Chapter 4

R&D and financial investors

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1. Introduction

This chapter aims to analyse the valuation of R&D investments at the firm level, taking the perspective of the investors operating in the financial markets. It will deal, in particular, with the relationship between R&D investments and the market value of traded firms, explaining why and how R&D investments should be reflected into financial investors' valuations and stock market prices. It is well known in the business and economics literature as well as in professional accounting practice that R&D investments affect firm performance, expected profits, and cash flows. Since in efficient financial markets investors evaluate a firm based on its expected cash flows (i. e., firm's market value should be equal to the present value of all the expected cash flows produced in the future), R&D investments should also be reflected in market values. Moreover, stock prices should embed all the information currently available on the firm's R&D investments and should react to any new information arrival about those investments (see Figure 4.1).

Under these conditions, stock markets can provide useful information on the value and the expected performance of R&D investments. In particular, because the returns to R&D investments may be spread over a number of years, a forward-looking and market-based measure, such as stock price,, which includes in principle all the expected effects of R&D investments over the entire firm's life cycle, may be more suitable than short-term accounting indicators such as Return on Equity (ROE) or Earnings Before Interest, Taxes, Depreciation and Amortization (EBITDA). The stock market valuation of corporate R&D investments could then contain important signals. In particular, the market reaction to specific announcements about R&D-related decisions could supply different actors with information about the expected value creation of those decisions (see the feedback line in Figure 4.1). Recent theoretical work has proposed that managerial behavior can be strongly influenced by stock market reactions to decisions related to R&D and technology (Benner, 2007). Empirically, Munari and colleagues (2005) have shown that different financial systems can affect, ceteris paribus, the level of firms' R&D investments.

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For these reasons, a number of researchers have turned to stock market value as an indicator of the firm's expected economic results from investing in R&D. Different approaches have been adopted in this respect. Some studies have analysed the relationship between R&D investments and a firm's market value at a given time (Griliches 1981; Jaffe 1986; Hall 1993a, 1993b; Hall and Oriani, 2006, among others), whereas others have focused on the short-term returns following corporate announcements about R&D activity (Chan et al. 1990; Woolridge and Snow 1990, among others). Many of the results are relatively robust across different studies. From the current theoretical and empirical research on the market valuation of R&D investments, we think that three topics deserve particular attention.

First, the most important question is whether R&D investments do create value for the firm. In general, the conclusion is that stock markets value firms' R&D investments positively. The market value of traded firms is positively affected by R&D investments (see Hall, 2000 and Czarnitzki et al., 2006 for a review and Oriani and Sobrero, 2003 for a meta-analysis) and stock prices react positively to announcements of new R&D investments (e.g., Woolridge and Snow, 1990; Szewczyck et al., 1996). However, several studies have shown that the market valuation of R&D investments is volatile over time (e.g., Hall, 1993a, 1993b), across industries (Jaffe, 1986; Cockburn and Griliches, 1988), and across countries (Hall and Oriani, 2006). This variability draws attention to the potential factors that affect the market valuation of R&D investments and the criteria that investors in the stock market adopt to evaluate these investments.

Second, expected results from R&D investments are subject to a very high degree of uncertainty (Mansfield et al., 1977). As a consequence, it is often hard to predict how they will impact on firm value and this fact is important to consider when analysing the market valuation of R&D investments (Oriani and Sobrero, 2008). An interesting question is which methods and criteria investors adopt in assessing the expected performance of a firm's R&D investments under uncertainty. Clearly, this issue is relevant to critical decisions of managers seeking shareholder wealth maximization, such as resource allocation to corporate innovative activities or the recourse to capital markets for R&D financing.

Third, recent empirical work suggests that corporate governance issues at the country- and firm-level can affect the market valuation of R&D investments (Hall and Oriani, 2006). Substantial differences are observed in the market value of R&D investments across countries. Moreover, within country, this valuation also seems to depend on the precise ownership structure of the firm.

Finally, it has to be said that several authors have proposed that financial markets are not always efficient in evaluating R&D investments, mainly because of the information asymmetries that R&D investments create between insiders, typically the managers, and outsiders, the investors (Aboody and Lev, 2000; Hall, 2002). In this chapter we do not deal with the efficiency and information problems, as they will be analysed in depth in chapter 5. It is important, however, to remark here that information problems with R&D investments can imply a higher cost of capital for these investments and a consequent underinvestment at the firm level (Lev, 2004).

The questions reviewed in this section are certainly important for researchers interested in the problems of R&D valuation and financing, but they can become also relevant for other subjects.

Managers will be interested in understanding how financial investors evaluate their R&D decisions, as this is a critical information for making R&D decisions. Financial investors can find the models and the results useful to better predict the values of traded firms. Policymakers would find these issues relevant as stock markets can represent one of the most important sources for R&D financing. In particular, as financing innovation often produces market failures (Hall, 2002), policymakers could be very interested in understanding how the investors evaluate firms' R&D investments in their country.

This chapter is organized as follows. In the next section we present the theoretical and empirical bases of the relationship between R&D investments and market value, and in the section following we describe the main empirical models. In the fourth section the main empirical results are reviewed. In this respect, three main question will be discussed: whether R&D investments create value, how investors deal with uncertainty and how different financial markets and ownership structures affect the market valuation of firms' R&D investments.

2. The relationship between R&D investments and firm market value: theoretical and methodological foundations

In this section we examine the bases for the relationship between R&D investments and firm market value. We first explain why we should expect such a relationship, which requires reviewing the assumption of market efficiency and its implications. Second, we describe the methodology for estimating the relationship.

2.1 R&D investments and market efficiency

The use of market-based measures to assess R&D performance clearly requires some assumptions on the way financial markets work. In particular, it builds on the statement of stock market informational efficiency, which implies that security prices fully reflect all available information (Fama, 1970, 1991). Fama (1970) makes a well known distinction between three degrees of market efficiency corresponding to different information subsets: the weak form, in which the information set consists only of historical prices; the semi-strong form, in which prices adjust to other information that is obviously public available, such as public announcements; the strong form, in which given investors have access to any information relevant for price determination.[1] Even though the debate is still open, there exists robust empirical evidence supporting the efficiency hypothesis, above all in the first two forms (see Fama, 1991 for a discussion). There is much more skepticism about the strong form of efficiency, above all because of the existence of information asymmetries between insiders and outsiders (i.e.,

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[1] These definitions implicitly require the precondition that information has no cost. However, it is possible to give a definition of market efficiency even in presence of costly information. In this case, security prices reflect all the available information to the point where the marginal benefits of acting on information do not exceed the marginal costs (Jensen, 1978).

managers have private information that investors on the market do not have). While the existence and the consequences of R&D-related market inefficiencies will be discussed in detail in chapter 5, in this section we highlight the fact that the most commonly used empirical models rely to some degree on the assumption of market efficiency.

