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Abstract

We study the product and process innovation choice of firms in which a managerial incentive à la Vickers (1985) is present. Taking a two-stage dynamic game approach, we show that managerial firms are led to over-invest in process innovation, as compared to standard profit-maximising firms, while they under-invest in product innovation. The reason is that process innovation allows to decrease cost, and this is consistent with a convenient increase in the production level. On the opposite, product innovation allows increasing price, which is in contrast with the taste for output expansion embodied in the objective function of firms run by managers. Preliminary empirical evidence on Italian companies suggests that in fact the managerial nature of firm associates with significantly smaller efforts in product innovation while the effect on process innovation is positive but non-significant.

[JEL Codes: D43, D23 C72, O31, O32]

[Keywords: Process innovation; Product innovation; R&D; Managerial incentive]

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Abstract - We study the product and process innovation choice of firms in which a managerial incentive à la Vickers (1985) is present. Taking a two-stage dynamic game approach, we show that managerial firms are led to over-invest in process innovation, as compared to standard profit-maximising firms, while they under-invest in product innovation. The reason is that process innovation allows to decrease cost, and this is consistent with a convenient increase in the production level. On the opposite, product innovation allows increasing price, which is in contrast with the taste for output expansion embodied in the objective function of firms run by managers. Preliminary empirical evidence on Italian companies suggests that in fact the managerial nature of firm associates with significantly smaller efforts in product innovation while the effect on process innovation is positive but non-significant.

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1. Introduction

In this paper, we study the optimal decisions of managerial firms concerning the efforts devoted to, respectively, product and process innovations. According to the seminal model introduced by Baumol (1958), subsequently revisited by Vickers (1985), Ferhstman and Judd (1987) and several others, we assume that the objective function of managers takes into account both the levels of profits and output. From two simple theoretical frameworks based on well-known two-stage games, we show that a managerial company, as compared to a standard profit maximising firm, ascribes a greater importance to process innovations and tends to under-invest in product innovations. What the two alternative models have in common is the assumption that firms aim at maximising an objective function featuring a linear combination of profits and output level. Following Vickers (1985), the weight associated to the output goal can be interpreted as a 'managerial incentive'. In the first model, we investigate process innovation in the form of R&D efforts aimed at reducing marginal production costs, nesting into a well established literature stemming from d'Aspremont and Jacquemin (1988). In the second, we describe product innovation in the form of quality improvements, in a vertically differentiated duopoly whose main features are known since Gabszewicz and Thisse (1979) and Shaked an Sutton (1982).

We show that the higher is the managerial incentive, the higher is the investment in process innovation and the lower is that devoted to product innovation. The intuitive explanation from these results is as follows. In view of the managerial preference for output expansion, process innovation is definitely attractive as it turns into an increase of the innovator's market share, *all else equal*. That is, the innovating firm easily (and fully) internalises the benefits of its investment. This is not true for product innovation, though, as it spills over to the rival and largely replicates the features of a public good. Adding up to the fact that any increase in quality brings about an increase in price, which in turn entails a decrease in output in contrast with managerial preferences, the lack of full appropriability reduces the managerial firm's incentive to carry out product innovation as compared to a pure profit-seeking unit.

The above theoretical conclusions are supported by preliminary evidence coming from a sample of Italian manufacturing firms. Such a sample is composed of medium-sized and large firms which are distinguished according to their managerial nature. Small firms are not taken into account because in their case ownership and control tend to be overlapped and it does not make sense to distinguish the few that are ruled by managers.

After controlling for relevant variables that may influence the prevailing type of innovative activity at firm level, we find that the managerial nature of firms exerts a quite different impact on the probability of introducing product and process innovations. The former is significantly lower for the firms that are run by managers while for that concerned with process innovations the ‘managerial’ effect, although positive, turns out to be not statistically significant.

To the best of our knowledge, this is the first attempt to study the bearings of managerial preferences on firms' propensity to invest in product or process innovations. Most of the available theoretical and empirical studies focus on the role exerted by firm size or markets' features. Yin and Zuscovitch (1998) study the relative convenience of product and process innovations and show that the efforts devoted to the latter rise with the size of firms. The relative profitability of product innovations, instead, has been found to increase with the size of markets (Rosenkranz, 2003) or the degree of product differentiation (Weiss, 2003). With respect to the empirical evidence, the firm size emerges as a key variable in explaining the extent of R&D expenditures devoted to process innovations. According to Cohen and Klepper (1996), who provide evidence on US firms, this finding is mainly ascribable to the fact that large companies are able to spread the cost advantages due to process innovations on higher volumes of output. Similar evidence is provided by Fritsch and Meschede (2001) for Germany, and Parisi et al. (2006) who estimate the probabilities of introducing product and process innovations by Italian manufacturing firms.

