregate, especially with respect to the technological peculiarities of the sectors in which firms operate, we further investigate this point to determine the sensitivity of our results. To do so, we choose the specification providing the strongest significance (that is column 5, where R&D employees are divided by type) and run six different models. Table 5 therefore replicates column 5 of Table 4, with each column representing a class of the Eurostat technological classification[11].

Table 5 – Estimates according to different technological intensities

Variables	(1) ht	(2) mht	(3) mlt	(4) lt	(5) kis	(6) lkis
log_empl	0.0908***	0.119***	0.221***	0.258***	0.110***	0.0873***
	(0.0156)	(0.00978)	(0.0301)	(0.0330)	(0.0133)	(0.0280)
log_pat	0.0583***	0.0852***	0.146***	0.000892	0.0543	0.165*
	(0.0213)	(0.0128)	(0.0354)	(0.0657)	(0.0420)	(0.0896)
tech_x	0.0438	0.186***	0.331**	0.271	0.0150	-0.371
	(0.127)	(0.0702)	(0.160)	(0.192)	(0.143)	(0.258)
research_x	0.0586	0.272***	0.0235	0.301	-0.0591	-0.435**
	(0.131)	(0.0755)	(0.223)	(0.208)	(0.157)	(0.210)
labs	0.188***	0.147***	0.271***	0.121	0.444***	0.668***
	(0.0571)	(0.0291)	(0.0791)	(0.0831)	(0.0806)	(0.132)
structure	-0.0328	0.0633	0.107	0.0467	0.312***	0.00209
	(0.0498)	(0.0435)	(0.128)	(0.174)	(0.0846)	(0.169)
extra_ita	-0.0237	0.0899***	0.0291	0.115	0.0633	0.280**
	(0.0543)	(0.0272)	(0.0867)	(0.104)	(0.0737)	(0.136)
extra_for	0.691***	0.169**	0.649***	0.441**	0.806***	1.166***
	(0.0675)	(0.0793)	(0.161)	(0.212)	(0.131)	(0.334)
Constant	-1.411***	-1.844***	-3.220***	-3.545***	-2.344***	-2.328***
	(0.203)	(0.114)	(0.304)	(0.465)	(0.266)	(0.430)
Observations	2,814	10,789	5,868	5,050	6,488	1,831

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

[11] Eurostat has adopted a classification of the manufacturing industries according to the level of their technological intensity (R&D expenditure/value added), using the Statistical Classification of Economic Activities in the European Community (NACE Rev.2) at the 2- or 3-digit level for compiling groups. Manufacturing activities are grouped to 'high-technology', 'medium high-technology', 'medium low-technology' and 'low-technology'. Service activities, on the other hand, are mainly grouped together into 'knowledge-intensive services (KIS)' and 'less knowledge-intensive services (LKIS)' and these groups are defined according to a similar logic at the NACE Rev.2 2-digit level.

In Table 5, only firm size is always highly positive and significant, regardless of the technological class concerned. The same is true for R&D carried out in dedicated laboratories (i.e. it is always positive and highly significant), except for firms belonging to low-technology sectors. The results for the variables measuring the number of researchers and technicians are unstable, behaving, like in the benchmark models, only in medium- to high-tech sectors. In particular, firms belonging to high-tech sectors and KIS firms have non-significant coefficients. We interpret this result as evidence that firms with higher R&D endowments do not have enough incentives to extended their R&D activities abroad due to the high risk of knowledge spillover. These results show that long-term non-globalisation (Patel and Pavitt, 1991) occurs, especially for firms in more technology-based sectors.

For all other variables, the significance and signs of the coefficients are different across technological class. We believe this result confirms our idea that internal R&D endowments are key for explaining R&D internationalisation, but they influence firms' strategies in a very heterogeneous way and according to their sectoral features. For instance, only sectors that rely on a significant knowledge base (such as those in columns 1–3 and 6) might be expected to get high returns from their patents when internationalising R&D because in those sectors, patents are the most common medium used to transfer, replicate and adapt knowledge already under development at home.

Overall, a broad range of R&D strategies can be observed in the population of Italian R&D performers. A case in point is the choice to source R&D services from non-affiliated firms abroad. In this case, the result is extremely robust with respect to extra-mural carried out abroad, reinforcing the results of the benchmark model concerning the importance of this variable. On the other hand, the role played by extra-mural R&D performed by Italian firms is relevant, positive and highly significant only in medium- to high-tech sectors.

5) Conclusions

The R&D internationalisation process has long been at the centre of the empirical debate on innovation and internationalisation. Even though the amount of R&D performed worldwide has grown over time, there are still several reasons for a country to use part of its R&D endowments at home. Most of the empirical analyses that have been carried out so far have focused on the country level and tried to identify the different drivers affecting the location of foreign R&D by considering whether country-specific variables may attract or deter the presence of R&D-intensive affiliates (e.g. Hedge and Hicks, 2008 for US). Another research question that has been deeply investigated, especially in international business literature, is the difference between the asset seeking and asset augmenting characteristics of this type of R&D investments. However, very little theoretical and empirical work at the firm level has included a detailed analysis of firm-level drivers, especially concerning the organisation of internal R&D activities. Most previous studies, while acknowledging the importance of each firm's R&D endowment, fail to realise the potential implications of the heterogeneity of the characteristics of internal R&D on R&D internationalisation strategies. We refer to the distinction between researchers and technicians, to the best combination of basic and applied research or to the differences between types of outsourced R&D. Therefore, one of the main aims of this study is to search for a relationship between patterns of R&D internationalisation and the way internal R&D resources and processes are managed.

