Risky innovation: The impact of internal and external R&D strategies upon the distribution of returns

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ABSTRACT

External innovation increases the profits of the median firm, but also increases dispersion and the kurtosis of the distribution of profits. This means that external strategies are risky and may require a very large number of attempts before average returns are obtained. This puts smaller firms into a position of disproportionately high risk. Despite the earlier evidence that the rewards from innovation are positively skewed, we find no effect of innovation strategies upon the skewness of the distribution of firms' profits.

1. Introduction

Both managers and policy makers with responsibility for innovation at the firm and the country levels are interested in knowing the impact of pursuing different innovation strategies. A specific classification of innovation strategies that has received recent attention is the one that distinguishes between internal and external strategies. While it is well known that external sourcing and internal production are often used by firms in many areas of activity, the tendency for firms to use external sources of knowledge in their search for innovation is relatively recent (see Chesbrough, 2003) and a small but growing literature has started investigating the impact of these strategies upon innovation outcomes and performance (Cassiman and Veugelers, 2006; Lokshin et al., 2008). This research has found that external R&D is productive in the sense that firms using external sources for their R&D strategies have better innovation outcomes, in particular if firms also undertake R&D in-house.

However, not all research outcomes translate into profits. Studies that have examined more than one dimension of the research outcomes have found that the determinants of the creation and appropriation of value are not the same as those of the number of innovations or of sales of innovative products. For example, Belderbos et al. (2004) found the determinants of labor productivity growth and growth in sales of new and innovative products to be different, while Okamuro (2007) found that technological and commercial success have different determinants.

Most of the research into the impact of alternative knowledge acquisition strategies has focused on how the changes in one variable of interest affect the mean performance of firms. However, the distribution of profits from innovation has been shown to be highly skewed, a small minority of innovations accounting for a disproportionate share of profits (Scherer and Harhoff, 2000). Given this typical shape of the distributions of gains from innovation, it is possible that different innovation strategies generate different distributions of performance. Knowing that a strategy may yield enormous returns in the few cases in which it works well is not the same as knowing that a strategy works well in most of the cases and provides positive albeit limited returns.

In this paper we move beyond asking if different innovation strategies display different results on average, and we also ask questions such as: Do the different innovation strategies present different degrees of risk? Is one strategy more or less likely to create breakthroughs evinced by a more skewed distribution of performance? Is one strategy more likely to generate distributions of performance with many outliers? In other words, we ask whether these strategies affect the variability, the skew, and the heaviness of the tails of the resulting distributions. A simple way of attempting to answer such questions would be to compare distributions of returns for firms following different innovation strategies. This, however, would not take into account that firms are different in

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many dimensions other than research strategy. In order to control for these differences our empirical strategy is based on quantile regressions, which we use to compare the outcomes of internal and external innovation strategies against those of firms that do not pursue any formal innovation efforts. Quantile regressions provide a methodology for estimating the impact of a given variable upon different points of the distribution of interest, while controlling for other variables of interest (see Koenker, 2005 for a survey). We estimate quantile regressions for a wide range of quantiles of firm performance and, based on these estimates, we compute the impact of the innovation strategies upon measures of dispersion, skewness, and kurtosis of the distributions of performance.

There are important implications from this knowledge. Even if a handful of firms benefit and the gains of those that benefit are large enough, from the society's point of view it should be desirable to pursue such strategies, as the losses of the many would be more than compensated by the gains of the few. However, if this is so, risk averse managers may not wish to engage in this type of activity, especially if their firms are small and lack the means to enter into a myriad of projects simultaneously. This may be particularly true if the strategies that lead to a breakthrough with high probability can also cause high losses with high probability. Managers may refrain from pursuing this strategy if they run the risk of being evaluated by the outcome of a few projects only. In such a case, policies should be designed to lead firms into activities that will lead to failure with very high probability. If most firms benefit, these policies are less needed. Even if distribution of gains is relatively symmetric, firms may be deterred from pursuing innovations if the distributions of gains have a very high kurtosis. In this case, the problem is not that only a handful of firms benefit but rather that, even if one average innovation pays off, the rate of convergence to the mean may be too slow and a firm may be required to engage in too many projects in order to have a reasonable degree of assurance of reaching positive outcomes. Concentration of research, or other mechanisms that offer some form of risk protection, seem to be needed if this is the case.