The assumption of market efficiency has several important implications for the relationship between R&D investments and market value. First, it implies that the market capitalization of the firm can be considered a reasonable proxy of its underlying value. Moreover, this value will change if and only if the stock market receives new general or firm-specific information that modifies investors' expectations about the expected cash flows of the firm (Pakes, 1985; Woolridge and Snow, 1990). Consequently, if R&D investments create or increase intangible capital which is able to generate future cash flows, these investments will affect the market valuation of the firm (Griliches, 1981). Second, the holders of shares of the firm will agree that all decisions, including decisions about investments with pay-offs in the long-run, should be evaluated according to their contribution to the market value of their residual claims on these cash flows (Fama and Jensen, 1985). Therefore, managers acting in the interests of shareholders are assumed to make investment choices aimed at the maximization of corporate value. Under these conditions, it is possible to show that R&D programs and other investment policies are maximizing the expected present value of the firm's future cash flows (Pakes, 1985; Hall, 1993b).

These assumptions on stock market efficiency and their implications for investment lie at the basis of the empirical relationships and models described below.

2.2 The empirical relationship between R&D investments and market value

In order to observe an empirical relationship between R&D investments and firm market value, we have to define the observable variables of interest and their relationships. Pakes and Griliches (1984) have presented the path diagram shown in Figure 4.2. Whereas the empirical models have evolved over time, as explained in the next paragraph, the diagram in Figure 4.2 still presents very clearly the general framework on which these models build. In particular, it relates the unobservable ΔK, which is the net addition to knowledge capital K during a particular time period, to a set of observables (patents and R&D investments), random disturbances (ν, ω), and several indicators of performance (Z), which may include the stock market value of the firm. Firm performance is also assumed to be influenced by other observable variables, such as investment and labor input (X) and unobservable effects (ε). The disturbance ω reflects the effects of informal R&D activities and the inherent randomness of inventive success, whereas v represents noise in the relationship between the patents granted to the firm and the associated increment to total technological knowledge.

Based on Figure 4.2, the empirical analysis of the relationship in which we are interested requires us to build measures for R&D and firm market value and then to define the functional form of the model linking these two variables. This will be discussed in detail in the next section of the chapter.

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3. Empirical models

In this section we will present two general categories of empirical models that analyse the relationship between R&D and market value. The first category is a group of models that relate the flow or the stock of R&D investments to the market value of the firm (often measured relative to tangible assets, that is, as Tobin's Q) at a given moment in time. The second category are models that relate the arrival of new information on R&D investments (R&D announcements) with changes in the stock price (stock returns).

Clearly, the two different classes of model examine slightly different questions, but they complement each other. The former tell us how the stock market is evaluating the resources that have already been invested in R&D at a given point of time, whereas the latter measures the incremental change in expected future cash flows due to an increase or decrease in R&D spending. Both are capable of yielding an estimate of the marginal value to the firm of an additional dollar (or other currency unity) spent on R&D at a given point in time. We discuss each of these models in turn in the next two subsections of the chapter.

3.1 Empirical models of Tobin's Q

The studies analysing the relationship between R&D investments and market value at a given time implicitly or explicitly assume that the stock market values the firm as a collection of tangible and intangible assets that are expected to yield cash flows in the future (Griliches 1981). The dependent variable in these models (i.e., the measure of market value relative to tangible assets, Tobin's Q) is normally proxied by the ratio between the market value and the book value of the firm's physical assets (plant and equipment, inventories, investments in other firms, etc.). These assets are those that appear on the balance sheet of the firm according to most accounting standards. Typically they exclude some intangible assets, such as those created by the firm's own R&D investments.[2] The market value measure is the sum of the current value of common stock, preferred stock, and debt "marked to market." We outline the model here, using a treatment that follows Hall (2000) and Hall and Oriani (2006).

In equilibrium, the "shadow" or marginal value of any asset results from the interaction between the capitalization of the firm's expected rate of return from investment in that asset and the

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[2] Some intangible assets, such as purchased patents, and the good will acquired via the acquisition of other firms, will appear on the balance sheet and be included in the denominator of Q.

market supply of capital for that type of asset (Hall 1993a). Assuming that we can enumerate all the cash-flow generating assets that compose the firm, it is possible to represent the market value V of firm i at time t as a function of these assets:

$$V_{it} = V(A_{it}, K_{it}, I_{it}^{1}, \ldots, I_{it}^{n}) \qquad [1]$$

where A_{it} is the book value of tangible assets, K_{it} is the replacement value of the firm's knowledge capital, in our case measured by the stock of R&D investments (R&D capital),[3] and I_{it}^{j} is the replacement value of the jth other intangible asset. If assets enter value in a purely additive way, and ignoring the other intangible assets for the sake of simplicity, it is possible to express the market value of the firm as follows:[4]

$$V_{it} = b\,(A_{it} + \gamma K_{it})^{\sigma} \qquad [2]$$

[3] Other researchers have sometimes used a patent-based measure of knowledge capital K (e.g., Cockburn and Griliches, 1988; Hall et al., 2005; Hall et al., 2008). We will not review these studies here because this chapter is focused on the market valuation of R&D investments.

[4] The additive functional form is the most commonly used form in the literature, and can be thought of as a first-order approximation to the value function. It is possible that other functional forms, such as additive in logarithms, might also be useful for estimation. Theory is to some extent silent on the exact relationship.

where b is the market valuation coefficient of the firm's total assets, reflecting its differential risk, overall costs of adjusting its capital, and its monopoly position, γ is the shadow value of R&D capital relative to tangible assets, and the product $b\gamma$ is the absolute shadow value of the R&D capital. In practice, $b\gamma$ reflects the investors' expectations about the overall effect of R&D capital K on the discounted value of present and future earnings of the corporation, while γ expresses the differential valuation of the R&D capital relative to tangible assets. When γ is unity, a currency unit spent on R&D has the same impact on market value of a currency unit spent in tangible assets. Conversely, values of γ higher (lower) than unity suggest that the stock market evaluates knowledge capital more (less) than tangible capital.

The expression [2] can be interpreted as a version of the model that is known in the economic literature as hedonic pricing model, where the good being priced is the firm and the characteristics of the good are its assets, both tangible and intangible. As in the case of the hedonic model, the coefficients of the right hand side variables are not "structural" or "deep" coefficients, but express the current equilibrium price of the particular asset. Because of this fact, they are not expected to be constant across time or sector.

Taking the natural logs of both the sides in [2], assuming constant returns to scale ($\sigma = 1$), and subtracting $log\ A_{it}$ from both sides, we obtain the following expression:[5]

$$log(V_{it}/A_{it}) = logb + log(1+\gamma K_{it}/A_{it}) \qquad [3]$$

The ratio *V/A* is a proxy for average Tobin's *Q*, the ratio of the market value of tangible assets to their physical value. The estimation of equation [3] allows one to assess the average impact of a euro, dollar, or other currency unit invested in knowledge on the market value of a firm at a particular point in time. Hall et al. (2005) estimate equation [3] using non-linear least squares (NLLS). Other authors applying the same model have used the approximation $log(1+x) \approx x$, obtaining the equation below, which can be estimated by ordinary least squares (Griliches 1981; Jaffe 1986; Cockburn et al. 1988; Hall 1993a, 1993b):[6]

$$log(V_{it}/A_{it}) = logb + \gamma K_{it}/A_{it} \qquad [4]$$

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[5] The assumption of constant returns to scale (homogeneity of degree one) in the value function has been confirmed repeatedly in the literature, at least for cross sections of firms.

