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Working papers

The role of ownership as R&D incentive in business groups

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ABSTRACT

Several empirical papers have shown that firms belonging to business groups have a higher propensity to engage in R&D. The purpose of the paper is to demonstrate that this higher propensity depends on the ownership share of controlled companies, besides the presence of co-ordination mechanisms. We develop an analytical model and we empirically test the predictions of the model using a dataset of Italian manufacturing firms. From the development of this model we derive three main implications: a) that there is no difference in R&D propensity between stand-alone firms and firms at the bottom of business groups; b) that head and intermediate firms have a higher R&D propensity compared to stand-alone and firms at the bottom of the group; c) that the intensity of R&D depends on the ownership shares in controlled companies. Overall the results of the empirical analysis are in accordance with the implications of the model.

Keywords: business groups; R&D investment; knowledge spillovers.

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1 Introduction

A business group is a set of firms owned and controlled by the same people by means of ownership ties. There are other ways of defining a business group, on the basis of stable contractual relations between firms (Granovetter, 1994; Goto, 1982). However, only ownership provides the control rights mentioned above. This is why in the economic and management literature the common way to define and delimit a business group is on the basis of ownership ties (Almeida and Wolfenzon, 2006; Feenstra et al., 2003). This is the definition we adopt in this paper since ownership is a central feature of our analysis.[1]

A large body of literature about business groups refer to emerging countries, where business groups are interpreted as organizational structures able to overcome the deficiencies of market institutions, especially financial markets (Colpan et al., 2010); these works often refer to the largest groups in a country (Choi and Cowing, 2002). In developed countries there is a long tradition of study that considers the group as a financial mechanism for separating ownership from control (Hilferding and Bottomore, 1981; Buzzacchi and Colombo, 1996; Morck and Yeung, 2005; Almeida and Wolfenzon, 2006).

Whatever the reasons for creating a business group, it can be considered as a multidivisional company in which the different businesses are managed as separate legal entities rather than as organizational units within the same corporation (Chandler, 1982). This allows the controlling owner(s) to involve minority shareholders in the companies of the group, thus separating the control rights, that remain in the hand of the vertex, from the cash flow rights, that are reduced according to the share of minority shareholders and the levels of the pyramid.

Some recent contributions have questioned the assumption of the group as a financial device, pointing out to the advantages of managing different businesses as separate legal

[1] Besides the definitions adopted in the economic and business literature, most countries have specific legislations defining a business group because firms controlling other firms are required to provide consolidated accounts. The definition of control (associated with ownership) is essential for delimiting the area of consolidation. The definition of business group used in this paper is also the one normally adopted by statistical agencies (Eurostat, 2003).

entities. Affiliated firms are supposed to benefits from the possibility to share the financial, technological and marketing resources that are available in the other companies of the group (Carney et al., 2011). In line with this approach, a recent strand of literature has emerged to test the hypothesis that the belonging to a group would enhance the propensity of firms to invest in R&D and to profit from such investment, thereby enhancing the innovation capabilities and economic performance of firms belonging to business groups

(Filatotchev et al., 2003; Mahmood and Mitchell, 2004; Mahmood and Chang-Yang, 2004; Chang et al., 2006; Belenzon and Berkovitz, 2010; Cefis et al., 2009; Blanchard et al., 2005). This hypothesis is based on two features of business groups that are expected to influence the R&D propensity of member firms. The first is the presence of an internal capital market that facilitates the financing of R&D projects. The internal capital market is expected to mitigate the asymmetry of information which is considered one of the main problems in the financing of R&D projects; within business groups the provider of funds (the head of the group) is supposed to have better information about the investor (affiliated firm) than external financiers. The second feature of business groups that is expected to raise the R&D propensity of member firms is the greater possibility to internalize the positive spillovers resulting from R&D investment (Cefis et al., 2009). In this paper we focus on the latter aspect.

As usual for empirical studies, the above mentioned papers show wide differences in the way innovation performance is defined and measured and in the methodology used to investigate the relations between variables. Despite these differences, in general they confirm the hypothesis that the affiliation to a group enhances the propensity to invest in R&D and the resulting innovation performance.

A common feature of these studies is that they assume the presence of co-ordination between the companies of the group. The superior possibility to internalize knowledge spillovers within groups depends on their ability to co-ordinate their R&D strategy and sharing its results.

Cefis et al. (2009), for example, examine how the presence of co-ordinated strategies in business groups influences the propensity of their member firms to invest in R&D. Their hypothesis is that "If product and process innovations have different externalities, the internalisation of these effects via *joint decision-making* may result in a different

R&D portfolio than that of independently competing firms" (Cefis, Rosenkranz & Weitzel 2009, p. 194, italics added). Besides the co-ordination of R&D decisions these studies also assume that "Knowledge transfer and sharing is easier among affiliates within the same business group than it is among unrelated firms" (Chang, Chung & Mahmood 2006, p. 639).