Our findings indicate that innovation strategies affect the performance of firms in more ways than commonly recognized. In particular, external innovation strategies are significantly associated with increases in median profits relative to firms that do not conduct R&D. They are also significantly associated with increases in dispersion of profits and with kurtosis, reflecting the fact that external innovation strategies increase the likelihood of very extreme outcomes. No significant effect upon the skew of the profit distribution is detected, however. The same pattern holds for internal strategies, but the effects are estimated to be smaller and not statistically significant.

The paper is organized as follows. In Section 2 we discuss the rationale for innovation strategies having an impact upon performance and the previous evidence on the topic. Section 3 presents the methodology. In Section 3.1 we discuss the quantile regression framework that is employed in the analysis and highlight how it can be used to help shed light on the impact of strategies upon the entire distribution of profit rather than on a single point of this distribution. Section 3.2 presents the data and Section 4 the results. Finally, Section 5 concludes the paper.

2. Internal and external innovation strategies

2.1. The nature of innovation outcomes

Firms engage in R&D projects in the hope that they will provide above average returns. However, R&D and innovation are also risky activities. For example, Mazzucato (2003) showed that firm growth rates and stock prices were more volatile in periods in which innovations were the most "radical" in two rather different industries

(1900–1930 in the American automobile and 1974–2000 in the PC industry). The gains from innovation are not only highly variable, but they have also been shown to be quite skewed. Using eight different data sets on the value of innovations, Scherer and Harhoff (2000) showed that the top 10% most valuable innovations accounted for a proportion of total value ranging from 48% to 92%. Other studies have confirmed that returns to innovation are uncertain and skewed. Looking at the distribution of pre-tax returns on inventive efforts, Astebro (2003) shows that few inventions received most of the inventions returns, most inventions obtaining negative returns. Marsili and Salter (2005) found that the shape of the distributions of revenues from incremental innovations and more advanced innovations are rather different. In the latter case, the distribution is characterized by a heavy right tail, indicating that innovations greatly increase the number of highly successful firms (see also Silverberg and Verspagen, 2007 on the fat right tails of distributions of returns). These studies have focused largely on the upside of the innovation process. They concentrate on measures of the gains that accrue to innovations and neglect the costs of the process. Therefore, they concentrate on the right tail and disregard the fact that, in many cases, costly efforts may lead to a negligible reward.

We propose that these extreme effects are more likely to emerge when firms follow innovation strategies that require close contacts with external parties, either through the joint development of projects or by acquisition of innovation services or results. External innovations strategies are likely to lead to higher performance, as reported in the literature, but may also lead to deceptive results. The rest of this section reviews the rationale for such an expectation.

2.2. Gains from external strategies

Firms may be led into external innovation strategies for different reasons (see Oliver, 1990 and Ozman, 2009 for typologies). By developing joint collaborations or by buying R&D in the market, firms can access a greater knowledge pool than would be available in-house. Chesbrough (2003) argues that firms resort more and more to open innovation strategies due to the combination of two factors: the rising costs of technology development, and the shorter product lives in the market. Looking for external sources of innovation enlarges the knowledge base of the firm and makes it more likely to market new products with commercial success (see Okamuro, 2007; Cassiman and Veugelers, 2006; Beneito, 2006). External partners also create greater flexibility for modifying or changing the knowledge base of a firm. Leiponen (2005) describes how greater uncertainty about technological developments makes it more likely that firms invest in external R&D in order to stay tuned to newer developments instead of investing solely in internal knowledge building. This means that the higher the depreciation rate of knowledge is, the more attractive external R&D activities become. Given an adequate internal knowledge base, access to external knowledge may accelerate organizational and technological learning of a firm. For example, Powell et al. (1996) found that for the biotechnology industry R&D collaborations are important for learning also in terms of general practices of collaborations.

