

**Privatization and Economic Returns to R&D Investments:
An Empirical Analysis Based on Tobin's q**

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Abstract

In this paper, we analyze the impact of privatization on the firm's R&D economic performance. Consistently with the literature on the performance improvements of privatized firms, privatization should be associated with a rise in R&D expected returns. However, two alternative hypotheses can be advanced on the timing of this effect. If privatization is considered a discrete event, improvements should take place immediately after the ownership change. On the contrary, a rise in R&D expected returns could not be attained in the short term because of deferred control transfer and firm-level organizational inertia. To test this issue, we refer to the literature on innovation and market value (Hall, 1999). Applying the hedonic methodology (Griliches, 1981), we examine the relationship between R&D investments and Tobin's q for a panel of 40 firms, including 20 firms privatized in the Western Europe that were matched at the country and industry level with 20 publicly traded firms. Our findings show that the effect of R&D investments on Tobin's q is systematically higher for publicly traded firms compared to privatized firms over a five years period after privatization. This suggests that R&D investments by newly privatized firms are undervalued by the stock market, coherently with the hypothesis of a deferred effect of privatization on firm's R&D performance. Implications for future research on privatization and innovation are discussed.

1. Introduction

In different countries, State-owned enterprises (SOEs) have historically played a main role in directing and qualifying the evolution of the national innovation systems, both directly, by means of their R&D investments and facilities, and indirectly, by means of their procurement strategies (Nelson, 1993). Over the last two decades, widespread privatization processes have consistently reduced the direct presence of the State as a major player in the economic arena (Siniscalco et al., 1999). Prior research on privatization experiences has generally shown that the change in ownership improves productive efficiency and profitability at the firm level (see Megginson and Netter, 2001, for a review). However, scarce attention has been paid to assessing if and how privatization affects the innovation performance of the firm. In general, as Parker (1998) and Villalonga (2000) point out, the dynamic efficiency gains associated to privatization, regarding investments, R&D and innovation, have been largely ignored, both in theory and in practice.

To this respect, some authors (Shleifer, 1998; Zahra et al., 2000) have argued that private ownership must be preferred to public ownership whenever the incentives to innovate and contain costs are strong and claimed that privatization processes can have a fundamental role

in establishing a new set of organizational dynamics that promote innovation. Nevertheless, more recent studies (Katz, 2001; Munari, 2002; Munari et al., 2002) suggest that the State divestiture can be followed by a consistent restructuring and scaling down of R&D facilities and investments of former public enterprises, especially when it coincides with the opening-up of formerly monopolistic markets to competition. Indeed, R&D investments are an input measure of the firm's innovation activity and nothing can be said yet on their expected economic results after State divestment.

Accordingly, this paper analyzes the effect of privatization on firm's R&D economic performance. In particular, it will focus on the private returns to firm's R&D investments depending on the commercialization of new products and technologies. Consistently with the literature on the performance of privatized firms and the impact of corporate governance on firm's innovation activity (see Munari and Sobrero, 2002a, for a review), privatization should be associated with both a rise in R&D efficiency and a tighter focus of R&D activities on the business (rather than social) needs, ultimately leading to higher private returns after the State divestment.

Indeed, several factors other than private-public distinction could affect the timing of the results improvements (Villalonga, 2000). With specific respect to the effect of privatization on private returns to R&D investments, two alternative hypotheses can be advanced. If privatization is considered a discrete event, as done in previous studies (e.g., Eckel et al., 1997), we should expect the improvements to take place immediately after the ownership change. On the contrary, a rise in R&D expected returns could not be attained by newly privatized firms in the short run for at least two reasons. First, in many cases governments tend to retain a significant stake in the privatized company, with significant effects on expected improvements (Boycko et al., 1996). Second, even after the control transfer to private shareholders, early stages after privatization could be still characterized by residual inefficiency, since organizations might be characterized by substantial inertia and resistance to change, as remarked by contributions in evolutionary economics (Nelson and Winter, 1982).