The hypothesis that firms belonging to the same group are more likely to co-ordinate their R&D strategies and share market and technological knowledge seems reasonable. However, none of the above mentioned studies provide a justification for the incentives of member firms to co-ordinate their R&D strategies and share the resulting knowledge. Neither the interest to co-operate or to share resources between companies in a group can be taken for granted. For example, Brusco and Panunzi (2005) demonstrate that, in general, the eventual requirement by headquarters to transfer to other divisions the results of managers' efforts generates a weakening of managerial incentives. This problem is even exacerbated when considering "…managers of less-mature businesses, who must be motivated to create new growth opportunities" (Inderst & Laux, 2005, p. 226), i.e. when managers must be motivated to invest in R&D.

In the case of business groups co-ordination problems are exacerbated by the fact that the units are separate legal entities, whose directors and CEOs are supposed to operate in the interest of the company they manage rather than (or before than) the group as a whole. Moreover, in business groups, there can be potential conflicts between the controlling owner(s) and the minority shareholders of controlled firms that invest in R&D, because minority shareholders will not benefits from the sharing of results.

The aim of this paper is to develop a model of R&D investment that considers the belonging of firms to business groups. The main feature of the model is that it relies only on the structural characteristics of the business group – i.e. the ownership relations with other member companies - and makes no hypotheses about the presence of coordinated strategy for R&D and sharing mechanisms of its results. Nonetheless, we show that firms in a business group have a higher possibility than standalone firms to internalize, at least partly, knowledge spillovers. This possibility depends on having ownership stakes in affiliated firms and the ownership share. In particular we demonstrate that this is not valid for all firms belonging to groups but only for those that control other firms (head and intermediate firms[2]); those at the bottom of the group's pyramid are supposed to have a similar behavior than standalone firms.

We provide also a first empirical analysis of the main predictions of the model, using data about Italian business groups. Overall the empirical results are in accordance with the predictions of the model.

The paper is organized as follows. Sections 2 presents the model and its results. Section 3 illustrates the data and methodology used in the empirical section. Section 4 presents and discusses the empirical results. Section 5 concludes and suggests further developments.

The model

We begin with a series of definitions.

Definition 1: business group. A business group is a set of legally independent firms owned and controlled by the same people (which we will refer to as the vertex of the group).

In general, control is associated with the owning of more than 50% of the shares. A vertex can directly control more than one firm (horizontal group) or can control firms through other firms (pyramid). A pyramid occurs when a firm controls at least another firm. A pyramid can have several layers and several firms in each layer. The layers in a group can be numbered from 1 (the head) to n (bottom of the group). In the model that follows we will suppose that the business group is organized as a pyramid with one firm at the head of the group.

Definition 2: head of a business group. A head (H) of a business group is the only firm which is not controlled by another firm (being directly controlled by the vertex) and that controls at least another firm.

Definition 3: intermediate firm in a business group. An intermediate firm (I) in a business group is a firm which is controlled by another firm and that controls at least another firm.

An intermediate firm exists only in business groups in which $n>2$ and occupies one of the layers from 2 to $n-1$.

[2] Definitions of these firms are provided in Section 2.

Definition 4: only controlled firm in a business group. The only controlled firm (*B*) in a business group is a firm which is controlled by another firm and which does not control other firms. It occupies the bottom of the group, i.e. layer $n>1$.

Definition 5: standalone firm. A standalone firm (*S*) is a firm which does not belong to a business group.

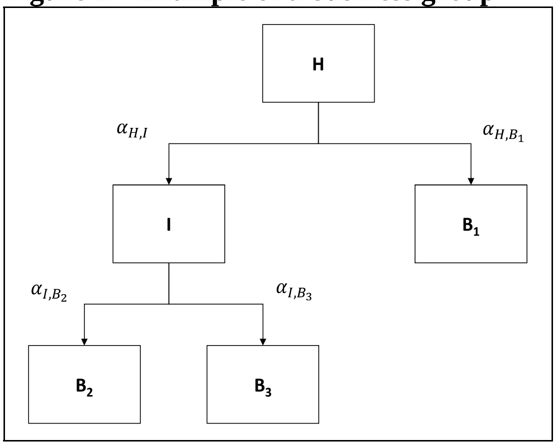
For the sake of simplicity, and without loss of generality, in the model we consider a group (pyramid) composed of three layers: a head (*H*), intermediate firms (*I*) and only controlled firms (*B*).

A relevant issue in a business group is the ownership structure of their member firms. Given that control may be attained by owing less than 100% of a firm, in the case of *B* firms (only controlled) we must distinguish between the direct share, i.e. the share through which firm *B* is controlled by the intermediate firm, and the *ultimate* share, i.e. the effective share of the head (*H*). The formal definition of *ultimate* ownership share is given in the definition below.

Definition 6: ultimate ownership share. Given the ownership share that firm *H* holds in firm *I* ($\alpha_{H,I}$) and the ownership share that firm *I* holds in firm *B* ($\alpha_{I,B}$), we define the *ultimate* ownership share that *H* holds on *B* as $\alpha_{H,I} \cdot \alpha_{I,B}$.