External partnerships are also a means of sharing the risk of the firm's projects pool. However, if the distribution of gains is highly asymmetric and has fat tails, increasing the number of projects in a pool does not necessarily reduce the variance of the gains in this pool. For example, De Vany and Walls (2004) used data from the Hollywood film industry to show that the variance of the gross box-office income of films is quite volatile and that increasing the number of films in the sample does not make the average income converge to any stable figure.

2.3. Costs of external strategies

Because knowledge is an asset that is difficult to trade, collaborating on joint projects may be the most economical way of accessing the knowledge pool of partners. However, the potential gains from collaborations or from buying R&D involve "organizational" costs (Williamson, 1985). Opportunistic behaviour from the collaboration partners (Jarillo, 1993), insufficient expertise of one partner (Flowers, 2007), or precaution measures for the possibility of information leaks regarding valuable technologies, especially in collaborations with competitors (Oxley and Sampson, 2004) may increase coordination costs and make external R&D less attractive.

More specifically, to the extent that partners become residual claimants on the project's gains, joint projects create incentives for partners to free ride. Thus, an optimal strategy may be to enter the joint projects with an eye to learning about the knowledge pool of partners (Hamel, 1991; Khanna et al., 1998; Kale et al., 2000) and making the other party expendable (Inkpen and Beamish, 1997). Not only does actively learning about the other's assets entail costs, protecting internal knowledge from spilling over to the partner does too.

External R&D collaborations may be particularly useful when the goal of the research is more about radical learning (exploration of new knowledge) than about incremental learning via the exploitation of existing knowledge (March, 1991). The two types of knowledge search are likely to have different risk profiles, as external collaborations increase thinking "outside the box". Collaboration can also increase costs if there is "too much" diversity amongst partners. Exceptionally valuable outcomes often come from cross-collaboration from different fields of science. However, the chances of achieving a positive outcome and, indeed, the average gain from collaborations increase if both partners' knowledge is within the scope of the same specific domain (Fleming, 2001). There may be a trade-off between the likelihood of achieving a breakthrough and the probability of project failure.

2.4. Earlier evidence on the effect of internal and external innovation strategies

The studies that systematically evaluate the impact of internal and external innovation strategies upon the performance of firms have employed different methodologies and used different measures of both strategies and performance. Still, they tend to agree that internal and external strategies have different impacts upon performance.

Peeters and van Pottelsberghe de la Potterie (2006) found that research strategy (measured by several dimensions including the extent of external R&D collaboration) was more closely related to innovation performance (propensity and number of patents) than other firm characteristics such as size and market power. Furthermore, they found that external R&D collaborations are positively related to the patent activities of a firm. Beneito (2006) also used patents as a proxy for a more radical type of innovations of firms in order to distinguish them from more incremental innovations, and also found that strategy matters. While internal R&D is positively related to both incremental and significant innovations, contracted R&D significantly impacts major innovations only if it accompanies internal R&D activities of the firm.

Measuring innovation performance by the share of sales that comes from new products, Cassiman and Veugelers (2006) found that the composition of internal and external innovation strategy matters. Moreover, it was found that complementarity between internal and external innovation strategies is context dependent; it depends on third factors. These authors identified access to basic research or contacts with universities/research centers for knowledge transfer to be an important environmental variable.

Looking at labor productivity, Lokshin et al. (2008) found the "level" of absorptive capacity (Cohen and Levinthal, 1990) of a firm to be a necessary condition for quantitative complementarity between internal and external R&D. They report that the positive impact of external R&D on firms' labor productivity is related to the level of internal R&D. Higher levels of internal R&D increase the positive effect of external R&D on labor productivity. However, the positive marginal productivity impact decreases with high levels of internal and external R&D.

2.5. The questions asked

From the survey above we see that earlier research has asked essentially the following questions: Do firms that conduct formal R&D activities display superior performance than those that do not have R&D? Are the effects different depending on the innovation strategy of the firm?