Our empirical analysis shows that, when the results are controlled for industry fixed effects, the size of firms does not significantly affect the relative propensity to introduce product and process innovations. The latter, however, is higher for the firms belonging to industries that rely particularly on scale economies. Obviously, the probability of investing in product innovations depends on industry characteristics too, but we find that it is significantly lower when companies are run by managers who, according to our model, are less prone to innovate products.

The theoretical findings and the empirical evidence provided in this paper offer additional insights in the long-standing debate – dating back to Schumpeter (1942) and Arrow (1962) – on the relationships between firm size and market structure on the one side and innovation efforts on the other. Along with other factors, we contend that the above relationships can also be shaped by the managerial nature of firms.

The structure of the paper is as follows. Section 2 presents the theoretical models. Section 3 is devoted to the empirical analysis based on a wide sample of Italian manufacturing firms. Conclusions and comments are gathered in Section 4.

2. Models

In order to investigate the interplay between strategic delegation and managerial incentives to invest in process and product innovation, we employ two well known models that have been widely debated in the existing literature. The first, featuring investments in process innovation, dates back to d'Aspremont and Jacquemin (1988);[1] the second, illustrating firms' incentives to increase product quality, can be traced back to Gabszewicz and Thisse (1979, 1980) and Shaked and Sutton (1982, 1983). In both settings, we focus our attention on non-drastic innovations.

2.1 Process innovation

We consider a situation in which two firms, 1 and 2, compete on a market for differentiated products. The utility function of the representative consumer is

$$(1) \qquad U = a(x_1 + x_2) - \frac{1}{2}(x_1^2 + x_2^2 + 2sx_1x_2), \quad a > 0, s \in [0,1]$$

as in Spence (1976) and Singh and Vives (1984), *inter alia*. Parameter s measures the degree of substitutability between the two varieties, so that they are identical if s=1, and completely independent of each other if s=0. Market competition takes place *à la* Cournot and the (inverse) demand functions faced by the two firms are respectively:

$$(2) \qquad p_1 = a - x_1 - sx_2$$

$$(3) \qquad p_2 = a - x_2 - sx_1$$

The production of goods entails a constant unit cost, according to the cost function

$$(4) \qquad C_i(x_i) = c_i x_i, \quad c \in [0, a), i = 1, 2$$

In a pre-market stage, firms may carry out R&D investments for innovation. Process innovation entails a unit cost reduction (as in the literature deriving from the seminal

[1] See also Kamien *et al.* (1992) and Suzumura (1992), *inter alia*.

paper by d'Aspremont and Jaquemin, 1988). We denote the investment effort by k_i (i=1,2). Thus, R&D activities devoted to process innovation mean that the relevant (total) cost function borne by firm i looks as follows:

$$(5) \qquad \Gamma_i(x_i, k_i) = (\bar{c} - k_i - \beta k_j)x_i + \frac{bk_i^2}{2}, \quad i = 1, 2, i \neq j$$

where $(\bar{c} - k_i - \beta k_j)$ is firm i's marginal production cost, b>0 is a parameter scaling the R&D cost and $\beta \in [0,1]$ measures the degree of technological spillovers characterising the R&D activity within the industry.

Finally, we assume that both firms are run by managers, who derive positive utility from the level of production in itself, so that the objective function of each firm is assumed to be

$$(6) \qquad M_i = \pi_i + \theta Q_i, \quad i = 1, 2,$$

where π_i denotes profit (revenues minus total costs, measured by (5)) and the term θQ_i (with $\theta \geq 0$) captures the managers' love for production, or –using the label proposed by Vickers (1985) – it represents the "managerial incentive". It is worth mentioning that a strand of literature starts from the seminal papers by Vickers (1985) and Fershtman and Judd (1987); in these models, managers aim at maximising a weighted average of profits and either sales or revenues, while the delegation contract for managers is written in such a way that the managerial incentive is 'optimally' set so as to maximise the stockholders' profits. Clearly, in the limiting case where $\theta = 0$, we are back to the benchmark setup with purely profit-maximising firm.

In what follows, we shall take the extent of delegation as given, i.e., we will treat θ as an exogenous parameter in order to study its effects on innovation incentives in terms of comparative statics.

The objective functions of the two firms' managers write as follows:

$$(7) \qquad M_1 = (a - x_1 - sx_2)x_1 - (\bar{c} - k_1 - \beta k_2)x_1 - \frac{bk_1^2}{2} + \theta x_1$$

$$(8) \qquad M_2 = (a - x_2 - sx_1)x_2 - (\bar{c} - k_2 - \beta k_1)x_2 - \frac{bk_2^2}{2} + \theta x_2$$