Figure 1 provides an example of a business group. In the figure B_1, B_2 and B_3 are all considered as bottoms firms because they do not control other firms.

Figure 1 – Example of a business group



Below are the assumptions on market and technology for all the firms.

Assumption 1. Each firm $i \in \{H, I, B, S\}$ operates in a monopolistic competition market with an inverse demand function $P_i = P_i(x_i)$, where x_i is output demanded.

The reason of assumption 1 lies in its simplicity. There is an important stream of literature, starting from D'Aspremont and Jacquemin (1988), that models R&D decisions with a game theory approach. This literature in interested, among others, in highlighting the differences between non-cooperative and co-operative decisions in R&D and their implications in terms of social welfare. Although these questions are surely relevant and interesting, they are beyond the scope of the present paper. The aim of our model is to demonstrate that the greater incentive to invest in R&D of firms belonging to groups does not necessarily depend on the hypothesis of cooperative behaviour but by the ownership shares in controlled companies which allows a partial internalization of R&D spillovers. In our model we consider a short term framework in which R&D and knowledge spillovers allow (some) firms to obtain extra-profits.

Assumption 2. Each firm $i \in \{H, I, B, S\}$ has the same cost function:

$TC_i = C(x_i) - b(r_i) - \sum_{j \neq i} s(r_j) + r_i + f_i$

Where x_i is i's output, r_i is the expense of R&D carried out by i and r_j denotes the expense in R&D carried out by the firm j (with $j \neq i$). $C(x_i)$ denotes i's variable costs, while f_i denotes i's fixed costs different from R&D. The expense r_i generates a reduction in i's fixed costs denoted by $b(r_i)$; R&D carried out by the firm j ($j \neq i$) generates a positive spillovers. Also positive spillovers generate a reduction i's fixed costs. Moreover we assume:

Assumption 3. For each firm $i \in \{H, I, B, S\}$ it results:

a) $C'(x_i) > 0$, $C''(x_i) > 0$ and $C(x_i = 0) = 0$

b) $b'(r_i) > 0$, $b''(r_i) < 0$ and $b(r_i = 0) = 0$

c) $s'(r_j) > 0$, $s''(r_j) < 0$ and $s(r_j = 0) = 0$

d) $\lim_{r_I \to +\infty} b'(r_I) = \lim_{r_j \to +\infty} s'(r_j) = 0$

This means that $C(x_i)$ is convex, $b(r_i)$ is concave (decreasing benefits of R&D) and spillover $s(r_j)$ is concave (decreasing benefits of R&D carried out by other firms) [3].

[3] A quite natural assumption would be that $b'(r_i) > s'(r_j)$, with $j \neq i$, i.e. that the benefits coming from own R&D are greater that the benefits coming from exploiting R&D engaged by another firm (see Suzumura, 1992). Even if this assumption is compatible with our model, it is not necessary for our results, and therefore it is not stated.

Therefore R&D enters the cost function in three ways: firstly, since r_i denotes i's R&D expense, it increases firm's cost. Secondly, this cost (r_i) generates a reduction in i's fixed cost[4]. Lastly, R&D carried out by other firms generates positive spillovers to i. The function $s(r_j)$ denotes the degree of appropriability of firm i on R&D carried out by the generic firm $j \neq i$.

Assumption 4. Each firm maximizes its profit function by choosing the optimal level of x_i and r_i:

$x_i, r_i \in \arg\max_{x_i, r_i} \Pi_i$ under the constraints:

(1) $x_i \geq 0$

(2) $r_i \geq 0$

Under the above assumptions, we are able to state the following results.[5]

Result 1.

Under assumptions 1-4, a firm S exhibits a positive expense in R&D if and only if also a firm B does.

Result 2.

Under assumptions 1-4, if a firm S exhibits a positive expense in R&D then also H firms and I firms do. The converse does not hold.

Result 3.

Under assumptions 1-4, if a firm $i \in \{H, I\}$ is engaging in R&D, its level of R&D spending is increasing with the ownership share in controlled firms and $\alpha_{i,h}$ ($i \neq h$).

The important result of this model is that H and I types (i.e. firms controlling other firms) have more incentives to engage in R&D (ceteris paribus) than B and S types *without* invoking any co-ordination mechanism and/or any obligation to share the results of R&D with the other companies in the group.

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[4] Therefore we are making the assumption that R&D is aimed at reducing fixed cost. Another possibility is that R&D can be targeted to the reduction of variable costs: see (Shaffer, 1984).
[5] Proofs are provided in the Appendix.

The assumption of a cooperative behaviour between the firms in a group (which is the common hypothesis of previous studies) would reinforce the results. Indeed, if these mechanisms were at work affiliated firms would have the possibility to completely internalize positive spillovers, while in our model this internalization is only determined by firm's incentives (profits); therefore it affects only *H* and *I* type and depends on their ownership shares in controlled firms.