We go beyond these questions by asking whether the effects of different innovation strategies are the same for all firms pursuing a given strategy. Earlier research acknowledged that firms are heterogeneous with respect to the strategies they pursue. We take into account that the impact of a given strategy upon firms may be heterogeneous itself and may lead to different degrees of uncertainty with respect to the outcomes of innovation. If this holds true, samples of firms pursuing different strategies may be significantly dissimilar with respect to different moments of their underlying distributions. Accordingly, we ask: Are external strategies likely to lead to more risky returns, that is, more dispersed distributions of returns? Are external strategies more likely to generate breakthroughs and thus create more (positively) skewed distributions of returns? Or are they also more likely to create big losses and thus generate distributions with both heavier right and left tails, that is, with higher kurtosis?

Formal innovation strategies are means of firms to increase the effort to discover and develop products and processes that can lead to profits. In the sections above, we saw that external strategies are means to increase the number of projects that firms may be involved in and to widen the knowledge base they draw from, as compared to not doing R&D at all or doing it only internally. Accordingly, we expect firms that do R&D, and in particular those that do it in collaboration with external partners, to be able to generate larger numbers of successful products and, likely, larger numbers of the kind of breakthroughs that can lead to very substantial profits. On the other hand, however, R&D has costs which, if the research efforts are unsuccessful, can lead to huge losses. External collaborations are means of sharing the costs of doing R&D but, as the review in Section 2.3 indicated, to the extent that they lead to potentially more adventurous areas can also lead to failures with great probability. Accordingly, we expect that firms that do R&D, and in particular those that do it with external collaborations, have greater profits that those that do not conduct R&D, but we also expect that the profit distribution of such firms is more dispersed. Depending on the prevalence of abnormal numbers of successes and failures we may also find that the distribution of profits is more skewed or have greater kurtosis than that of the comparison category.

If we find that the distribution of gains of one strategy is more dispersed, it means that this strategy is riskier than the comparison category. If the distribution is more skewed, it means that the strategy will lead to abnormally high outcomes, be those gains in the case of positive skew or losses in the case of negative skew. If the strategy correlates with an increase in kurtosis, it means that the probability of extreme (positive and negative) outcomes is high and that it is more difficult to predict the average returns of such projects. This will also mean that increasing sample sizes, i.e. the

number of R&D projects in a firm, may not lead to convergence to the true mean values, except with extremely high numbers.

3. Methodology

3.1. Statistical model

We are interested evaluating the impact that internal and external innovation strategies exert upon higher order moments of the distribution of profits such as dispersion, skewness, and kurtosis. Such higher moments of the empirical distributions can be evaluated with statistics that are based on sample quantiles, and we use the estimated coefficients from quantile regressions (Koenker and Bassett, 1978, 1982) to compute the conditional analogues of these measures.

Quantile regressions express the different quantile of distributions conditional on a given set of values of the relevant attributes, just as conventional regression expresses the mean of the dependent variable conditional on those attributes. Quantile regressions are, therefore, very useful when the impact of the variable of interest upon the dependent variable is likely to be different across the distribution of the dependent variable, and a number of recent studies have used quantile regressions for evaluating the impact of different aspects of R&D and innovation (see Coad and Rao, 2008; Bulut and Moschini, 2009; Love et al., 2009; Ebersberger et al., 2010).

The estimated coefficients of these regressions at various quantiles can be combined in measures that evaluate the impact of those attributes upon the dispersion, skewness and kurtosis of the distribution of the dependent variable. Statistics of scale, skewness, and kurtosis based on quantiles can be defined as

$$\text{Scale} = \frac{Q\left\{0.75\right\} - Q\left\{0.25\right\}}{Q\left\{0.75\right\} + Q\left\{0.25\right\}}$$

$$\text{Skewness} = \frac{Q\left\{0.75\right\} + Q\left\{0.25\right\} - 2Q\left\{0.5\right\}}{Q\left\{0.75\right\} - Q\left\{0.25\right\}\big)}$$

$$\text{Kurtosis} = \frac{Q\left\{0.90\right\} - Q\left\{0.10\right\}}{Q\left\{0.75\right\} - Q\left\{0.25\right\}}$$

These measures are rather intuitive. The scale statistic is simply the ratio of a measure of width of the distribution over a measure of location. Noting that the numerator of the skewness measure can be written as $Q(0.75) - Q(0.5) - (Q(0.5) - Q(0.25))$, it is clear that symmetric distributions will lead to values of this measure that are close to zero, while the kurtosis measure simply compares the width of the distribution between the 10th and the 90th percentiles with the width at the first and the third quartiles, thus measuring the weight of the tails of the distribution (for references on the statistics and their properties see e.g. Oja, 1981 and Ruppert, 1987).