Our empirical test on the Italian case has confirmed the idea that larger firms with more R&D employees invest more in R&D abroad. However, this is true only for firms with dedicated R&D laboratories that perform applied research at home. The propensity for R&D internationalisation does not hold when firms perform basic research or R&D in production facilities. As the breakdown of internal R&D is concerned, a twofold conclusion emerges: R&D internationalisation is favoured by a more structured organisation of R&D at home (that is, using R&D laboratories); but it is negatively affected by larger efforts in basic research at home, probably signalling firms more prone to keep strategic assets closer to the headquarters.

As outsourced R&D is concerned, our results show that the most relevant component is R&D contracted out to foreign non-affiliated partners. Firms accustomed to outsourcing R&D to foreign external partners seem to gain an ability in better managing research activities within foreign affiliates. The lower coefficients on the other two components (that is R&D contracted out to domestic affiliates or external partners in Italy and R&D contracted out to Italian firms' foreign affiliates), then, suggest that is not outsourcing per se that fosters R&D activities abroad, but rather a stronger experience in a softer type of internationalisation, that is commonly named "contract offshoring R&D".

A limitation of our study is its focus on a single country. As we highlighted in the descriptive analysis, Italy is endowed with a peculiar technological structure made up of a few large firms that are major actors in the international R&D market. Although this category of top R&D performers is quite homogeneous across countries (as in many studies using the EU Industrial R&D Investment Scoreboard sample), the low number of observations for the Italian case might limit the validity of results. Further research should aim to determine whether the same pattern we found in Italy is also present in other countries. In particular, we think that two directions can be envisaged: in the first place, after having identified countries with a similar technological structure as Italy, we can think to see whether the internationalisation patterns found for Italy are observable in those countries as well in terms of internal organisation of R&D versus internationalisation strategies. In the second place, we could compare internationalisation strategies across countries that present very different structural and contextual characteristics, such as for example the German case.

A further new research avenue could be represented by the deepening on the study of the role of sectorial specificities: this paper mainly aimed to show how a deeper analysis of R&D variables, such as the context in which firms operate, might help to explain why different models of R&D internationalisation are adopted. These observations are not exhaustive and an analysis of R&D internationalisation in connection to a range of technological regimes is beyond the scope of this paper but could be valuable for the future.

Appendix A

Table A1 – Double hurdle model

Variables	(1) above	(3) hurdle	(4) above	(6) hurdle	(7) above	(9) hurdle	(10) above	(12) hurdle
log_empl	-0.0369**	0.461***	-0.0374**	0.466***	-0.0134	0.494***	-0.0132	0.501***
	(0.0156)	(0.0332)	(0.0156)	(0.0329)	(0.0191)	(0.0352)	(0.0190)	(0.0350)
log_pat	0.0919***		0.0918***		0.104***		0.104***	
	(0.0121)		(0.0121)		(0.0124)		(0.0124)	
tech_x	0.125**				0.140***			
	(0.0548)				(0.0536)			
research_x	0.145**				0.154***			
	(0.0582)				(0.0569)			
labs	0.210***		0.209***		0.220***		0.220***	
	(0.0276)		(0.0276)		(0.0273)		(0.0273)	
structure	-0.000530		-0.00107		0.00729		0.00638	
	(0.0345)		(0.0345)		(0.0348)		(0.0347)	
log_extramural_tot	0.0102*	0.146***	0.0100*	0.148***				
	(0.00602)	(0.0175)	(0.00598)	(0.0174)				
applied			0.0898*				0.0813*	
			(0.0507)				(0.0490)	
basic			-0.0489				-0.0547	
			(0.105)				(0.103)	
extra_ita					0.0895***		0.0891***	
					(0.0260)		(0.0260)	
extra_for					0.270**	1.131***	0.264**	1.152***
					(0.106)	(0.330)	(0.104)	(0.330)
Constant	-0.919***	-3.541***	-0.816***	-3.571***	-1.108***	-3.296***	-1.001***	-3.322***
	(0.175)	(0.177)	(0.169)	(0.176)	(0.209)	(0.235)	(0.203)	(0.234)
Observations	33,476	33,476	33,476	33,476	33,476	33,476	33,476	33,476

Standard error in parentheses

*** p<0.01, ** p<0.05, * p<0.1

Appendix B

Statistical surveys of R&D performing firms are regularly undertaken by most countries following the guidelines given by the OECD Frascati Manual which provides survey managers with standardised concepts and definitions, as well as a few basic methodological guidelines. In 2015, the OECD released the seventh edition of the Manual, although the data used in this paper have been collected according to the recommendations given in the sixth Manual (2002). The Frascati Manual does not define a standard set of variables to be collected by business R&D surveys, leaving countries to identify their own national needs and designing their survey questionnaires according to such needs. On the other hand, an international harmonisation of statistical R&D variables has been developed more than ten years ago by the Statistical Office of the European Union (Eurostat) in order to be eventually incorporated in the EU statistical legislation and becoming mandatory for EU member countries, including Italy. As a consequence of this process of co-ordination at European level, a model EU questionnaire is now widely based on the collection of two main sets of data: R&D expenditure data and R&D personnel data. They include only quantitative variables measuring the resources – both financial and human – invested in the R&D activities. Eurostat asks EU countries to produce only two main indicators but broken down in a very detailed way according to a range of different features (e.g: type of costs, type of funding, type of R&D, regional breakdown, occupation of the R&D personnel, time spent on R&D, sex, age, nationality and qualification of the R&D personnel and so on). A detailed description of the Eurostat approach can be found at this webpage: http://ec.europa.eu/eurostat/statistics-explained/index.php/R_%26_D_expenditure. Of course, some EU countries, including Italy, used to integrate the two key modules of the Eurostat R&D questionnaire with a third module where some country-specific questions are asked mostly about the internal organisation of R&D activities by the performing firms and the co-operation with external actors including foreign affiliates performing R&D.

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