Moreover, the consequence of the presence of co-operative mechanisms is not straightforward as hypothesized by the empirical literature: i.e. raising the incentive of affiliated firms to engage in R&D. For example, the obligation to share the results of R&D with the other firms of the group could reduce the incentive of the managers of an affiliated firm to invest in R&D activity, unless a specific 'compensation' mechanism is at work. In our model we show that this 'compensation' mechanism is automatically in place for *H* and *I* firms, thanks to their ownership shares in controlled firms which allow them to appropriate part of the profits arising from knowledge spillovers. However, this is not the case for *B* firms or when considering the relations between *I* firms in the same group. This is true not only for manager incentives. Minority owners in *B* and *I* firms are not necessarily interested in sharing valuable assets (such as the new knowledge resulting from R&D) with other companies in the group, unless specific compensation mechanisms are in place.

The main implications of our model are that it is not just the belonging to a business group that matters but the position of the company within the group and the ownership shares between controlling and controlled companies.

The model makes some simplifying assumptions about the spillover mechanisms. We assume that spillovers have the same impact both in firms belonging to groups and in standalone firms. However, it would be reasonable to assume that the intensity of spillovers is greater between companies in the same groups than between standalone companies and the 'vicinity' of firms in terms of industry or geographical areas they belong to. Moreover, the return for the controlling firm would crucially depend not only on the ownership share but also on the size of the controlled firm.

While these aspects are relevant for the theoretical and empirical analysis, their introduction would not alter the basic results of the model. Capitalizing on these results we propose the following hypotheses to be empirically tested.

H_1: there is no significant difference in R&D propensity[6] between *S* firms (standalone firms) firms and *B* firms (firms at the bottom of the group).

H_2: *H* firms (head of groups) and *I* firms (intermediate) show a higher R&D propensity than *S* firms and *B* firms.

H_3: The level of R&D propensity/intensity of firms is increasing with their (ultimate) ownership shares.

Data and Methodology

To test the above hypotheses we use quantitative analysis based on secondary data derived from the Capitalia dataset. This dataset is based on a periodical survey (every three years) of a representative sample of about 4,000 Italian manufacturing firms with more than ten employees. Data refer to the period 2001-2003. The Capitalia survey requests information on whether a firm belongs to a business group and on its position within the group. The Capitalia dataset does not provide information on the exact level of the pyramid to which the company belongs. Nevertheless, it asks companies belonging to a group whether: a) they control other companies but are not controlled by a company (head of the group); b) they are controlled by a company and control other companies (intermediate position); c) they are controlled by a company but do not control other companies (bottom of the pyramid). This allows us to distinguish between *H*, *I* and *B* types. Moreover, the dataset allows us to compare the differences between standalone firms (*S* firms) and those belonging to a business group. The Capitalia dataset has been widely used in studies about business groups and manufacturing firms in general (Piga, 2002; Filatotchev et al., 2003).

Dependent variables

Our dependent variables are:

a) *R&D propensity*: it is a dummy variable which equals one if firms engaged in R&D spending in 2003.

[6] By R&D propensity we mean the decision to invest or not in R&D. By R&D intensity we mean a measure of R&D spending.

b) *R&D intensity*: it is measured as the ratio between R&D expenses and sales in 2003.

Independent variables

In order to test our hypothesis we use a set of dummy variables:

Bottom vs standalone: it is a dummy variable which equals one if the firm is at the bottom of the group and zero if the firm is standalone. This variable is employed to test the first hypothesis (H_1).

Standalone/bottom vs head/intermediate: it is a dummy variable which equals one if the firm is a *H* or a *I* type and zero if the firm is a *B* or a *S* type. This variable is employed to test hypothesis two (H_2).

Group position : it is a multinomial dummy which is equal to one if the firm is a *B* or a *S* type; it is equal to two if the firm is a *I* type and 3 if the firm is a *H* type. This variable is employed as a proxy of the ownership share in other firms to test hypothesis three (H_3).

To properly test hypothesis H_3 we would need the ultimate share of *H* and *I* firms in their controlled firms (*B*). Unfortunately, Capitalia dataset does not provide information about the characteristics of controlled firms. By using g*roup position* we make the implicit assumption that, on average, the higher is the position of a firm in a group, the higher is the amount of shares it holds in other firms and, as a consequence, the possibility to appropriate the results of positive spillovers as dividends from controlled companies. Moreover, it is worthwhile noting that the Capitalia survey considers only manufacturing firms. It follows, therefore, that the heads of groups are always manufacturing companies and not “pure” holding firms.

In testing the three hypotheses we control for other variables that potentially might affect both the *R&D propensity* and *intensity* of firms. In particular, we consider firm size in terms of employees (log of employees in 2001), and the industry to which the firm belongs. About firm size we expect a positive relationship with R&D spending. To take into account industry effects on R&D propensity/intensity we use Pavitt’s classification of sectors based on innovation patterns (Pavitt, 1984). This classification distinguishes between four macro sectors: scale intensive, supplier dominated, science based, and specialized supplier. It is a classification of industries in terms of technological regimes rather than market structure, that we capture with another variable (see below). In the empirical analysis we use the supplier dominated sector as a reference.

