



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.

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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.

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