In order to identify the sub-game perfect Nash equilibrium of the two-stage game, we proceed as usual by backward induction. In the market phase, taking as given the investment efforts chosen at the first stage, each firm sets the optimal amount of production, simultaneous to the opponent's choice. From the system of first order conditions one derives the pair of optimal outputs:

$$(9) \qquad x_1^* = \frac{a(2-s) - 2(\bar{c} - k_1 - \beta k_2) + s(\bar{c} - k_2 - \beta k_1) + \theta(2-s)}{4-s^2}$$

$$(10) \qquad x_2^* = \frac{a(2-s) - 2(\bar{c} - k_2 - \beta k_1) + s(\bar{c} - k_1 - \beta k_2) + \theta(2-s)}{4-s^2}$$

Of course optimal outputs depend on the investment efforts decided upon in the first stage of the game. Substituting (9-10) in the objective functions, and taking the first derivative w.r.t. k_1 and k_2 respectively, we can easily find the optimal level of symmetric investment efforts:

$$(11) \qquad k_i^* = \frac{2(a-c+\theta)(2-\beta s)}{b(2-s)(2+s)^2 - 2(1+s)(2-\beta s)}, \quad i = 1,2; \quad \forall\, b > \frac{2(1+s)(2-\beta s)}{(2-s)(2+s)^2}$$

with the corner solution

$$(12) \qquad k_i^* = 0 \quad \forall\, b \le \frac{2(1+s)(2-\beta s)}{(2-s)(2+s)^2}$$

Provided that an interior solution does exist [2] at the first stage of the game, then it is immediate to note that

$$(13) \qquad \frac{\partial k_i^*}{\partial \theta} > 0 \quad .$$

This means that the larger is the extent of delegation to managers, the higher will be the investment efforts devoted to process innovations. In other words, compared to standard profit-oriented firms without any managerial incentive, firms that are run by managers interested in expanding output levels will tend to devote a larger amount of resources to activities aimed at process innovation. The economic intuition behind this result is quite clear, as any reduction in production costs entails, all else equal, an increase in output, which in turn is appealing to managers whose objective function is defined as in (6).

[2] The condition ensuring positive R&D efforts at the sub-game perfect equilibrium coincides with that ensuring the asymptotic stability of the equilibrium itself. See Henriques (1990).

This conclusion replicates those of Zhang and Zhang (1997), Kraekel (2004) and Kopel and Riegler (2006), where the extent of delegation is exogenously determined prior to the R&D stage.

2.2 Product innovation

The vertical differentiation model we adopt to study product innovation draws upon a two-stage game analysed in several contributions (Choi and Shin, 1992; Dutta *et al.*, 1995; Wauthy, 1996; Lambertini *et al.*, 2002, *inter alia*). Two single-product firms, labelled as H and L, supply goods of qualities $Q > q_H \geq q_L \geq 0$. Consumers are uniformly distributed with density equal to one over the interval $[\Theta - 1, \Theta]$, with $\Theta > 1$. Therefore, the size of the total population of consumers is equal to Θ . Each consumer is indexed by a marginal willingness to pay for quality $\vartheta \in [\Theta - 1, \Theta]$, and either buys one unit of the vertically differentiated good or doesn't buy at all. His net utility from consumption is:

$$(14) \qquad U = \begin{cases} \vartheta q_i - p_i \geq 0 & (if \;\; he\; buys) \\ 0 & (if \;\; he\; doesn't\; buy) \end{cases}$$

where p_i is the price of the good supplied by firm i.

For the sake of simplicity, all variable production costs are assumed to be nil, while quality improvements involve a convex R&D effort $\psi_i(q_i)$. This, in addition to ensuring the concavity of the objective function w.r.t. the quality level, also involves the presence of decreasing returns to R&D efforts for quality improvements. It is sensible to assume that a higher quality requires a higher R&D effort, and therefore we pose $\psi_H(q_H) > \psi_L(q_L)$.

The market demand functions for the two goods are:

$$(15) \qquad x_H = \Theta - \vartheta_H \; ; \quad x_L = \vartheta_H - \vartheta_L$$

where ϑ_H is the marginal willingness to pay for quality characterising the consumer who is indifferent between q_H and q_L at the price vector $\{p_H, p_L\}$, i.e., it is the solution to:

$$(16) \qquad \vartheta_H q_H - p_H = \vartheta_L q_L - p_L \Leftrightarrow \vartheta_H = \frac{p_H - p_L}{q_H - q_L}$$

while ϑ_L is the marginal evaluation of quality associated with the consumer who is indifferent between buying the low quality good and not buying at all, $\vartheta_L = p_L / q_L$. Productions' levels turn out to be

(17) $$x_H = \left(\Theta - \frac{p_H - p_L}{q_H - q_L} \right); \quad x_L = \left(\frac{p_H - p_L}{q_H - q_L} - \frac{p_L}{q_L} \right)$$

while firms' profits, net of R&D costs, are:

(18) $$\pi_H = p_H \left(\Theta - \frac{p_H - p_L}{q_H - q_L} \right) - \psi_H(q_H); \quad \pi_L = p_L \left(\frac{p_H - p_L}{q_H - q_L} - \frac{p_L}{q_L} \right) - \psi_L(q_L)$$

As in the previous model, also here the delegation contract allows for the assignment of an extra weight to sales, so that the managers of firm *i* wants to maximise

(19) $$M_i = \pi_i + \theta_i x_i \, .$$

In this case we allow for different managerial incentives, i.e., $\theta_H \neq \theta_L$, in view of the *ex ante* asymmetry between the two firms. Again, we take θ_i as exogenously given.