We control for the effect of the intensity of competition (market structure) on the decision to invest in R&D. Since we do not have a direct measure of the intensity of competition, we use the size of competitors as a proxy. This information comes from the Capitalia survey which asks firms whether their competitors are small, medium-sized or large. We expect that the larger the competitors, the greater their R&D spending and, as a consequence, the need to compete by investing in R&D.

Given the presence of financial markets imperfections (e.g. information asymmetries) we control for the availability of internal funds which should, in principle, increase both the R&D propensity/intensity. In particular, we consider the financial leverage (i.e. the ratio debt/equity). For similar reasons we control also firm's past performance in terms of return of investment (ROI). In both cases data refer to the beginning of the period (2001). While in the case of leverage we expect a negative relation with R&D investment, in the case of ROI we expect a positive sign, since ROI can be viewed as a proxy for the internal generation of cash and for the expected profitability of investment.

Another characteristic that is supposed to have an important impact on firms' R&D efforts is absorptive capacity, i.e. the ability to identify, incorporate and use the know-how generated inside and outside the firm (Cohen and Levinthal, 1990). Absorptive capacity has a positive effect on the ability to exploit external knowledge and also on the efficiency of internal efforts to innovate (Becker and Peters, 2000; Veugelers, 1997). A firm's absorptive capacity depends on past investment in R&D. Firm's past investment in R&D generates a cumulative process according to which firm is expected to increase its effort in innovation in the present. In the empirical estimates we control for this effect by considering the firm's R&D stock, measured as the ratio of intangible assets to total fixed assets.

We control also for age. In principle we expect that new firms should exhibit higher innovative efforts than older firms, even if as noted by Huergo and Jaumandreu (2004) the relation with firm age could be more troublesome.

Finally, according to Belenzon and Berkovitz (2010, p. 520), group affiliation might be endogenous since business groups could acquire standalone firms with good innovation capacity, higher profitability, etc. We deal with this potential source of bias by controlling for whether, in the period considered, the firm was involved in an acquisition and/or hiving off of operations using the dummy variables, *acquisition* and *hiving off* which are equal to 1 if the firm was involved in an acquisition (hiving off) in the period.

The list of variables and their definitions are presented in Table 1. Table 2 offers some descriptive statistics of the variables we include in the econometric analysis.

Table 1 – Variables used in the estimates

Variable	Description
R&D propensity	Dummy variable for engagement in R&D activity in 2003
R&D intensity	Ratio between R&D expenses and sales in 2003
Bottom vs standalone	Dummy variable used to discriminate whether the firm is *S* type (0) or if it is a *B* type (1)
Standalone/bottom vs head/intermediate	Dummy variable used to discriminate whether the firm is a *H* or a *I* type (1) or if it is a *B* or a *S* type (0)
Group position	Multinomial variable which is equal one if the firm is a *B* or a *S* type, two if the firm is a *I* type and three if the firm is a *H* type
Age	Age of the firm: years from foundation
Pavitt sector dummies:	Dummies for industry sectors based on Pavitt taxonomy: Scale intensive = scale intensive sectors Specialized suppliers= Specialized supplier sectors Science based = Science based sectors Supplier = supplier dominated sectors (which is taken as reference)
Firm size	Logarithm of the employees the firm in 2001
Leverage	Ratio between financial debts and equity in 2001
ROI	Return on assets in 2001
Competitors	Intensity of competition measured by the size of competitors. Multinomial dummy taking values from 1 to 3 according to the average size of competitors: 1=small; 2=medium; 3=large
R&D stock	The ration between intangible assets and fixed assets
Acquisition	Dummy variable indicating whether the firm has carried out acquisitions in the period 2001-2003
Hiving off	Dummy variable indicating whether the firm has carried out hiving offs in the period 2001-2003

Table 2 – Descriptive statistics (mean values)

	Total firms	Standalone firms	Firms belonging to groups[a]		
			Head	Intermediate	Only Controlled
Number of firms	3,446	2,342	274	251	575
R&D propensity (% of firms)	37.4	33.4	49.6	54.8	40.2
R&D intensity (% on sales)	0.84	0.66	2.02	1.07	0.92
Firm size (employees in 2001)	132	57	337	484	187
ROI %	6.26	6.74	5.64	5.30	4.99
Leverage	2.11	2.42	1.90	1.54	1.15
R&D stock	0.084	0.077	0.085	0.085	0.116
Age (years)	28.12	28.42	33.72	29.85	23.82

[a] The sum of heads, intermediate and controlled does not equal the firms belonging to groups due to missing values about the position of the firm within the groups.