[6] As the knowledge intensity of firms as grown over time, the approximation has become more and more inaccurate, so later authors are more likely to use the nonlinear form of the equation (that is, [3] rather than [4]).

The next problem in empirical implementation is the measurement of the R&D capital (*K*). A measure of R&D capital has been often computed as the capitalization of present and past R&D expenditures using a perpetual inventory formula like that used for tangible capital (Griliches and Mairesse, 1984; Hall, 1990):

$$K_{it} = (1 - \delta)\, K_{i,t-1} + R_{it} \qquad [5]$$

where K_{it} is the R&D capital at time t, R_{it} is annual R&D expenditures at time t and δ is the depreciation rate of the R&D capital from year $t-1$ to year t. The use of expression [5] to capitalize R&D investments is needed because, as will be explained in chapter 5, the Generally Accepted Accounting Principles (GAAP) in the US and the IAS accounting standards in Europe require R&D costs to be expensed as incurred (with a few exceptions) because of the lack of a clear link between these expenses and subsequent earnings. Therefore, the balance sheet of the firm does not contain a measure of the R&D capital created by its own investments. The use of a depreciation rate is justified by the fact that knowledge tends to decay or become obsolescent over time, losing economic value due to advances in technology and the investments of the firm's competitors.

Most of the studies that have estimated the model in equation [4] have used a constant annual 15% depreciation rate (Jaffe 1986; Cockburn and Griliches 1988; Hall 1993a, 1993b; Blundell et al. 1999; Hall and Oriani 2006). Other studies have used an estimation procedure that allows one to determine industry- and time-specific economic depreciation rates (for example, Lev and Sougiannis 1996).[7] There also exist analyses using annual R&D expenditures as an alternative measure of R&D capital (Cockburn and Griliches 1988; Hall 1993a, 1993b; Munari and Oriani 2005). Because R&D spending is usually fairly persistent over time at the firm level (Hall et al. 1986), results from specifications using the flow of R&D tend to be quite similar to those using the stock after they are adjusted by the appropriate capitalization rate (the inverse of the growth plus depreciation rates). For the same reason (persistence in R&D), it has proved difficult to estimate detailed depreciation schedules for R&D. Using the Tobin's Q equation for a large sample of U.S. manufacturing firms, Hall (2009) shows that R&D depreciation rates in the ICT sector are likely to much higher than those in the chemicals sector (25-30 per cent as opposed to 15 per cent), reflecting the fast pace of technological change in that sector in the recent past.

3.2 Empirical models based on event studies

The models that analyse the relationship between R&D announcements and the response of share prices are mainly based on the event study methodology, which has been widely applied to investigate the effect of other strategic decisions as well as R&D investment decisions on firm market value (among others, McConnell and Muscarella, 1985; Woolridge and Snow, 1990; Chan et al., 1997; Das et al., 1998; Bajo et al., 1998). Event study methodology relates

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[7] More precisely, the authors estimate a regression model in which the dependent variable is the annual operating income and the independent variables are the lagged values of total assets and advertising expenditures and a vector of the past R&D investments.

unexpected announcements of changes to existing investment programs to the excess market returns in the trading days immediately before and after the announcement. The implicit assumption is that the investors consider these announcements to be unexpected “news” about investment strategies (McConnell and Muscarella, 1985). They therefore generate a revision in the investors’ expectations about expected returns and, in efficient financial markets, a change in the stock price (McConnell and Muscarella, 1985; Woolridge and Snow, 1990; Chan et al., 1990).

Conceptually, excess returns are that part of stock returns not explained by the returns of the market portfolio (in practice, a broad-based stock index). According to the Capital Asset Pricing Model (CAPM), they are generally calculated estimating the following equation over a time period preceding the event by a month or more to avoid contamination from the event itself.[8] For example, using a window that runs from 3 months to 1 month before and event that is assumed to take place at $t = 0$), we have the following:

$$r_{it} = \alpha_i + \beta_t r_{mt} + e_{it}\,, \quad t = (-90,-30) \qquad [6]$$

[8] See Brealey, Myers, Allen (2005), chapters 7-9, for details on CAPM. Some studies adopt the more general three-factor models of Fama and French where stock returns do not only depend on the return of the market portfolio, but also on the returns of two other portfolios (see Fama and French, 1992).

where r_{it} is the daily return of stock i in day t, r_{mt} is the daily return of the market portfolio (for example, S&P500) in day t and e_{it} is an independent error term. The excess return of stock i is the predicted residual of equation [6], i.e., the difference between the predicted and the realized stock return, computed over a period that brackets the event (for example, the period ($t = -1$ to $t = +3$)). After estimating the excess returns, two different measures are normally selected for analysis: Cumulative Abnormal Returns (CAR), equal to the sum of the daily excess returns over the observation period or Average Excess Returns, equal to the daily average excess return in the observation period.

4. The empirical results

Application of the models reviewed above to data has led to several interesting results. The hypothesis that R&D investments are positively valued by the stock market has been generally confirmed, although the magnitude of its impact is highly variable. In particular, the existing literature raises some questions of particular interest that can be summarized as follows:

1. How does the market value R&D investments?
2. How does uncertainty affect the market valuation of R&D investments?
3. Does the type of corporate governance have any impact on the market valuation of R&D investments?

These questions will be addressed in this section by referring to the results provided in the existing literature on these topics.

4.1 How does the market value R&D investments?

The question of how the stock market evaluates firms' R&D investments has attracted the interest of many scholars and is still being studied, as is demonstrated by the publications of very recent date. Following the seminal contribution of Griliches (1981), a large number of studies have used variations of a model similar to that in equation [2] to analyse the relationship between R&D (measured either by R&D capital or R&D expenditures) and market value. The main results are summarized in Table 1, which reports the value of the estimated coefficients for either R&D capital (R&D cap) or annual R&D expenditures (R&D exp) and information about the sample and data sources. Clearly, the coefficients of R&D expenditures are on average greater than those of R&D capital, because annual expenditures are lower than capitalized R&D. Two main results seem in general confirmed, as also pointed out by previous surveys (e.g., Hall, 2000). First, stock markets generally value R&D positively (that is, $\gamma > 0$). Second, market valuation of R&D has progressively decreased over time from the 1970s to the present time, as appears, for example, in a comparison of the results of Hall and Oriani (2006) with those of earlier studies such as Jaffe, 1986 and Cockburn and Griliches, 1988.