In our case, we are interested in evaluating the impact of internal and external innovation strategies upon the attributes of the distribution of profits. The impact of a strategy upon the different measures can be obtained by combining the estimated coefficients at the relevant quantiles according to the expressions above.

3.2. Data

This investigation is based on data from the Swiss Innovation Survey (SIS), the Swiss counterpart of the Community Innovation Survey (CIS). In contrast to CIS, SIS is conducted every third year and a panel of Swiss firms was observed across three periods (1999, 2002, and 2005). Data collection was done by the Swiss Economic

Institute (KOF) at the ETH Zurich, by means of three postal surveys. The questionnaires include questions on firm characteristics, innovation, and R&D activities, amongst other things. The surveys were based on a stratified random sample of firms having at least five employees covering all relevant industries in the manufacturing, construction, and service sectors. Stratification is on 28 industries and, within each industry, three firm size classes (with full coverage of the upper class of firms). Responses were received from 1470 firms (33.8%), 1938 firms (39.6%), and 2555 firms (38.7%) for the years 1999, 2002, and 2005, respectively. Overall, we have a highly unbalanced firm-panel with 5963 observations.

The survey enabled us to distinguish between different approaches taken by firms with respect to formal R&D activities, ranging from firms that conduct no formal R&D, to those that conduct only internal R&D activities, and those that contracted third parties to perform R&D (buy R&D) or cooperate with external partners on R&D projects. Hence, we can classify firms as follows. A firm is said to pursue an external strategy if it contracted third parties to perform R&D and/or cooperated with external partners during the past three years. A firm is said to pursue an internal strategy, if it had only in-house R&D activities during the past three years. Firms without internal R&D and without external R&D arrangements (contracted R&D or cooperation) are classified as "no formal R&D" firms. Ideally, for classifying firms as pursuing internal or external R&D strategies, we would like to use the proportion of the R&D effort that is outsourced or done in cooperation with external partners. Unfortunately, the survey contains only information on whether a firm pursued any of these activities, not on the magnitude of the corresponding effort. Therefore, we are limited to using dummy variables for classifying firms with respect to the type of innovation strategy.

All three strategies can be seen as viable options to improve firm performance. Firms may wish to bear costs for R&D in order to keep the option of higher revenues through new products; some may wish to do it internally, while others may do it with external parties also. The benchmark against which we compare these firms are those firms that do not invest in R&D, but instead rely on alternative means (e.g., their marketing budgets) to increase revenues.

Internal strategies are pursued by 314, 450, and 327 firms in the 1999, 2002, and 2005 samples, respectively, the corresponding figures for external strategies being 582, 627, and 653. Thus, external strategies are the most frequent way of organizing the R&D activities, a pattern that was also found by Cassiman and Veugelers (2006). Finally, 1270, 1503, and 1581 firms do not have any R&D activities in the surveys examined, respectively. A residual category (buying only) is also present in our sample, but in very small numbers. Only 18, 0, and 1 firm(s) reported buying R&D and not doing any R&D internally in the 1999, 2002 and 2005 surveys, respectively. These firms are found mostly in the services and construction sectors and, in most cases, this occurs when firms buy research-intensive, specialized software programs and implement them without having any internal R&D activities.