To test H_1 and H_2 we use Probit estimations for the factors affecting R&D propensity. In order to test H_3 we use the Heckman two-step method to cope with the problem of sample selection. In the first step we estimate a Probit model (selection equation) for the dummy variable *R&D propensity*. This first step enables to compute an inverse Mill's ratio which will be used in the second step. The second step consists in estimating an OLS model for the variable *R&D intensity* only for those firms showing positive values of this variable (selected sample) by using the inverse Mill's ratio as regressor. In order to avoid identification problems we have to exclude from the outcome equation at least one variable used in the selection equation (Cameron and Trivedi, 2005).

This choice is often troublesome since the variable(s) excluded should be not significant in the outcome equation (second step), but should be significant in the selection process (first step). We present three different specifications: in the first one we exclude the variable *Competitors* (competitors' size) from the outcome equation; in the second one the variable *Firm size*; and in the third specification both variables. *Competitors* and *Firm size*, as we will show in the following section, are both highly significant in the selection equation but not in the outcome equation.

In order to cope with possible endogeneity problems, we use lagged values for the control variables: size and economic indicators refer to 2001, which is the beginning of the period. Before introducing the econometric estimations, we present the correlation matrix for the main independent variables included in the regressions (Table 3).

Table 3 - Correlation matrix

	Group position	*R&D intensity*	*Firm Size*	*Leverage*	*ROI*	*R&D stock*	*Age*
Group position	1						
R&D intensity	0.0573	1					
Firm size	0.3780	0.0380	1				
Leverage	-0.0090	-0.0101	-0.0035	1			
ROI	-0.0383	-0.0256	-0.1261	-0.0377	1		
R&D stock	0.0025	0.0892	0.0161	-0.0087	-0.0589	1	
Age	0.0855	0.0317	0.1818	-0.0229	-0.0190	-0.1182	1

Empirical results

The results of our estimations are shown in Table 4. The first hypothesis we test is whether type *S* firms and type *B* firms have the same R&D propensity. The dependent variable we use is the dummy *Bottom vs standalone*. Among the independent variables we use a proxy variable for the belonging to a group, the size of the firm, three dummy variables to account for the Pavitt sectors, leverage and ROI as measures of financial capacity and firm profitability respectively. As expected, there is not a significant difference in R&D propensity between standalone firms (*S* type) and only controlled ones (*B* type). The coefficients of the other variables show the expected sign. The size of the firm has a positive and strong influence on R&D propensity. Past economic performance (ROI) and leverage have the expected sign, but are never statistically significant. The results emphasize the importance of the sector in which the firm operates. Compared to *Supplier dominated* sectors (taken as the reference category) firms in the *Specialized suppliers* and in the *Science based* sectors show a significantly higher propensity to engage in R&D. The size of the firm's competitors increases the probability of the firm undertaking R&D activities. This confirms that market structure is relevant for R&D propensity. R&D stock is highly significant and shows the expected sign. The variables for acquisition/hiving off are not significant.

The second hypothesis we test is whether type *H* and type *I* firms exhibit a higher R&D propensity than type *S* and type *B* firms. The dependent variable we use for this analysis is, as said above, is the dummy *Standalone/bottom vs head/intermediate*. The independent variables are the same of the previous regression. The results are shown in column 2 of Table 4.

Also hypothesis 2 is supported by the empirical evidence, since the main dependent variable *Bottom/standalone vs head/intermediate* has a positive and strong influence in explaining the R&D propensity of firms. Concerning the other variables, firm size, R&D stock, *Specialized suppliers* and *Science based* sectors, competitors, acquisitions, hiving off have, at various level, a positive impact on R&D propensity.

According to the third hypothesis, both R&D intensity and R&D propensity are increasing with the ownership (and ultimate ownership) shares firms hold. Since Capitalia does not provide us with such information, we use as proxy the variable *Group position*. This variable, as said above, equals one if the firm is a *S* or a *B* type, equal two if it is a *I* type, and three if it is a *H* type. In this sense we make the implicit assumption that a *H* firm holds ownership (ultimate ownership) shares greater than a *I* firm. This variable is similar to the one used by Filatotchev et al. (2003). However, differently from Filatotchev et al. (2003), following the predictions of our model we do not discriminate between *S* firms and *B* firms.

In testing H_3 we used three different specifications by dropping *Competitors* and/or *Firm size* from the outcome equation. We note that the variables dropped (*Competitors* and *Firm size*) are not significant in the outcome equations. Overall, the empirical evidence is in accordance with the H_3, even if the significance of *Group position* varies according to the specifications and is more significant in explaining R&D propensity than in explaining R&D intensity.