From the first order condition on prices:

(20) $$\frac{\partial M_H}{\partial p_H} = \frac{p_L - 2p_H + \Theta(q_H - q_L) - \theta_H}{q_H - q_L} = 0$$

(21) $$\frac{\partial M_L}{\partial p_L} = \frac{p_H q_L - q_H(2p_L + \theta_L)}{q_L(q_H - q_L)} = 0$$

we obtain the following Nash equilibrium prices, given the vectors of qualities and delegation parameters:

(22) $$p_H^* = \frac{q_H[2\Theta(q_H - q_L) - 2\theta_H - \theta_L]}{4q_H - q_L}$$

(23) $$p_L^* = \frac{q_L[\Theta(q_H - q_L) - \theta_H] - 2q_H\theta_L]}{4q_H - q_L}$$

The solution of the quality stage cannot be worked out analytically;[3] nevertheless, one can resort to the implicit function theorem to highlight that

$$(24) \qquad \frac{\partial p_i}{\partial \theta_i} = \frac{\partial p_i}{\partial q_i} \cdot \frac{\partial q_i}{\partial \theta_i}$$

and therefore

$$(25) \qquad sign\left(\frac{\partial q_i}{\partial \theta_i}\right) = sign\left(\frac{\partial p_i}{\partial \theta_i} / \frac{\partial p_i}{\partial q_i}\right)$$

Observe that, all else equal, any increase in quality brings about an increase in price, i.e., $\partial p_i / \partial q_i > 0$, and expressions (22-23) yield $\partial p_H / \partial \vartheta_H = \partial p_L / \partial \vartheta_L = -2q_H /(4q_H - q_L) < 0$. This ultimately implies $\partial q_i / \partial \theta_i < 0$, *i=H,L*.

The intuition behind the negative relationship emerging between the effort to increase product quality and the extent of managerial delegation can be grasped by observing that, for any given level of the rival's quality, any increase in quality by firm *i* produces (i) a positive externality to the opponent, via the increase in product differentiation, which mimics the features typically associated to public goods; and (ii) a decrease in market share via the increase in price, which is in contrast with the taste for output expansion embodied in the objective function.

Summing up the foregoing analysis, there neatly emerges that the taste for expanding production levels leads managers to over-invest in process innovations and under-invest in product innovations as compared to what would be the outcome of pure profit-seeking behaviour.[4] In the presence of separation between ownership and control, firms run by managers are more keen on increasing the output levels (by fully internalising the beneficial effects of process innovation), while having little or no motivations to foster product innovation. In other words, the separation between ownership and control leads firms to increase output levels, given the structure of managerial incentives. If the (constant) operative cost is given, this means lower profit levels and lower amount of resources devoted to product innovation. On the contrary, if the operative cost is endogenous, and depends on the efforts in process innovation, a manager has further reasons to aim at attaining a lower marginal cost, since this permits him to further increase the output level.

[3] Due to the presence of the delegation parameter θ_i, this holds irrespective of the specific form of the cost function $\psi_i(q_i)$, even in the simplest case where it is nil.

[4] A result with a similar flavour emerges in Cellini and Lambertini (2008), where a differential game approach is taken.

3. Empirical evidence

3.1 Data base, definition of variables and descriptive statistics

The data we consider for the empirical analysis, come from the Survey on Manufacturing Firms (*Indagine sulle imprese manifatturiere*), currently conducted in Italy by UniCredit (formerly, by Mediocredito Centrale and Capitalia). Specifically, we consider the last wave of the survey carried out in 2004 and referring to the period 2001-2003.

Such a survey is based upon questionnaire submitted to all the Italian manufacturing firms with more than 500 employees and to a stratified sample of firms below such a threshold but with more than 9 employees. In total, the firms included in the last wave were 3452.

Although previous editions of the same survey are available in digital formats and have been used in a number of empirical works (see, among the most recent ones, Parisi et al., 2006; Hall et al., 2007), we consider here only the last wave simply because, for the first time, it provides very detailed information on the composition of the firms' total employment.

For the specific purpose of our study, the most interesting information refers to the presence of three top professional positions: entrepreneurs, family managers and external managers. With these data it is possible to find a measure of managerial presence and, then, to distinguish managerial firms from those in which the ownership is not fully separated from control.