3.3. Empirical specification

We use the following empirical model in our analysis.

$$\text{Profit} = \beta_0 + \beta_1 \ \text{INTERNAL} + \beta_2 \ \text{EXTERNAL} + \beta_3 \ \text{lagged profit}$$
$$+ \beta_4 \ \text{SIZE} + \beta_5 \ \text{EDUCATION} + \beta_6 \ \text{TIME} + \sum_j \beta_j \ \text{IND}_j + \varepsilon_i \quad (1)$$

Our dependent variable is the price cost margin (PCM) of firms, which accounts not only for the value creation side but also for the overall costs involved in the creation of this value. PCM is used in

Variable	Description
Dependent variable	
PCM	(log of) 100 minus the share of intermediate inputs on sales minus the share of personnel costs on sales.
Strategic orientation of firms	
INTERNAL	Dummy variable; 1 for firms that in year $t-1$ conduct in-house R&D exclusively, 0 for firms that combine in-house R&D with external R&D or do not have R&D at all.
EXTERNAL	Dummy variable; 1 for firms that in year $t-1$ conduct in-house R&D and have external R&D (cooperate with other firms/institutions on R&D projects and/or contract third parties to perform R&D). 0 for firms with in-house R&D exclusively or no R&D activities.
No R&D	Omitted category: firms that in year $t-1$ do not have any R&D activities.
Control variables	
EDUCATION	Share of employees with tertiary-level vocational education (universities, universities of applied sciences, other business and technical schools at tertiary level)
SIZE	The size of firms is measured through the number of employees expressed in full-time equivalents.
IND	27 industry dummies
TIME	Time dummy for the year 2005

logarithmic transformation, summary statistics being presented in Table 1.

We measure internal and external innovation strategies using two dummies. INTERNAL indicates whether the firm carries out internal R&D only, while EXTERNAL indicates whether the firm conducts external in addition to internal R&D (all variables are described in Table 2). The lagged values of these variables are used to avoid endogeneity problems, firms with no formal innovation strategy being the omitted class. Our data source has only information on whether firms conduct internal or external R&D, not on the magnitudes spent. Therefore, we could not use the percentage of R&D that is spent internally and externally or the magnitude of internal and external R&D as a proportion of sales.

As control variables, we include firm size (SIZE), the level of education (EDUCATION) of the labor force, plus a set of 27 industry dummies (IND_{1-27}). Finally, we include the lagged dependent variable to control for other persistent factors at the firm level that may affect performance in any period and that are not accounted for by the other control variables. Because we use lagged variables, we lose one cross-section, therefore we work with two cross sections only. A time dummy (TIME) is included to control for unspecified changes between periods.

Table 2
Descriptive statistics for the dependent variable.

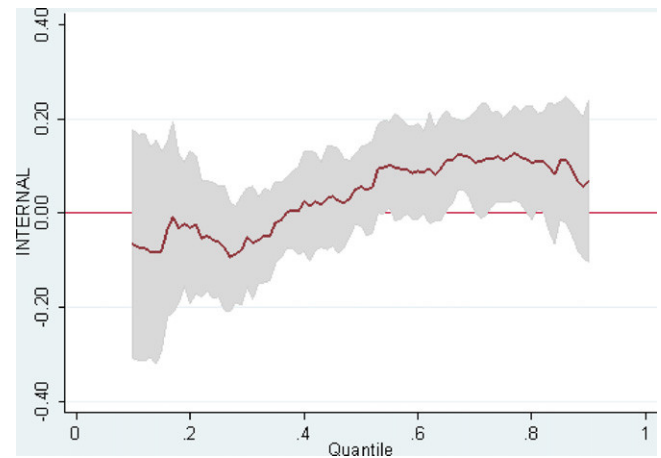|	PCM	
	2002	2005
Mean	10.510	10.354
Stand. Dev.	2.174	2.348
Percentile 10	9.657	9.386
Percentile 25	10.280	10.139
Percentile 50	10.806	10.697
Percentile 75	11.360	11.270
Percentile 90	11.896	11.861
Percentile 95	12.146	12.177
Percentile 99	12.622	12.846
Observations	675	814

Fig. 1. Marginal effects of INTERNAL on firm profits (PCM) for all percentiles between 10 and 90 (confidence interval 90%).