The meta-analysis conducted by Oriani and Sobrero (2003) on a sub-sample of these studies provides support for this finding. One of the main explanations for this result is a speeded up depreciation of R&D expenditures due to the shortening of technology cycles, which makes past R&D expenditures less valuable to investors. If R&D capital is constructed using the usual 15 per cent depreciation rate when the true depreciation rate is higher, then the resulting coefficient will be lower than it would be if the R&D capital were correctly measured. A second possible reason is the increased number of firms in many sectors that are pursuing R&D strategies, which will tend to drive the returns to this activity down.

The analysis of Table 4.1 also poses other interesting questions. A first observation is that the coefficients, although positive in general, vary a lot across the different studies. Apart from the time dimension already discussed, there could be several important factors at the country-, industry- and firm-level that affect the market valuation of R&D. Those related to uncertainty and corporate governance will be discussed later in this section. Other findings are very clear and rather straightforward. The strength of the appropriability regime enhances the market value of R&D (Cockburn and Griliches, 1988). Moreover, market share positively impacts on the valuation of R&D (Blundell et al., 1999, for UK data, confirmed by Hall and Vopel (1997) for US data), suggesting that size and market power may matter when appropriating the results from R&D investments.

Note that most of the earlier work summarized in Table 4.1 used US data from the Compustat Database, whereas recently there has been a significant amount for work using data on other countries: Australia, Japan, and several European countries.

--- Insert Table 4.1 about here ---

In Table 4.2 we summarize the studies that have used an event study methodology to assess the reaction of the stock markets to announcements concerning a firm's R&D investments. As explained in the previous section, stock market reaction is measured by the short-term cumulative (CAR) or average excess returns within a time window of few days around the date of the announcement. The results, although obtained from a slightly different perspective, provide several interesting insights that complement and integrate those provided by the studies on Tobin's Q.

First, Table 4.2 shows that the stock returns following an announcement of an unexpected increase in R&D investments or a new R&D project are generally positive. This result is consistent with the positive coefficients for the R&D capital found by the studies reviewed in Table 4.1 and reinforces the idea that the stock market places a positive value on the money spent in R&D. Second, also in this case there is variability of the excess returns depending on the study and its characteristics.

With respect to the factors affecting the excess returns, it is worth noting that the stock market reacts more positively in high-tech vs. low tech industries (Chan et al., 1990). Moreover, the level of competition seems to have an effect. The excess returns are higher in more concentrated industries (Doukas and Switzer, 1992) and in industries where competitors do not aggressively react to a firm's R&D announcements (Sundaram et al., 1996). These two results suggest that investors expect that firms are more able to appropriate the returns to their R&D investments when competition is softer.

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4.2 How does uncertainty impact on the market valuation of R&D investments?

An important problem related to the market valuation of R&D investments is the high level of uncertainty that characterizes their expected returns (Mansfield et al., 1977). Several authors have claimed that under these conditions, traditional valuation methods (i.e., net present value, NPV) can fail to capture the full value of R&D investments (e.g., Kogut and Kulatilaka, 1994). The question, therefore, is how financial investors evaluate R&D investments of traded firms.

An increasing number of studies have suggested that real options (RO) theory can complement existing theories in understanding the value created by R&D investments. Some authors have developed formal models for R&D valuation at the project level (e.g., Schwartz and Moon, 2000), whereas others have simply applied an RO logic to analyse technological choices at the firm level (e.g., McGrath and Nerkar, 2004).

According to the latter approach, decision makers, such as managers or external financial investors, implicitly or explicitly use an 'option lens' (Bowman and Hurry, 1993) to analyse the value of different forms of flexibility inherent to R&D investments. Firms' R&D investments create a portfolio of options, whose underlying asset is the present value of the cash flows that can be acquired through discretionary subsequent investments (McGrath and Nerkar, 2004). Since there is no obligation to exercise these options, their value (and the value of the whole portfolio) increases with the variance of the returns on the underlying assets. Accordingly, the volatility of the expected returns from R&D investments is relevant for market valuation.

In a recent contribution, Oriani and Sobrero (2008) have recognized that this volatility can be ascribed to different sources of uncertainty (Huchzermeier and Loch, 2001). In particular, they focus on the distinction between market and technological uncertainty. Faced with market uncertainty, managers have two alternative choices (Folta and O'Brien, 2004). They may delay the investment of additional resources in R&D, thus holding an option to wait or acquire a growth option by committing to incremental preemptive R&D investments. Similarly, faced with technological uncertainty, managers may decide not to invest additional resources in R&D, waiting for the evolution of the technology. Alternatively, as a form of hedging, they can devote incremental R&D investments to the creation of an option to switch to alternative technologies. Financial investors in the marketplace evaluate the firm conditional on its R&D decisions. Based on this reasoning, market and technological uncertainty, real options, and firm value can be linked within a comprehensive framework, which is presented in Figure 4.3.

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When all the real options embedded in R&D investments are considered jointly, the two forms of uncertainty have a non-linear impact on the market valuation of R&D investments. In particular, the empirical results of Oriani and Sobrero (2008) on a sample of British traded firms show that the effect of market uncertainty on the market valuation of R&D is U-shaped, whereas the effect of technological uncertainty is inversely U-shaped.[9] Their empirical results are summarized in Figure 4.4 and 4.5. Figure 4.4 shows the market valuation coefficient of R&D at different levels of the measure of market uncertainty. As it is possible to see, the market valuation of R&D investments decreases up to a certain level of market uncertainty and increases after that. The results show that NPV might not be the only component of R&D value considered by financial investors. The sole NPV, in fact, does not explain the fact that the market valuation of R&D investments starts to increase after a certain level of market uncertainty (NPV would predict a monotonically decreasing relationship between market uncertainty and the valuation of R&D investments).

Figure 4.5 shows that the market valuation of R&D investments first increases and then decreases with technological uncertainty. Also in this case, the real options reasoning and the results indicate the existence of a non-linear relationship between market value of R&D investments and technologically uncertainty that is not consistent with NPV.

[9] Please refer to Oriani and Sobrero (2008) for more complete results and the definition of the indicators of market and technological uncertainty.

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4.3 Does corporate governance have an effect on the market valuation of R&D investments?

A last issue that the recent literature has studied is the possible effect of corporate governance on the market valuation of R&D investments. This effect can be observed at two different levels. At the country level, features of the financial system and resulting investors' behavior can be relevant for R&D (for example, Tylecote and Ramirez, 2006). At the firm level, we might observe an effect of ownership structures on the value that the stock market places on R&D investments. Clearly, the effects of the financial system and the ownership structure could interact, as we will discuss later in this subsection.

With respect to country level differences, Hall and Oriani (2006) analyse the market valuation of R&D investments in several continental European countries, and compare it with two Anglo-Saxon countries (United Kingdom and United States). This paper is the first in-depth empirical analysis of the valuation of firms' R&D by the stock market in European countries other than the United Kingdom. Extending the analysis to these countries is important for several reasons: the importance of their economies, the different nature of their corporate governance systems as compared to Anglo-Saxon countries, and the variations in the public incentive schemes for private R&D. With specific respect to capital markets, it is generally recognized that publicly traded firms in continental European countries are subject to less shareholder pressure on their investment decisions (see for example, Franks and Mayer, 1990). This could be for the good, in the case of profitable long-term investments that might not be undertaken by firms with short horizons, or the bad, if it implies that rate of return tests might not be imposed on these investments, or that projects might be continued too long when they have been demonstrated to be unsuccessful. Under the admittedly strong assumption of efficient capital markets, these differences should also imply market valuations of capital and R&D investments that may be either higher or lower on average than those in the US.