Table 4 – R&D propensity and intensity of firms (t statistics in parentheses)

	Probit[a]	Probit[a]	Heckman two step procedure[a]		
			H_3		
	H_1	H_2	(1)	(2)	(3)
R&D intensity					
Group position			.0179** (2.09)	.0101* (1.85)	.0111** (2.05)
Firm size			.0124 (1.11)		
Competitors				-.0047 (-1.05)	
ROI			-.0352 (-0.78)	-.0549 (-1.45)	-.0546 (-1.43)
Leverage			-.0002 (-0.57)	-.0001 (-0.36)	-.0001 (-0.40)
Age			.0003* (1.92)	.0002* (1.70)	.0003* (1.85)
R&D stock			.1057*** (3.56)	.0814*** (3.96)	.0843*** (4.11)
Scale intensive			-.0052 (-0.54)	-.0030 (-0.35)	-.0035 (-0.40)
Specialized suppliers			.0285 (0.51)	.0082 (0.98)	.0100 (1.20)
Science based			.0931*** (3.72)	.0698*** (4.86)	.0715*** (4.98)
Acquisition			.0097 (0.92)	.0041 (0.47)	.0050 (0.58)
Hiving off			.0126 (0.76)	.0027 (0.21)	.0041 (0.31)
R&D propensity					
Bottom vs standalone	-.1092 (-1.55)				
Bottom/standalone vs head/intermediate		.3574*** (4.79)			
Group position			.1903*** (4.19)	.1903*** (4.19)	.1903*** (4.19)
Firm size	.3260*** (10.38)	.2709*** (10.20)	.2772*** (10.52)	.2772*** (10.52)	.2772*** (10.52)
ROI	.4797 (1.41)	.4108 (1.28)	.4026 (1.26)	.4026 (1.26)	.4026 (1.26)
Leverage	-.0020 (-0.96)	-.0016 (-0.82)	-.0017 (-0.83)	-.0017 (-0.83)	-.0017 (-0.83)
Age	.0022 (1.55)	.0018 (1.42)	.0018 (1.43)	.0018 (1.43)	.0018 (1.43)
R&D stock	.6563*** (3.58)	.5303*** (3.13)	.5307*** (3.13)	.5307*** (3.13)	.5307*** (3.13)
Competitors	.0999*** (2.59)	.0865** (2.44)	.0910*** (2.57)	.0910*** (2.57)	.0910*** (2.57)
Scale intensive	-.03200 (-0.44)	-.0429 (-0.64)	-.0393 (-0.58)	-.0393 (-0.58)	-.0393 (-0.58)
Specialized supplier	.4958*** (8.15)	.4456*** (7.93)	.4472*** (7.96)	.4472*** (7.96)	.4472*** (7.96)
Science based	.5041*** (3.66)	.5459*** (4.36)	.5479*** (4.38)	.5479*** (4.38)	.5479*** (4.38)
Acquisition	.1437 (1.53)	.1358* (1.74)	.1405* (1.80)	.1405* (1.80)	.1405* (1.80)
Hiving off	.2244 (1.58)	.2396* (1.94)	.2494** (2.02)	.2494** (2.02)	.2494** (2.02)
N° of observations	2,711	3,126	3,123	3,123	3,123
Censored obs.			1,920	1,920	1,920
Uncensored obs.			1,203	1,203	1,203
Lr chi^2 (prob > chi^2)	279.54 (0.0000)	391.96 (0.0000)			
Wald chi^2 (prob > chi^2)			41.42 (0.000)	51.56 (0.000)	49.98 (0.000)
Pseudo R^2	0.0797	0.0940			
Mills			.0865 (1.47)	.0160 (0.93)	.0235 (1.49)

[a]Regressions include a constant term.
Legend: ***significant at 1%; **significant at 5%; * significant at 10%
Source: elaborations on Capitalia dataset

Conclusions

Several empirical studies have shown that firms belonging to business groups have a higher propensity to engage in R&D. One of the explanations for this result is based on the hypothesis that affiliated companies coordinate their R&D investment and share its results. In this paper we demonstrate that the higher propensity of affiliated firms to invest in R&D does not necessarily depend on the hypothesis of cooperative behaviour but may also rely on the incentives provided by ownership shares in controlled firms. Specifically, firms that control other firms can partly appropriate the positive spillovers of their R&D from controlled companies. This appropriation depends on the ownership share in controlled companies.

Another result of our model is that it is not the belonging to a business group *per se* that matters but the owning of other firms. For this reason firms at the bottom of the group (i.e. firms that do not control other firms) are supposed to be more similar to stand-alone firms than to firms at the head of the group or in an intermediate position. This result is important because, in principle, the presence of coordinated strategies between firms belonging to groups cannot be taken for granted. Moreover, the presence of cooperative behaviour or imposed sharing mechanisms can also have ambiguous effects by reducing the incentives of member firms to engage in R&D.

We show that the higher propensity to engage in R&D and the higher intensity of R&D expenses of head and intermediate firms depend on economic incentives (the cash flow rights in controlled firms) without assuming the presence of collaborative mechanisms. From the results of our model we derive three main implications that can be empirically tested: a) that there is no difference in R&D propensity between stand-alone firms and firms at the bottom of business groups; b) that head and intermediate firms have a higher R&D propensity compared to stand-alone and firms at the bottom of the group; c) that the intensity of R&D depends on the ownership shares in controlled companies.