However, such a distinction makes sense only for companies of medium and large size, given that the overwhelming majority of small firms are ruled by entrepreneurs who are in charge of both ownership and control. As a consequence, from the firms included in the last survey we dropped out those with less than 100 employees. In doing so, we moved from 3452 to about 860 firms (a finding that highlights quite effectively the small average size of Italian manufacturing companies). Moreover, for 34 firms, some of the variables needed to perform our empirical analysis were missing so that, in the end, our sample reduces to 826 companies of medium and large size.

As already mentioned, for each firm we were able to get the number of entrepreneurs, family managers (i.e. belonging to the family that holds the company) and external managers. The latter could have an objective function different from that of the ownership. Thus, without ambiguity, a *proper* managerial company can be detected if it is fully controlled by external managers. Accordingly, we defined 'managerial' all the firms in which the following condition is met:

$$\frac{External\ managers}{External\ managers\ +\ Entrepreneurs\ +\ Family\ managers} = 1$$

that is, family managers and entrepreneurs are absent in the management.

Although the above criterion seems quite restrictive, we found that 354 out the 826 firms considered (43%) can be classified as managerial, in this strict sense. As expected, the percentage of managerial companies rises when one moves from medium-sized to large firms (Table 1). In spite of that, it is remarkable that also within the medium size class almost one firm out of three is of managerial nature, according to our criterion.

Table 1 – Number of firms and percentage of managerial firms by size class

	Number of firms	Number (and percentage) of managerial firms
Medium-sized firms (from 100 to 249 employees)	489	152 (31.1%)
Large size firms (250 and more employees)	337	202 (59.9%)
Total	826	354 (43.0%)

The second and crucial step in the empirical analysis is represented by the measurement of the efforts devoted by each firm to product and process innovations. In the UniCredit survey firms were asked to report, with a yes/no answer, whether they had introduced product or process innovations, or both, over the period 2001-2003. Along with the drawback of measuring the simple presence rather than the extent of innovative outputs, the problem of using dichotomous answers is that the majority of firms tend to report both product and process innovations.

In our case, as Table 2 shows, this happens both in the whole sample of medium and large firms and in each of the four sectors identified by Pavitt (1984) in his well known technological taxonomy of firms[5]. However, looking at the presence of sole product or process innovations, some remarkable differences emerge. In line with the expectations, 'supplier dominated' and 'scale intensive' firms tend to be more engaged in process innovations while the opposite occurs to 'specialised suppliers' and 'science based' firms. Note that non-innovative firms (i.e., firms reporting no innovations) account for about 31% of the sample, a figure consistent with that arising from the previous waves of the UniCredit survey (cf. Parisi et al., 2006); 'supplier dominated'

[5] According to Pavitt's taxonomy 'supplier dominated' firms (such as those producing traditional consumer goods) "make very little contribution themselves either to their product or their process technology" since "most innovations come from suppliers of equipment and materials" (Pavitt, 1984, p. 354). In-house engineering and R&D capabilities are instead stronger in 'specialised suppliers' (e.g. firms producing specialised machinery, precision instruments and medical equipment) which thrive on product innovation. The same applies to 'scale intensive' firms which, however, focus on process innovations in order to exploit latent economies of scale (the classical examples are the industries of motor vehicles, domestic appliances and basic chemicals). Finally, the highest commitment to R&D is recorded in 'science based firms' (such as those producing pharmaceuticals and IT equipments). A table of concordance between the Pavitt's sectors and the NACE three digit codes of manufacturing industries is provided by the UniCredit (formerly Capitalia) survey (cf. Capitalia, 2002).

and 'scale intensive' firms are characterised by above average percentages of non-innovators (35 and 34 %, respectively).

Table 2 – Propensity to product and process innovations according to different types of firms

	Total firms	Firms reporting product innovations only		Firms reporting process innovations only		Firms reporting both product and process innovations		Firms with positive share of total sales due to new products	
	No.	No.	%	No.	%	No.	%	No.	%
Supplier dominated	372	49	13	87	23	109	29	160	43
Scale intensive	154	15	10	37	24	50	32	69	45
Specialized suppliers	253	52	21	34	13	103	41	163	64
Science based	47	7	15	4	9	22	47	31	66
Total	826	123	15	162	20	284	34	423	51

The only indicator of quantitative output associated with innovative activities that can be obtained from the survey is the share of total sales due to *new products* (referred to the last surveyed year, i.e. 2003). This is an interesting way of measuring the extent of a firm's innovative outputs originally introduced by the first Community Innovation Survey (CIS) carried out in 1993 and covering the years 1990-1992 (see Eurostat, 1997)[6].