In order to estimate the private returns to R&D investments of privatized firms, we recall the literature that, moving from the seminal work of Griliches (1981) and using the hedonic model, has assessed the specific effect of innovation-related assets on the market value of the firm (see Hall, 1999 and Oriani and Sobrero, 2002, for a review). In our case, the use of stock market measures is preferred to accounting profits because the change of managerial incentives brought by the privatization could affect accounting data even in absence of

performance improvements (Eckel et al., 1997). We choose in particular Tobin's q as indicator of firm's expected performance, consistently with previous empirical studies on the effect of corporate governance on firm's performance (e.g. Cho, 1998; Demsetz and Villalonga, 2001; Volpin, 2002). Moreover, since in our case a pre- and post- comparison is not feasible because firms are not normally traded before privatization, we adopt a matched-paired research design and use data from a panel of 40 firms - including 20 privatized firms that were coupled at the country and industry level with 20 publicly traded firms. The first group refers to a set of companies which were privatized through public share offering in different countries of Western Europe over the period 1982-1997. This choice relies on the fact that Western Europe generated the vast majority of privatization programs that occurred worldwide since the pioneering experience of the UK in the early 80s under the Thatcher's government (Megginson and Netter, 2001)². We examine in a regression framework the relationship between R&D investments and Tobin's q for both privatized and matched firms in the five years following the IPO, in order to test the existence of significant differences between the two groups. We adopt panel data techniques in our analysis to address the problem posed by the unobserved firm heterogeneity. Moreover, we deal with the problem of the potential simultaneity between R&D investments and Tobin's q by estimating both a simultaneous equations and an instrumental variables regression model.

If the privatization event instantaneously enhances the expected returns to firm's R&D activities, no difference should emerge in the stock market valuation of R&D investments of privatized and matched firms; on the contrary, a negative difference should be found under the hypothesis of organizational inertia impeding the improvements of R&D performance in newly privatised firms. The regression analyses show that R&D investments by newly privatized firms are systematically underestimated by the stock market compared to the firms in the matched sample; this evidence is robust to our controls for firm-specific effects and endogeneity issues. Therefore, our findings support the latter interpretation and hence the idea that privatization can not be seen as a discrete event, at least with respect to the innovation activity of the firm.

The rest of the paper is organized as follows. In Section 2 we first provide theoretical foundations to justify the expectation of relevant changes in R&D performance after privatization and then explain how the models analyzing the relationship between R&D

² Using a database compiled by Privatisation International including 1.867 privatizations in 113 countries between 1977 and 1997, Siniscalco et al. (1999) conclude that privatizations in Western European countries account for around 30% of all operations and around 50% of global privatization revenues.

investments and Tobin's q can be usefully applied to the analysis of our research question. In Section 3 we describe the sample used in the empirical analysis and the technique adopted to build the industry-matched control group. In Section 4 we discuss the estimation models and in Section 5 we present the results of the different regression analyses. In the final Section we draw main conclusions from the theoretical and empirical analysis, and discuss the implications for future research.

2. Theoretical background

The change in the allocation of property rights from public to private sector brought by privatization consistently impacts on the principal-agent relationship (De Alessi, 1987; Vickers and Yarrow, 1988). The divestment of the government leads to a profound reformulation of the agent's objectives and incentives, which presents significant implications for R&D investment decisions and outcomes. In this section we first review the impact of privatization on firm's R&D investments and then investigate its consequences for R&D performance. As to the latter point, we specifically refer to the literature that has used the market value of the firm to assess the expected returns to R&D investments. We then formulate competing hypotheses on the timing of R&D performance improvements after privatization and conclude by discussing the endogeneity issues emerging in the estimation of the relationship between R&D investments and market value of privatized firms.

2.1 The impact of privatization on firms' R&D performance

Since R&D projects are typically risky, unpredictable, long-term oriented and idiosyncratic (Holmstrom, 1989), they inherently involve high agency costs and thus become a potential arena of acute conflicts of interest between executives and shareholders. Therefore, the characteristics of the firm's governance and ownership structure significantly influence the undertaking and performance of R&D activities (Baysinger et al., 1991). Along this line of inquiry, we focus on the specificities of having the government as the sole or dominant shareholder for R&D investments and on the impact of its divestment after privatization on innovation performance at the firm level.