We provide a first empirical test of these implications using a representative sample of Italian manufacturing firms. Overall the empirical results are in accordance with the implications of the model. Moreover, since we do not have the necessary information on ownership shares to test the third implication, we use a position variable which discriminates between head, intermediate, and bottom/stand-alone firms, making the implicit assumption that heads hold more ownership shares than intermediate ones. Also in this case the empirical evidence is in accordance with the prediction of the model.

This paper has some limitations that give space to further development.

The theoretical model assumes that R&D spending is targeted to reducing fixed costs. It could be extended to consider the impact of R&D on variable costs or on product innovation. Another extension of the model could consider the strategic interactions between firms. Although these extensions could enrich the results of the model, we do not think that they will alter dramatically the main implications about the incentives linked to the ownership mechanism.

On the empirical side it would be useful to have more information about the firms controlled by head and intermediate firms, their ownership shares, and their ability to exploit knowledge spillovers. This could lead us to a direct test of the third implication of the model.

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Appendix

First of all we note that since by assumptions 2 and 3 the expense in R&D is independent from the output, and since the two variables are independent also in the constraints, then $x_i, r_i \in \arg\max_{x_i, r_i} \Pi_i(x_i, r_i)$ can be decomposed in: $x_i \in \arg\max_{x_i} \Pi_i^x(x_i)$ and $r_i \in \arg\max_{r_i} \Pi_i^r(r_i)$.In the following, since we are not interested in determining the optimal amount of x_i, we will restrict our attention to the optimal level of r_i.

Proof of Result 1

It is trivial. Let's consider the profit function of firm *S* and *B*. Thanks to definitions 4 and 5 and assumptions 2, 3 and 4 it results:

$$r_S \in \arg\max_{r_S} \left\{ \Pi_S^r = b(r_S) + \sum_{j \neq S} s(r_j) - r_S \right\} \quad r_B \in \arg\max_{r_B} \left\{ \Pi_B^r = b(r_B) + \sum_{j \neq B} s(r_j) - r_B \right\}$$

Since $\Pi_S = \Pi_B$, and since also the constraints are the same, $r_S^* = r_B^*$, firm *S* decides to engage in R&D spending ($r_S^* > 0$) if and only if also firm *B* does. □

Proof of Result 2

Let's begin by considering a firm *S*.

$$r_S \in \arg\max_{r_S} \left\{ \Pi_S^r = b(r_S) + \sum_{j \neq S} s(r_j) - r_S \right\}$$

under the constraint:

(1) $r_S \geq 0$

Now let's consider the *I* firm. By considering definitions 3 and 6 and assumptions 2, 3 and 4 and by assuming, without loss of generality, that firm *I* controls only one *B* firm:

$$r_I \in \arg\max_{r_I} \Pi_I^r = b(r_I) + \sum_{j \neq I} s(r_j) - r_I + \alpha_{I,B} \Pi_B^r$$

under the constraint:

(1) $r_I \geq 0$

Note that if a firm decides to engage in R&D, it is because the benefits of R&D outweighs its costs, otherwise it would choose r*=0. This corresponds to:

$r_S \leq b(r_S)$ [I]

$r_I \leq b(r_I) + \alpha_{I,B}\, s(r_I)$ [II]

By assumptions 2 and 3 it results that $b(r_S) = b(r_I)$. Always by assumption 3 it results that $\alpha_{I,B}\, s(r_I) > 0$. Therefore if [I] is satisfied for some positive values of r_S, [II] is also satisfied. However the converse is not necessarily true. A similar argument holds for firm H . □

Proof of Result 3

Let's begin by considering a firm S.

$$r_S \in \arg\max_{r_S} \left\{ \Pi_S^r = b(r_S) + \sum_{j \neq S} s(r_j) - r_S \right\}$$

under the constraint:

(2) $r_S \geq 0$

Now let's consider the I firm. By considering definitions 3 and 6 and assumptions 2, 3 and 4 and by assuming, without loss of generality, that firm I controls only one B firm:

$$r_I \in \arg\max_{r_I} \Pi_I^r = b(r_I) + \sum_{j \neq I} s(r_j) - r_I + \alpha_{I,B} \Pi_B^r$$

under the constraint:

(2) $r_I \geq 0$

Note that if a firm decides to engage in R&D, it is because the benefits of R&D outweighs its costs, otherwise it would choose r*=0. This corresponds to:

$r_S \leq b(r_S)$ [I]

$r_I \leq b(r_I) + \alpha_{I,B}\, s(r_I)$ [II]

By assumptions 2 and 3 it results that $b(r_S) = b(r_I)$. Always by assumption 3 it results that $\alpha_{I,B}\, s(r_I) > 0$. Therefore if [I] is satisfied for some positive values of r_S, [II] is also satisfied. However the converse is not necessarily true.

A similar argument holds for firm H . □