In a recent study based on CIS micro-data, Mohnen et al. (2006, p. 394) argue that the share of innovative sales "can be viewed simply as the sales weighted number of innovations and seems to be generally well understood by firm respondents. […] Of course, such as measure only captures product innovations, but the surveys indicate that most firms innovating in processes also innovate in products". In principle, by means of changes in product design and quality, also process innovations may generate new and, above all, improved products. However, as far as most of them are devoted to reduce the production costs of old products, process innovations do not give rise to new sales. Accordingly, it is hard to find a direct indicator of the outcomes of process innovations so that they are usually approximated by a dummy variable indicating the mere presence of them or by input measures, such as the extent of R&D devoted to new processes (Cohen and Klepper, 1997; Fritsch and Meschede, 2001). In our case, product and process R&D cannot be distinguished at firm level, so that we are compelled to use only a dummy variable for process innovations.

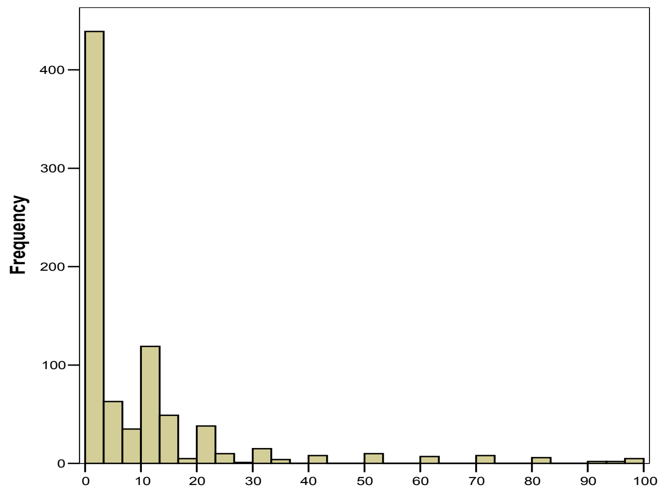
[6] Up to now, other three waves of the CIS have been conducted. The last edition (CIS4) refers to 2004.

The last column of Table 2 shows that the number of firms with positive share of sales associated with new products (423) is even higher than the sum of those reporting product innovations only and both types of innovation (404). This discrepancy is probably due to the fact that the firms with very small shares of innovative sales did not answer positively to the yes/no questions on the types of innovation introduced.

Although imperfect, the percentage of sales due to product innovations is the only indicator we have to distinguish the firms according to the 'prevalent' type of innovation they are involved in. Among the 423 firms reporting a positive share of innovation output, those that declared to have introduced product innovations only can be safely classified as firms with a 'prevalence of product innovation'. Similarly, the 403 firms that indicated a zero share of innovative sales and reported process innovations only can be defined as firms with a 'prevalence of process innovation'. To identify the group in which the firms reporting both product and process innovations should be included, we inspected the frequency distribution of the percentages of sales due to new products.

Figure 1 shows that such a distribution is very skewed with 402 out the 826 firms reporting a zero share of innovative sale and a few firms with shares greater than 20%. The distribution, however, does not decrease monotonically: after that corresponding to zero, there is a second mode at 10%. Another interesting feature of the distribution is that the percentages are concentrated on rounded values simply because the firm respondents were not able to report precise figures and, then, provided rounded estimates of the sales due to new products.

Figure 1 - Frequency distribution of innovation output (share of sales due to new products)



In order to identity the firms particularly involved in product innovations, we used two alternative cut points, corresponding to 5 or 9%. Thus, the firms that introduced both product and process innovations but reported a share of innovative sales above these thresholds are included in the group with a 'prevalence of product innovations' while the others in the alternative group. At a first sight, the two cut points could seem rather low to detect a priority for product innovations. However, looking at the distribution of innovative sales, this is not the case. If, as already said, one considers that almost 49% of the firms did report a zero share, by applying the thresholds of 5 and 9 percentage points it emerges that the firms with a 'prevalence of product innovations' account, respectively, for 40% and 35% of the sample. By slightly increasing the threshold up to 10%, a priority for product innovations would be identified for only 22% of the sampled firms which, in light of the available evidence, appears too small to be a plausible share[7].

By applying the above criteria, table 3 shows the numbers and the percentages of firms according to the prevalent type of innovative activities. It is important to stress that the percentages do not sum up to 100 because they refer to the entire sample, including also non-innovative firms.

Table 3 – Number and percentage of firms by prevalent type of innovation*

	Cut point of 5% of innovative sales				Cut point of 9% of innovative sales			
	Firms with a prevalence of product innovations		Firms with a prevalence of process innovations		Firms with a prevalence of product innovations		Firms with a prevalence of process innovations	
	No.	%	No.	%	No.	%	No.	%
Supplier dominated	144	38.7	101	27.2	124	33.3	121	32.5
Scale intensive	41	26.6	61	39.6	40	26.0	62	40.3
Specialized suppliers	143	56.5	49	19.4	137	54.2	55	21.7
Science based	29	61.7	6	12.8	27	57.4	8	17.0
Total	357	43.2	217	26.2	328	39.7	246	29.9

* The percentages refer to the whole sample of 826 firms.