It is possible to advance two different but interrelated explanations to justify the expectations of consistent changes in the firm's R&D investments and performance following

privatization (Munari et al., 2002). First, R&D activities within State-owned companies should be more oriented to fulfil general national goals of generating and diffusing the public good of knowledge rather than exclusively addressing business specific objectives, given their wider mission of maximizing social welfare. On the contrary, when the firm goes public, managers are posited by the stock market to make investment choices aimed at the maximization of the corporate value (Fama and Jensen, 1985). Second, if we recall the arguments of public choice theory (Niskanen, 1971; Buchanan, 1972), and property rights theory (De Alessi, 1987; Vickers and Yarrow, 1988) a possible reduction of resources devoted to R&D after privatization may be rather ascribed to efficiency gains in the use of resources under private ownership. These two different lines of reasoning lead to opposite conclusions about the possible consequences of privatization for social welfare in the long run, but converge in suggesting that the private returns to R&D investments are likely to increase after the divestment of the State.

An empirical analysis based on a sample of firms privatized in Western Europe shows that, after controlling for inter-industry differences, privatization processes lead to a reduction of R&D investments and to a contemporaneous increase in the number of patents assigned and in their quality, as measured by the number of citations received by following patents (Munari and Sobrero, 2002b)³. These results combined document a significant improvement in R&D productivity after the State divestiture.

Accordingly, we should expect that, *ceteris paribus*, any currency unit invested in R&D activities after the privatization should generate higher private returns than any currency unit invested under the State ownership. However, the timing of performance improvements is still object of discussion. Part of the literature interprets privatization as a discrete event and implicitly assumes that it should lead to an increase in the firm's economic performance (e.g., Eckel et al., 1997). According to this view, privatized firms should exhibit higher expected returns to their R&D investments immediately after the State divestment. On the contrary, efficiency growth brought by privatization could be slower and take place through a gradual process. At least two different explanations support this view. First, in many cases governments tend to retain a significant stake in the privatized company, a decision having significant implications on the intensity and rapidity of the expected performance improvements. Restructuring and performance improvements following privatization are thus more likely to occur when private shareholders get control rights (Boycko et al., 1996).

³ The degree to which this measure assesses the quality and the technological importance of a patent is broadly discussed in Hall et al. (2000).

Second, privatization impacts on performance through an internal organizational change process which may require a major effort and a long period of time to be completely implemented (Martin and Parker, 1997; Villalonga, 2000; Cuervo and Villalonga, 2000). In fact, organizations do not adapt instantaneously to a different institutional and competitive context, being characterized by substantial inertia and resistance to change (Nelson and Winter, 1982). Accordingly, in the early stages of privatization firms may still be characterized by residual conformity to public sectors routines (Kogut and Spicer, 2002). These considerations suggest that the positive effect of privatization on the expected returns to R&D investments do not materialize in the short term.

2.2. Tobin's q and the assessment of private returns to R&D investments in newly privatized firms

The market value of the firm can be an useful indicator to assess the expected economic performance of the firm's R&D activities after privatization for at least two reasons. First, market value is a forward-looking measure expressing, under the assumption of market efficiency, the investors' expectations on the firms' performance. Second, previous empirical literature has already shown that it is possible to assess the specific effect of different technology-related assets, including R&D investments, on the market value of the firm (Hall, 1999).

These considerations can be fruitfully applied to the analysis of R&D performance of newly privatized firms. In particular, we refer to the studies applying the hedonic methodology assess the specific effect of R&D-related assets on the market value, that reflects the investors' expectations on the overall effect of these assets on the discounted value of the expected future earnings of the corporation (Griliches, 1981). Most of these analyses (Griliches, 1981; Jaffe, 1986; Cockburn and Griliches, 1988; Hall, 1993b) adopt a functional form where the dependent variable is the Tobin's q, that, in particular, has the advantage to be a ratio between financial price and accounting data, allowing comparisons between outputs, measured by the market valuation of the firm, and inputs, measured by the replacement cost of the firm's assets (Lindenberg and Ross, 1981). We will refer to this specific literature to measure private returns to R&D investments after the privatization.

Unfortunately, data on market value are not available before the privatization, and hence pre- and post-privatization comparisons are not feasible. However, it is possible to analyze

the impact of R&D investments on market value of privatized firms in comparison to a sample of matched publicly-held firms. This is the strategy we will follow in the paper.