The results obtained by Hall and Oriani exhibited several interesting features. German and French samples show a statistically significant and robust positive valuation of R&D capital by the stock market, although the estimated coefficients of R&D capital are considerably less than unity in all countries, suggesting that R&D investments are less valued by the stock markets than investments in tangible assets. The coefficients are also significantly smaller than the coefficients reported by previous studies using data on US and UK firms. Nevertheless, when permanent unobserved differences across firms were controlled for, the results for the Anglo-Saxon countries were consistent with those for the continental European countries, which confirms that the market valuation of R&D expenditures has decreased in all the countries over time, in line with the previous discussion. In addition, the very narrow gap observed between the R&D coefficients across countries is consistent with the anecdotal evidence of a progressive alignment of the European financial markets to the Anglo-Saxon ones within the last two decades (see Rajan and Zingales 2003).

An interesting finding was that the UK sample shows a substantially greater valuation of R&D capital in the cross section. From the perspective of financial investors, this means that a currency unit spent on R&D by a company in the United Kingdom has on average an impact whose magnitude is nearly three times larger than in France and Germany. The fact that Bond et and colleagues (1998) find much higher marginal productivity of R&D in the UK than in Germany confirms that this result is probably real. It suggests that UK firms face a somewhat higher cost of R&D capital than US firms or firms\ in continental Europe.

With respect to the ownership structures of corporations, the study of Munari and Oriani (2005) on the effect of privatization on R&D performance has shown that R&D investments of privatized firms are evaluated by the stock market significantly and consistently less than those of a control sample of private firms. This result suggests the presence of some form of inefficiency due to the former State ownership. A second interesting finding on ownership structures is provided by Hall and Oriani (2006), who show that in France and Italy, the market places a significantly positive value on R&D spending only for firms without large controlling shareholders. In some cases, especially in France, this may be because the large shareholder is the government. In other cases, it may simply be that majority holders do not respond to market pressures that signal low values for their investment strategies. One avenue for future research could be further exploration of the relationship between the types of large shareholders (governments, families, or other firms) and the valuation of firm-level R&D strategy.

Another issue worthy of exploration is the interaction between corporate governance systems at the country level and ownership structures at the firm level. In fact, agency problems specifically related to R&D investments are likely to arise between the controlling and the minority shareholders because the former are relatively protected from takeover threats and monitoring activities and have the opportunity to divert firms' profits from outside investors to their own benefit. This problem can be exacerbated by a weaker legal protection of minority shareholders. In a series of studies adopting a legal approach to financial markets, La Porta and colleagues (among others, La Porta et al., 1998, 2002) have reported that civil law systems, such as those of France, Germany and Italy, grant fewer rights to minority shareholders than common law systems of Anglo-Saxon countries.

5. Conclusions

In this chapter we have analysed how investors in financial markets value firms' R&D investments. This issue is important because stock prices can provide managers with useful information on the value of the firm's R&D activities. In the first part of the chapter we have reviewed the theoretical and methodological foundations of the studies on the market valuation of R&D investments and the models adopted. This was necessary in order to better understand their results and implications. Based on our review, we have identified three main open questions about the market valuation of R&D investments. First, how does the stock market evaluate R&D investments? In this respect, we have observed that in general the investors place a positive value on the money that firms invest in R&D activities. However, the valuation is rather erratic over time and across countries and industries. This raises questions about whether all the factors affecting the market valuation of R&D investments have been controlled for.

Second, how does uncertainty impact R&D valuation? We know that the returns to R&D investments are subject to a high degree of both market and technological uncertainty. In this chapter we have reported the results of the recent work of Oriani and Sobrero (2008), where a real options logic has been applied to better understand how financial investors evaluate the R&D investments of traded firms. The study shows that the valuation is consistent with real options theory and suggests that the traditional valuation methods based on NPV capture only a part of the market value of R&D investments.

Third, how do corporate governance and ownership structures affect the market valuation of R&D investments? Based on recent studies dealing with these issues, we have proposed that corporate governance provisions both at the level of the firm and the country can have a significant effect on how R&D investments are evaluated by the stock market.

The issues reviewed and the results reported and discussed in this section have some potentially important implications for different actors and highlight opportunities for future steps in the research on the market valuation of R&D investments. The fact that stock markets in general positively evaluate R&D investments of traded firms is a signal for managers, who are reassured about the possible market myopia on R&D investments. Policymakers receive a confirmation about the importance of stock markets for the financing of innovation and of the measures to favor the listing of younger and more innovative firms. However, the high variability of the results also remarks that several aspects of the market valuation of R&D investment have still to be clarified. In particular, it seems that firm-specific factors affecting R&D market value have been not been fully investigated as yet. In particular, given the recent attention to the role of corporate governance for firm performance (for example Gompers et al., 2003) and innovation development (for example, Tylecote and Ramirez, 2006), the relationship between corporate governance arrangements (including ownership structures), management of R&D and firm value seems a particularly promising avenue for future research.

Aboody, D. and B. Lev (2000), 'Information asymmetry, R&D, and insider gains', *Journal of Finance*, 55 (6), 2747-2766.

Bajo, E., Bigelli, M., and S. Sandri (1998), 'The stock market reaction to investment decisions: Evidence from Italy', *Journal of Management and Governance*, 2 (1), 1-16

Benner, M. J. (2007), 'The incumbent discount: Stock market categories and response to radical technological change', *Academy of Management Review*, 32 (3), 703-720.

Ben-Zion, Uri (1984), 'The R&D and Investment Decision and Its Relationship to the Firm's Market Value: Some Preliminary Results', in Zvi Griliches (ed.), *R&D, Patents, and Productivity,* Chicago: The University of Chicago Press.

Bloch, C. (2008), 'The market valuation of knowledge assets', *Economics of Innovation and New Technology*, 17 (3), 269-284.

Blundell, R., R. Griffith and J. Van Reenen (1999), 'Market share, market value and innovation in a panel of British manufacturing firms', *Review of Economic Studies* 66 (228), 529-554.

Bond, S., D. Harhoff and J. Van Reenen (1998), 'R&D and productivity in Germany and the United Kingdom', mimeo, Mannheim: ZEW.

Bosworth, D. and M. Rogers (2001), Market value, R&D and intellectual property: An empirical analysis of large Australian firms, *The Economic Record* 77 (239), 323-337.

Bowman, E. H. and D. Hurry (1993), 'Strategy through the option lens: an integrated view of resource investments and the incremental-choice process'. *Academy of Management Review*, 18 (4), 760-782.

Chan, S. H., Martin, J. D., and J. W. Kensinger J. W. (1990), 'Corporate research and development expenditures and share value', *Journal of Financial Economics*, 26 (2), 255-276.