4. Results

Figs. 1 and 2 display the estimated coefficients for the INTERNAL and EXTERNAL dummies across all quantiles from 10 to 90 and clearly reveal a heterogeneous pattern for the effects of internal and external innovation strategies upon profits. Table 3 displays the complete results of estimating quantile regressions for all the deciles of the PCM distribution. The estimated coefficients for both strategies increase as we move from lower to upper deciles. The coefficients start negative at the bottom of the distribution and become positive somewhere before the median. The effects are significant only at the top of the distribution (in quantiles 70 and 80 for internal strategies and for all the deciles above the median for external innovation strategies). The magnitudes of the estimates of the effect of external strategies are greater than those of internal innovation. However, the impacts of internal and external strategies are still too close to be said to be significantly different from a statistical point of view. Therefore our results indicate that firms that do R&D are more profitable than those that do not, especially at the top of the profit distribution. The effect of doing R&D internally only is weaker, and is statistically significant over only a limited range of the distribution of profits.

The impacts of pursuing the two innovation strategies upon the various measures of the distribution of profits are displayed in Table 4. Internal strategies are not found to exert any statistically significant effect upon the different measures of the distribution
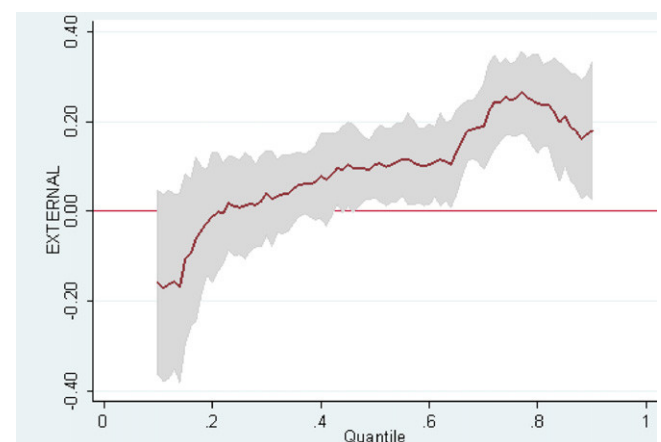

Fig. 2. Marginal effects of EXTERNAL on firm profits (PCM) for all percentiles between 10 and 90 (confidence interval 90%).

Table 3
Results of quantile regressions.

	q10	q20	q30	q40	q50	q60	q70	q80	q90
INTERNAL	−0.066	−0.030	−0.052	0.026	0.057	0.089	**0.108**	**0.107**	0.068
	0.138	0.099	0.081	0.064	0.067	0.063	0.057	0.060	0.097
EXTERNAL	−0.159	−0.012	0.041	0.079	**0.105**	**0.105**	**0.190**	**0.241**	**0.179**
	0.131	0.101	0.070	0.053	0.050	0.056	0.073	0.078	0.109
PCM-1	**0.906**	**0.678**	**0.424**	**0.254**	**0.126**	**0.086**	**0.067**	**0.054**	**0.058**
	0.120	0.164	0.126	0.101	0.067	0.031	0.016	0.011	0.015
EDUCATION	−0.007	−0.001	−0.000	0.003	**0.004**	**0.004**	**0.004**	**0.006**	**0.007**
	0.005	0.003	0.003	0.002	0.002	0.002	0.002	0.003	0.004
SIZE	−0.000	−0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
TIME	**0.293**	**0.183**	**0.107**	**0.108**	**0.128**	**0.094**	**0.129**	**0.171**	0.111
	0.108	0.075	0.052	0.046	0.044	0.042	0.042	0.053	0.077
Constant	−0.325	2.546	**5.495**	**7.367**	**8.830**	**9.390**	**9.670**	**10.108**	**10.425**
	1.201	1.719	1.308	1.043	0.706	0.315	0.182	0.165	0.169

Note: For each variable, the first figure is the regression coefficient. The figure below coefficient is the corresponding bootstrapped (100) standard error. Coefficients in bold are significant at least at the 10% level. Model also includes 27 industry dummies. Number of observations: 1489.

Table 4
Impact of innovation strategies on location, scale, skewness, and kurtosis of the distribution of profits.