2.3 Hypotheses

Previous discussion allows us to formulate two different hypotheses on the timing of the effect of privatization on the market valuation of R&D investments of newly privatized firms. If privatization is a discrete event bringing immediate improvements in the R&D expected returns, no significant difference should emerge in the market valuation of R&D investments of the privatized and matched firms. On the contrary, if considerable lags exist between the change in ownership and the improvements in expected returns to R&D investments, we should observe an initial underevaluation by the stock market of the R&D investments of privatized firms compared to publicly-held firms.

2.4 Endogeneity issues

In the analysis of the relationship between R&D investments and Tobin's q of privatized firms, R&D investments can not be treated as an exogenous variable for two main reasons. First, since R&D is chosen on the basis of economic incentives, it is unlikely that it is independent from firm's market valuation (Griliches, 1995). In fact, previous empirical literature has shown that R&D investments depend on firm's expected economic performance, and in particular on Tobin's q (Blundell et al. 1992; Bond and Cummins, 2001). This issue creates confusion on the causality direction between R&D investments and Tobin's q . Previous empirical work has already recognized this potential issue and has treated R&D investments as an endogeneous variable (e.g., Jaffe, 1986).

Second, both Tobin's q and R&D investments are likely to be jointly affected by the exogenous change in corporate governance led by the firm's privatization. Empirical literature has shown that privatization positively affects different measures of firm's performance, such as profits (D'Souza and Megginson, 1999; Bortolotti et al., 2002), stock returns (Dewenter and Malatesta, 1997, 2001; Megginson, 2000) and Tobin's q (Claessens et al., 1997). At the same time, it has been shown that R&D investments decrease over time after privatization (Munari and Sobrero, 2002b). To the extent that this endogeneity issue exists, a problem of simultaneity between R&D investments and Tobin's q arises. In this case, a plain OLS estimator would lead to inconsistent coefficients. In this paper, we will

address these questions treating R&D investments as endogeneous within a simultaneous equations and an instrumental variables estimation model.

3. Data

3.1 Sample

We created an original dataset including R&D expenditures and accounting and stock market information for a match-paired sample of privatized and publicly held companies. We started our data collection with a sample taken from two articles by Megginson et al. (1994) and D'Souza and Megginson (1999), including 174 companies, operating in 35 different industries, that were fully or partially privatized worldwide through public share offering in 32 countries between 1980 and 1997. Following Megginson et al. (1994), our definition of privatization includes any measure that transfers some or all of the ownership and/or control over SOE to the private sector. We decided to consider only companies privatized through public sale, in order to control for information asymmetries, which might be generated by private solicitation processes and could not be controlled effectively.

We further integrated this initial sample with information on privatization processes derived from: (1) the complete list of companies privatized worldwide in the 80s compiled by the World Bank (Candoy-Seske, 1988); (2) the description of privatization programs adopted by the countries of the European Union provided by Parker (1998); (3) additional information taken from business journals and publications reported in the archive Lexis-Nexis. The final sample we were able to draw up after this initial phase included 182 firms from 32 countries.

We then decided to limit our analysis only to firms which were privatized in Western European countries for several reasons. First, the vast majority of privatization programs that occurred worldwide in the period 1977-1997 took place in Western European countries (Siniscalco et al., 1999). Second, obtaining information on the key-variables for non-Western European firms is extremely difficult, especially with regards to data on R&D expenditures. Moreover, by considering firms from Western European countries, we were able to collect data at country and industry level as well, using the OECD official statistics, as we describe later on.

We then kept from the initial sample only those reporting R&D expenditures in their financial statements in the period of observation. We decided to drop the public utilities (telecommunications, energy and water services) from this intermediate sample, because, as

these firms typically operated under a monopolistic regime, it was not possible to accurately match them at country and industry level⁴. After cleaning the initial sample by following these criteria, we were left with a final sample of 20 privatized companies operating in 6 Western European countries (Finland, France, Germany, Holland, Italy and United Kingdom) and 10 different manufacturing industries.

As a second step, we gathered data for a set of firms that were publicly-traded throughout the same time period, in order to constitute a control group. We followed two fundamental criteria in our matching process. First, each privatized firm had to be matched with a company operating in the same country, in order to take into account possible country-specific effects in the treatment of R&D expenditures (i.e. the existence of fiscal incentives or legal differences in the capitalization and disclosure of R&D expenditures) and market valuation. Second, we operated an industry-level matching, given that the amount of technological opportunities and the incentives to invest in R&D activities consistently vary across different sectors (Cockburn and Griliches, 1988; Cohen and Levin, 1989).