Chaney, P. K., Devinney, T. M., and R. S. Winer (1991), 'The impact of new product introductions on the market value of firms', *Journal of Business*, 64 (4): 573-609.

Cockburn, I. and Z. Griliches (1988), 'Industry effects and appropriability measures in the stock market's valuation of R&D and patents', *American Economic Review*, 78 (2), 419-423.

Czarnitzki, D., Hall, B. H., and R. Oriani, (2006), 'The Market Valuation of Knowledge Assets in US and European Firms", in Derek L. Bosworth and Elizabeth Webster (eds.), *The Management of Intellectual Property*, Cheltenham, UK: Edward Elgar, pp. 111-131.

Das, S., Sen, P. K. and S. Sengupta (1998), 'Impact of strategic alliances on firm valuation', *Academy of Management Journal*, 41 (1): 27-41

Doukas, J. and L. Switzer (1992), 'The stock market's valuation of R&D spending and market concentration", *Journal of Economics and Business,* 44 (2): 95-114

Fama, E. F. (1970), 'Efficient capital markets: A review of theory and empirical work', *Journal of Finance*, 25 (2), 383-417.

Fama, E. F. (1991), 'Efficient capital markets: II', *Journal of Finance*, 46 (5), 1575-1617.

Fama, E. F. and K. R. French (1992), 'The cross-section of expected stock returns', *Journal of Finance*, 47 (2), 427-465.

Fama, E. F. and M. C. Jensen (1985), 'Organizational forms and investment decisions', *Journal of Financial Economics*, 14 (1), 101-119

Franks, J. and C. Mayer C. (1990), 'Capital markets and corporate control: A study of France, Germany and the UK', *Economic Policy*, 10 (1), 189-232.

Gompers, P., Ishii, J. and A. Metrick (2003), 'Corporate governance and equity prices', *Quarterly Journal of Economics*, 118 (1), 107-155.

Griliches, Z. (1981), 'Market value, R&D and patents', *Economics Letters*, 7 (2), 183-187.

Griliches, Z. and J. Mairesse (1984), 'Productivity and R&D at the Firm Level', in Zvi Griliches (ed.), *R&D, Patents, and Productivity,* Chicago: The University of Chicago Press.

Hall, B. H. (1990), ‘The Manufacturing Sector Masterfile: 1959-1987’, National Bureau of Economic Research Working Paper 3366, Cambridge, MA.

Hall, B. H. (1993a), ‘Industrial research during the 1980s: did the rate of return fall?’, *Brookings Papers on Economic Activity. Microeconomics*, (2), 289-343.

Hall, B. H. (1993b), ‘The stock market's valuation of R&D investment during the 1980's’, *American Economic Review*, 83 (2), 259-264.

Hall, B. H. (2000), Innovation and Market Value, in R. Barrell, G. Mason and M. O’Mahoney (eds.), *Productivity, innovation and economic performance*, Cambridge: Cambridge University Press.

Hall, B. H. (2002), ‘The financing of research and development’. *Oxford Review of Economic Policy*, 18 (1), 35-51.

Hall, B. H. (2009), ‘Measuring the returns to R&D: The depreciation problem’, *Annales d'Economie et de Statistique*, forthcoming.

Hall, B.H., A.B. Jaffe and M. Trajtenberg (2005), ‘Market value and patent citations’, *Rand Journal of Economics*, 36 (1), 16-38.

Hall B. H. and R. Oriani (2006). ‘Does the market value R&D investment by European firms? Evidence from a panel of manufacturing firms in France, Germany, and Italy’, *International Journal of Industrial Organization*, 24 (5), 971-993.

Hall, B. H. and K. Vopel (1997), ‘Market value, market share, and innovation’, NBER, the University of California at Berkeley, and the University of Mannheim, www.econ.berkeley.edu/~bhhall/papers/HallVopel97.pdf

Haneda, S., and H. Odagiri, (1998), ‘Appropriation of returns from technological assets and the values of patents and R&D in Japanese high-tech firms’, *Economics of Innovation and New Technology*, 7 (4), 303-322.

Huchzermeier A and C. H. Loch (2001), ‘Project management under risk: using the real option approach to evaluate flexibility in R&D’, *Management Science*, 47 (4), 85-101.

Jaffe, A.B. (1986), ‘Technological opportunity and spillovers of R&D: evidence from firms' patents, profits, and market value’, *American Economic Review*, 76 (5), 984-1001.

Jensen, M. C. (1978), ‘Some Anomalous Evidence Regarding Market Efficiency’, *Journal of Financial Economics*, 6 (2/3), 95-101.

Kelm K. M., Narayanan V. K., and G. E. Pinches (1995), ‘Shareholder value creation during R&D innovation and commercialization stages’, *Academy of Management Journal*, 38 (3), 770-786.

Kogut B. and N. Kulatilaka (1994), 'Options thinking and platform investments: Investing in opportunity', *California Management Review*, 36 (2): 52-71.

La Porta, R., Lopez-De-Silanes, F., Shleifer, A., and R. Vishny (1998), 'Law and finance', *Journal of Political Economy*, 106 (6), 1113-1135.

La Porta, R., Lopez-De-Silanes, F., Shleifer, A., and R. Vishny (2002), 'Investor protection and corporate valuation', *Journal of Finance*, 57 (3), 1147-1170.

Lev, B. (2004), 'Sharpening the intangibles edge', *Harvard Business Review*, 82 (6), 109-116.

Lev, B. and T. Sougiannis (1996), 'The capitalization, amortization, and value-relevance of R&D', *Journal of Accounting & Economics*, 21 (1), 107-138.

Mansfield, E., Rapoport, J., Romeo, A., Wagner, S. and J. Beardsley (1977), 'Social and private rates of return from industrial innovations', *Quarterly Journal of Economics*, 91 (2), 221-240.

McConnell, J. J. and C. J. Muscarella (1985), 'Corporate capital expenditure decisions and the market value of the firm', *Journal of Financial Economics*, 14 (3), 399-422.

McGrath, R. G. and A. Nerkar (2004), 'Real options reasoning and a new look at the R&D investment strategies of pharmaceutical firms', *Strategic Management Journal*, 25 (1), 1-21.

Munari, F. and R. Oriani (2005), 'Privatization and economic returns to R&D investments', *Industrial and Corporate Change*, 14 (1), 61-91.

Munari F., Oriani R., and M. Sobrero (2005), 'Do Owner Identity and Financial Markets Affect R&D Investments? An Analysis of European Firms', Paper presented at the Annual Meeting of the Academy of Management, Honolulu, HI, USA, August 5-10.

Oriani, R. and M. Sobrero (2003), 'A Meta-Analytic Study of the Relationship between R&D Investments and Corporate Value', in Mario Calderini, Paola Garrone and Maurizio Sobrero (eds), *Corporate Governance, Market Structure and Innovation*, Cheltenham, UK: Edward Elgar, 177-199.