	Location	Scale	Skewness	Kurtosis
INTERNAL	0.057 (0.067)	3.283 (7.958)	−0.350 (0.631)	0.772 (0.898)
EXTERNAL	0.105** (0.050)	0.929* (0.561)	0.195 (0.408)	1.417** (0.630)

Note: Measures defined as: location (q50), scale ([q75] − [q25]/([q75] + [q25]), skewness ([q75] + [q25] − (2*[q50]))/([q75] − [q25]), and kurtosis (([q90] − [q10])/([q75] − [q25])). Bootstrapped (5000) standard errors in brackets.
* Significant at the 10% level.
** Significant at the 5% level.

of profits. External strategies, however, are found to exert a positive and significant effect not only upon location, but also upon scale and kurtosis. External innovation strategies, therefore, not only increase the median return, but also increase risk. The data did not reveal a statistically significant effect of either internal or external innovation strategies upon the skewness of the distribution of profits, but again external strategies were found to exert a significant impact upon the kurtosis of the distribution of profits.

Overall, our results can be summarized by saying that external strategies improve profitability. The distribution of profitability has a significantly higher dispersion and kurtosis, although it does not display any increased skewness. These results mean that profitability is significantly more dispersed for firms that follow external innovation strategies, but that this increased variability does not come primarily from an expanded right tail. Instead, it comes from an increased concentration of observations at both the right and left tails of the distribution. Innovation strategies involve high costs. If successful, innovation efforts translate into high profits. If unsuccessful, however, the additional costs of formal innovation programmes translate into high losses.

5. Conclusions

We investigated the impact of internal and external innovation strategies on the profitability of firms. We found that external strategies (contracting external R&D or cooperating with external partners in R&D projects) exert a positive impact upon performance. The estimated magnitude of this effect is greater than the estimated impact of conducting in-house R&D activities only and the former is clearly significant while the second is not.

We were, however, able to generate deeper insights of these effects by combining the results from regressions at different quantiles of the distribution of profits and were able to describe a more complex pattern of effects of internal and external innovation strategies than what is commonly reported. Our results also reveal that external innovation strategies are riskier. The distribution of profits is significantly more spread for firms with external innovation strategies than for firms with no formal innovation activities, whereas no such contrast could be found for firms with internal innovation only. A more skewed distribution might also be expected, given that some recent studies on the distributions of returns to innovations have found these distributions to be rather skewed. However, we found only a negligible and insignificant effect of both internal and external innovation strategies upon the skewness of the distribution of profits. Instead, we found that external strategies lead to distributions of profits with heavy tails (more leptokurtic), suggesting that these strategies can lead to a high incidence of highly successful projects, but also to a high number of unsuccessful projects. We suspect that the emphasis on skewness in earlier studies on the distribution of returns to innovation arises from the fact that those studies focus on the gross returns to innovation and largely neglect the cost side of these projects.

Our finding that external innovation strategies are risky has several implications. On the one hand, it calls for more detailed investigations on the particulars of managing these strategies. While Chesbrough (2003) describes open innovation strategies as a source of superior performance in a number of firms, he also alerts us to a number of mistakes that firms following these strategies may easily commit and that may be responsible for poor performance. Furthermore, Laursen and Salter (2006) find that openness spurs innovation activity but the benefits to openness are subject to decreasing returns. This study also indicates that costs of pursuing external strategies do not decrease with the number of external R&D projects. "Learning" in terms of lowering costs given decreasing returns seems to be limited. Hence, the decreasing returns are not likely to be compensated through decreasing costs or 'economies of scale' in managing external ties.

On the other hand, the finding that external innovation strategies significantly increase the kurtosis of the distribution of profits means that the observed results from innovation projects will converge to the true mean at a slower pace than would be the case if the distribution were less leptokurtic. Returns are thus less predictable and, unless one is able to assemble very large samples, it is difficult to assure convergence to the true mean. Sample size, in this

context, refers to the number of projects in which a firm is involved, the implication being that firms entering cooperative arrangements in the pursuit of risk reduction should be advised to do so mostly if they are very large and can afford to be involved in a very large number of projects at the same time. Because external cooperation means increased productivity and profits, it may be in the interest of society to promote such collaborations. But if they increase private risk, as suggested by our findings, then rational managers may enter a lower number of such ventures than what would be optimal from the point of view of society as a whole. There may be a role for research policy here.

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