For the whole sample, a prevalence of product innovations is detected and appears particularly strong in 'science based' firms and 'specialized suppliers'. On the contrary, 'scale intensive' firms are always characterised by a higher propensity for process innovations. The case of 'supplier dominated' firms is peculiar since they show a prevalence of product innovations when the lower threshold of innovative sales is used while by adopting the 9% cut point the two types of innovative activity are equally important. This is consistent with previous empirical evidence concerned with the Italian manufacturing firms producing traditional consumer goods. Many of them have a high propensity to innovate productive processes by investing in new machinery and equipment and, then, taking advantage of embodied technological change (Santarelli

[7] Our conclusion is supported by the fact that the majority of firms' R&D efforts are concerned with product innovations. Cohen and Klepper (1996) found that 72% of the total R&D of the US firms included in their sample is devoted to product innovations. The share found by Fritsch and Meschede (2001) for a sample of German firms is 61%.

and Sterlacchini, 1994). Accordingly, the distinction based on the higher threshold is slightly preferable. In any case, since we do not have other strong justifications for choosing the less or more restrictive criterion, in the following section we shall perform two distinct regression analyses.

3.2 Regression analysis

This section is devoted to a regression analysis based upon the data illustrated in the previous one. Table 4 presents the results arising from Probit regressions with the principal aim of testing whether the managerial nature of the firm significantly affects the probabilities of being mainly involved in product and process innovations. The sample is constituted by the 826 firms described in Section 3.1.

Obviously, our goal cannot be performed without taking simultaneously into account a set of control and behavioural variables that, according to the relevant literature, are important for explaining the dependent variable. Thus, among the explanatory variables, we inserted three dummy variables for the sectors of Pavitt's taxonomy, along with the constant term, and the log of total sales as a proxy for the size of firms.

Coehn and Klepper (1996) found that, in the US, larger firms are more involved in process R&D and contended that this is due to their capability of spreading the R&D costs over a greater level of output. Fritsch and Meschede (2001), for a sample of German firms, show that both product and process R&D are affected by firm size and the difference is not statistically significant. A similar result is found by Parisi et al. (2006) who estimate the probabilities of introducing product and process innovations by Italian manufacturing firms. In any case, the impact of firm size must be controlled for sector specific effects which are likely to capture both technological opportunities and appropriability conditions and, thus, should account for a large portion of the variability recorded in the propensities to innovate products and processes. The descriptive picture provided by Tables 2 and 3 confirms that also in our case the sectoral dimension is indeed important. The inclusion of sales among the explanatory variables is similarly important especially because we saw that, in our sample, the presence of managerial companies tends to rise with firm size (see Table 1). In effect, the correlation coefficient between the dummy for managerial firms and the log of total sales is statistically significant, although not particularly high (0.365).

Along with the above mentioned control variables, we inserted in the regressions two further variables that capture the extent of innovative efforts (or inputs) undertaken by the firms: R&D expenditures and investments in machinery and equipment expressed in percentage of total sales. According to the prevailing empirical evidence, we expect that the intensity of R&D should be particularly effective in raising the propensity to innovate products while that of investment in machinery should mainly enhance process innovations (in support of the latter hypothesis see, in particular, Parisi et al., 2006). Our estimates confirm the above expectations. Table 4 shows that both the intensity of R&D and investment in machinery are highly significant, but the former affects exclusively the prevalence of product innovations while the latter only enhances that of process innovations. Also sectoral effects turn out to be particularly significant and especially in the first panel of regressions based on the 5% threshold of innovative sales. 'Specialised suppliers' and 'science based' firms tend to assign a higher priority to product innovations and, as a consequence, less importance to process innovations. The opposite occurs to 'scale intensive' firms but only in the second panel of estimates.

Table 4 - Probit regression for the prevalent type of innovation

Dependent variables	Prevalence of product innovations		Prevalence of process innovations	
Cut point of 5% of innovative sales				
	Coefficient	Robust Std. Error	Coefficient	Robust Std. Error
Constant	0.983	0.774	-1.151	0.830
Log of total sales	-0.075	0.044	0.021	0.047
R&D expenditures on total sales (%)	0.152	0.036***	-0.026	0.026
Investment in machinery and equipment on total sales (%)	0.011	0.012	0.048	0.013***
Managerial firm	-0.231	0.098**	0.033	0.104
Scale intensive firm	-0.261	0.132**	0.334	0.128***
Specialised suppliers firm	0.405	0.108***	-0.228	0.116**
Science based firm	0.433	0.218**	-0.480	0.259*
Wald χ^2 (7) [Prob.> χ^2]	73.99	[0.000]	36.51	[0.000]
Log pseudo-likelihood	-516.52		-455.87	
Cut point of 9% of innovative sales				
	Coefficient	Robus Std. Error	Coefficient	Robust Std. Error
Constant	1.410	0.782*	-1.567	0.810*
Log of total sales	-0.106	0.045**	0.053	0.046
R&D expenditures on total sales (%)	0.110	0.031***	0.008	0.023
Investment in machinery and equipment on total sales (%)	0.006	0.012	0.051	0.013***
Managerial firm	-0.206	0.099**	0.001	0.102
Scale intensive firm	-0.122	0.134	0.175	0.127
Specialised suppliers firm	0.517	0.108***	-0.332	0.114**
Science based firm	0.527	0.216**	-0.562	0.259**
Wald χ^2 (7) [Prob.> χ^2]	74.90	[0.000]	37.27	[0.000]
Log pseudo –likelihood	-512.22		-483.47	