Oriani R. and M. Sobrero (2008), 'Uncertainty and the market valuation of R&D within a real options logic', *Strategic Management Journal*, 29 (4), 343-361.

Pakes, A. (1985), 'On patents, R&D, and the stock market rate of return', *Journal of Political Economy*, 93, 390-409.

Pakes, A. and Z. Griliches (1984), 'Patents and R&D at Firm Level: A First Look', in Zvi Griliches (ed.), *R&D, Patents, and Productivity,* Chicago: The University of Chicago Press.

Rajan, R.G. and L. Zingales (2003), 'Banks and markets: The changing character of the European finance', National Bureau of Economic Research Working Paper 9595, Cambridge, MA.

Rogers, M. (2001), 'Firm performance and investment in R&D and IP', Melbourne Institute Working Paper No. /01, Melbourne, Australia.

Schwartz, E. S. and M. Moon M. 2000. 'Evaluating research and development investment', in Michael J. Brennan and Lenos Trigeorgis (eds.) *Project Flexibility, Agency, and Competition*, Oxford: Oxford University Press, 85-106.

Sundaram, A. K., John, T. A. and K. John (1996), 'An empirical analysis of strategic competition and firm values: The case of R&D competition', *Journal of Financial Economics*, 40 (3), 459-486.

Szewczyck, S., Tsetsekos, G. P. and Z. Zantout, (1996), 'The valuation of corporate R&D expenditures: Evidence from investment opportunities and free cash flow', *Financial Management*, 25 (1), 105-110.

Toivanen, O., Stoneman, P. and D. Bosworth (2002), Innovation and market value of UK firms, 1989-1995, *Oxford Bulletin of Economics and Statistics* 64 (1), 39-61.

Tylecote, A. and P. Ramirez 2006. 'Corporate governance and innovation. The UK compared with the US and 'insider' economies'. *Research Policy*, 35 (1), 160-180.

Woolridge J. R., and C. C. Snow (1990), 'Stock market reaction to strategic investment decisions', *Strategic Management Journal*, 11 (5), 353-363.

Zantout, Z. Z. (1997), 'A test of the debt-monitoring hypothesis: The case of corporate R&D expenditures", *Financial Review*, 32 (1), 21-48.

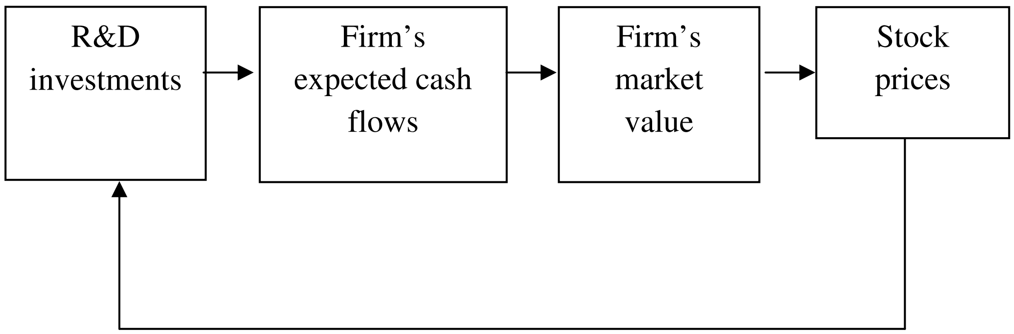

Figure 4.1. The relationship between R&D investment and stock prices

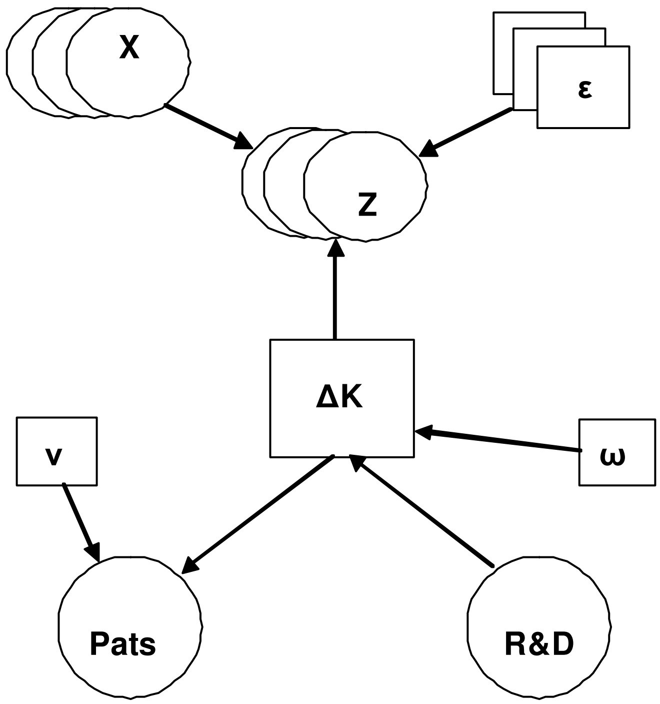

Figure 4.2: The empirical relationship between R&D investment and firm market value (adapted from Pakes and Griliches 1984)

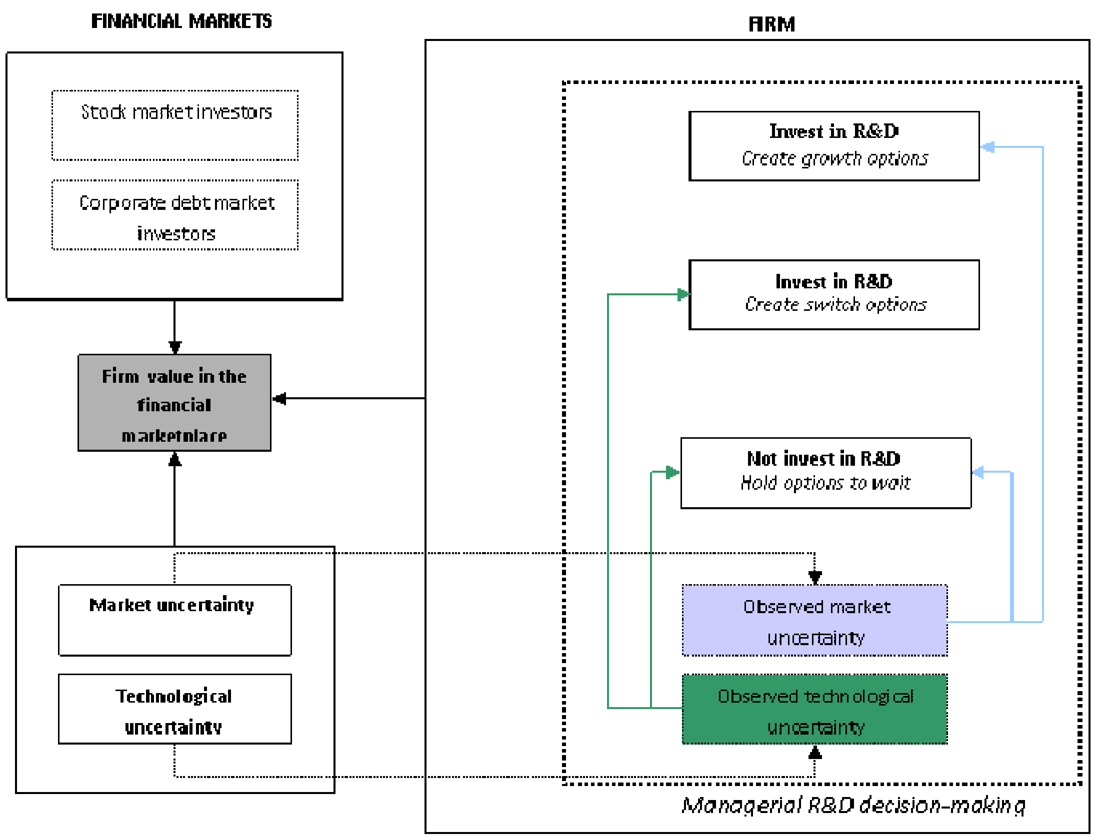

Figure 4.3. Uncertainty, R&D investments, real options, and firm market value (source: Oriani and Sobrero, 2008)

Figure 4.4. Market uncertainty and the R&D market valuation coefficient (source: adapted from Oriani and Sobrero, 2008)

[redacted]

Figure 4.5. Technological uncertainty and the R&D market valuation coefficient (source: adapted from Oriani and Sobrero, 2008)

Table 4.1: Overview of the main empirical findings of the models based on Tobin's Q

Study	*R&D coefficient*	*Sample characteristics (country, no. of firms, years, data source)*
Griliches (1981)	Predicted R&D exp: 1.23 Surprise R&D exp: 1.58	US, 157 firms, 1968-1974, Compustat
Ben-Zion (1984)	R&D exp: 3.376	US, 93 firms, 1969-1977, Compustat
Jaffe (1986)	R&D cap: 2.95	US, 432 firms, 1973 and 1979, Compustat
Cockburn and Griliches (1988)	R&D exp: 11.96 R&D exp * Appropr.: 2.788 R&D cap: 1.442 R&D cap * Appropr.: .303	US, 722 firms, 1980, Compustat
Hall (1993a)	R&D exp: 3.10 R&D cap: .48	US, 2400 firms, 1973-1991, Compustat
Hall (1993b)	By year (1971-1990): R&D exp: from 2.0 to 10.0 R&D cap. from .5 to 2.0	US, 3000 firms, 1959-1991, Compustat
Haneda and Odagiri (1998)	R&D cap: ~2.3	Japan, 90 firms, 1981-1991, NEEDS database
Blundell et al. (1999)	R&D cap 1.582 R&D cap * Market share 1.745	UK, 340 firms, 1972-1982, LBS Share Price Database and Datastream
Bosworth and Rogers (2001)	R&D exp: 2.268	Australia, 60 firms, 1994-1996, Australian Stock Exchange and IBIS database
Rogers (2001)	R&D exp: 3.405	Australia, 721 firms, 1995-1998, Australian Stock Exchange and IBIS database
Toivanen et al. (2002)	By year: R&D exp: from 2.6 to 4.2	UK, 877 firms, 1989-1995, Extel financial company analysis
Munari and Oriani (2005)	Privatized R&D exp: -1.41 Private R&D exp: 3.059	Finland, France, Germany, UK, Italy, Netherlands, 1982-1999, 38 privatized firms and 38 control firms, Datastream and Centrale dei bilanci
Hall et al. (2005)	R&D cap: 1.736	US, 4800 firms, 1965-1995, Compustat
Hall and Oriani (2006)	France - R&D cap: 0.28 Germany - R&D cap: .33 Italy - R&D cap: .01 UK - R&D cap:.88 US - R&D cap: .33	France (51 firms), Germany (80 firms), UK (284 firms), Italy (49 firms) 1989-1998; Datastream, Global Vantage, Worldscope, Centrale dei bilanci
Greenhalgh and Rogers (2006)	R&D exp: 3.509	UK, 347 firms, 1989-1999, Extel financial company analysis and Thomson
Bloch (2008)	R&D cap: 2.28	Denmark, 61 firms, 1989-2001, Danish Centre for Studies in Research and Research Policy's R&D statistics, Account Database of Copenhagen Business School, Danish Stock Database
Oriani and Sobrero (2008)	R&D cap : 1.19	UK, 290 firms, 1989-1998, Datastream

Table 4.2: Overview of main empirical findings of the models based on event study

Study	*Excess returns (%)*	*Sample characteristics (country, announcements, years, data source)*
McConnell and Muscarella (1985)	Average excess return: (days –1, 0) 0.21	US, 8 announcements of R&D increase from Wall Street Journal Index and Predicasts F&S Index, 1975-1981, Investment Statistics Laboratory (ISL) Database
Chan et al. (1990)	CAR (days -30, -1) -0.21 CAR (days 0, +1) 1.38 CAR (days +2), +12) 0.39 CAR (days 0, +1): high-tech 2.1 low-tech -0.9	US, 167 announcements of R&D increase from the Dow Jones News Wire, 1979-1985, CRSP
Woolridge and Snow (1990)	CAR (day -1) 0.80 CAR (day 0) 1.13 CAR (day 5) 0.81	US, 52 announcements of new R&D projects from Wall Street Journal, 1972-1987, CRSP
Doukas and Switzer (1992)	CAR (days -2, 0) 0.56 CAR (days –2, 0) for firms in High concentration markets 1.44 Low concentration markets -0.01	US, 87 announcements of unexpected variations of R&D expenditures from Wall Street Journal Index and Predicasts F&S Index, 1965-1984, CRSP
Zantout and Tsetsekos (1994)	CAR (days 0,+1): announcing firms 0.742 competing firms -0.563	US, 114 announcements of R&D increase from Dow Jones News Wire, 1979-1990, COMPUSTAT and CRSP
Kelm et al. (1995)	Average excess return (days -1,0): innovation 0.88 commercialization 1.02	US, 501announcemens on progresses in R&D projects (innovation) or new product introduction (commercialization) from Wall Street Journal, 1977-1989, COMPUSTAT and CRSP
Szewczyck et al. (1996)	CAR (days 0,+1): - Firms with Tobin's Q high 0.929 low -0.160 - Firms with CF/A high 0.499 low 0.227	US, 252 announcements of R&D increase from the Dow Jones News Wire, 1979-1992, COMPUSTAT, CRSP and Standard & Poor's Stock Guide
Sundaram et al. (1996)	CAR (days 0, +1) Loose competition +0.8 Aggressive competition -0.6	US, 125 announcements of unexpected variations of R&D expenditures from the Dow Jones News Wire, 1985-1991, CRSP and Business Week R&D Scoreboard
Zantout (1997)	CAR (days –10,-1) 0.059 CAR (days 0,+1) 0.474 CAR (days +2,+10) -0.369	US, announcements of R&D increase from the Dow Jones News Wire, 1979-1992, CRSP and COMPUSTAT