***=Significant at 0.01 level of confidence. **= Significant at 0.05. *= Significant at 0.10.

The size variable has a negative and significant coefficient only when the threshold of 9% of innovative sales is adopted suggesting that larger firms tend to assign a lower priority to product innovations. By applying the 5% cut point, the log of total sales is instead not significant when inserted together with the managerial dummy (see below). Finally, the size of firms is never significant in the regressions concerned with process innovations.

Moving to the variable of major interest for the purposes of our study, the dummy for managerial firms (taking the value 1 when the company is fully controlled by external managers) exerts a negative and significant impact on the prevalence of product innovations, while it is not significant when the prevalence of process innovations is the dependent variable.

The negative coefficient for the managerial nature of firms, in the regression for the product innovation, is not substantially affected by the adopted threshold of innovative sales. However, due to the correlation with the firm size (see above), the managerial dummy's coefficient would increase from 0.21-0.23 to 0.28 if the log of total sales was excluded from the regression. In short, being correlated, both the firm size and the presence of full managerial control depress the propensity to be mainly engaged in product innovations. However, the managerial dummy exerts a more significant impact, especially when the threshold of 5% of innovative sales is considered.

In conclusion, focussing on medium-sized and large Italian companies, we find that the managerial nature of firms significantly depresses the probability of introducing product innovations,[8] while it has a (positive but) non-significant effect on the introduction of process innovations, ceteris paribus.

4. Concluding remarks

This paper has made a very simple point: managerial firms tend to under-invest in product innovation as compared to standard profit-oriented firms, and to over-invest in process innovation. This has been modelled in a two-stage game framework, in which managerial firms can influence either the production cost (via investment devoted to process innovation) or the product quality (via investment devoted to product innovation), in a pre-market stage, and then compete on the market in a second phase.

Our theoretical outcomes find some preliminary support from empirical evidence coming from the UniCredit data base on Italian manufacturing firms. In fact, our regression analysis has shown that, for a wide sample of medium-sized and large companies, the managerial nature of firms significantly affects – negatively – the introduction of product innovation. The impact on process innovation is different, since the managerial nature exerts a (positive but) not significant effect.

[8] To investigate whether the managerial dummy affects, along with the probability, also the extent of product innovations we carried out an Interval Regression analysis for the share of sales due to new products. We adopted this estimation method because, due to the innovative sales' distribution (see Figure 1, Section 3.1), both the OLS and Tobit procedure are unsuitable. In all the performed regressions, we found that the managerial variable has a weak impact on the percentage of sales due to new products. In fact, although the managerial dummy turns out to be negative and statistically significant, it does not determine a remarkable change in the probability of observing a firm within a particular interval.

In sum, the distinction between product and process innovations appears to be really relevant from both a theoretical and an empirical standpoint. The extent of these different innovative activities has been shown to be influenced also by the presence of managerial incentives.

By introducing this element into the long-standing debate on how firm size and market structure affect innovation it is possible to draw interesting implications. On the one hand, if we interpreted the extent of managerial incentive as a factor leading to harsher market competition – as long as it entails larger levels of production – we should conclude that this associates with higher efforts for the R&D devoted to process innovation and a lower amount of product R&D, i.e. an Arrovian and a Schumpeterian conclusion, respectively. On the other side, at odds with the argument put forward by Arrow (1962), a strategic delegation *à la* Vickers implies that even companies with a dominant market position may have an incentive to introduce cost-reducing innovations greater than standard competitive firms. In any case, managerial firms, as compared to those ruled by entrepreneurs, have lower incentives to undertake efforts for innovating products. This is consistent with Winter (1984) who, reconciling the early and late works of Schumpeter (1911; 1942), stressed that two different technological regimes may coexist or alternate over time: an 'entrepreneurial regime' less favourable to large established companies and mainly focussed on product innovations and a 'routinized regime' in which incumbent firms tend to concentrate their efforts on process innovations. The prevalence of a given regime over the other can be due to a variety of factors such as technological opportunities, appropriability conditions and financial constraints (see, among others, Audretsch, 1995; Malerba and Orsenigo, 1997). Along with them, we contend that also the extent of managerial incentives may play an important role.

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