More precisely, for each privatized firm in our sample we formed a list of all the publicly-traded R&D-doing firms in the same country and the same industry, classified using the 2-digit SIC code. When no R&D-doing firm was available in the same industry, we picked the firms in the closest 2-digit SIC industry. From this list, we then chose the company that was more similar to the privatized firm with respect to total sales at the year after the public offer and retained it if complete data were available for the following years. In the end, we were able to match the 20 privatized firms of the first group with 20 firms which were privately held throughout the same period. The constituents of the two samples are reported in Table 1.

--- Insert Table 1 about here ---

3.2 Variables

For each firm in both samples we collected data on the main accounting figures and the market capitalization for the five years following the public offer. The source of accounting figures is Datastream International, which provides a full coverage of British firms and a coverage superior to 75% of the publicly traded companies from other European countries. Data on R&D expenditures for all the countries have been firstly obtained from Datastream International. However, as the disclosure of annual R&D expenditures is compulsory only for

⁴ The only firm in the utility industry we were able to match was British Gas (see Table 1)

British firms, this information is not always available for other European companies. For firms in these countries we gathered data on R&D expenditures from two more databases: Worldscope and Global Vantage.

We finally gathered the following accounting data: annual R&D investments (RD), other intangible assets (I), mainly consisting of trademarks and goodwill, total financial debt (D) obtained by summing up short- and long-term borrowing, net tangible assets (A) and total sales (S). The R&D capital (RDC) has been computed as a perpetual inventory of the past R&D expenditures with a 15 percent constant depreciation rate, as described in detail by Griliches and Mairesse (1984) and Hall (1990a).

The total market value (V) should be calculated as the sum of the market capitalization of the firm and the market value of its debt. However, the data on the market value of debt are often not available. Some of the studies on US samples try to define proxies for the market value of debt using data on corporate bond market (see for example Hall, 1990a). This solution was not feasible for European samples because of the very limited development of corporate bond markets. Therefore, according to previous similar analyses on UK data (Blundell et al., 1992, 1999), we calculate the market value of the firm adding the value of outstanding debt to market capitalization.

At industry level, we calculated two measures: the R&D intensity for each year and country ($RDIND$) and the output growth ($INDGR$). These measures are based on the STAN and the ANBERD databases. Both the databases are maintained by OECD and are compatible. $RDIND$ was computed as the ratio between the R&D investments at 2-digit ISIC code reported in the ANBERD database and the 2-digit ISIC code value added reported in the STAN database. $INDGR$ was calculated as the annual growth rate of the 2-digit ISIC industry output reported in the STAN database. Variables description and computation is illustrated in detail in Table 2.

--- Insert Table 2 about here ---

4. Model specification

According to the theoretical background, in order to compare the private returns to R&D investments of privatized and publicly held firms, the empirical analysis intends to estimate the impact of the R&D investments on the market value of the firm for both samples. To this

purpose we recall the empirical literature on innovation and market value (Hall, 1999). Some specific adjustments will be adopted to deal with the questions related to firm-specific effects and endogeneity issues.

4.1 Basic model

Some studies following the seminal contribution of Griliches (1981) have used the Tobin's q to infer the value of the firm's stock of knowledge (among others Jaffe, 1986; Cockburn and Griliches, 1988; Hall, 1993b; Blundell et al., 1999; Hall et al., 2000). In these analyses, the firm is assumed to be a bundle of independent tangible and intangible assets (Hall, 1999). The impact of each specific asset on the market value is the result of the interaction between the firms' demand of funds to finance the investment in that asset and the investors' supply of the funds for that assets (Hall, 1993b). Accordingly, the market value of the firm (V), under the assumption of constant returns of scale, is normally expressed as follows (Hall, 1999):

$$[1] \quad V_{it} = b (A_{it} + g_K K_{it})$$

where i denotes firms, t years, A is the book value of net tangible assets, K is firm's knowledge capital. Since the firm's stock of knowledge is not directly observable and is hard to measure, it has been often computed as an R&D-based measure. The main assumption made in this perspective is that R&D investments contribute to the generation of an intangible capital that is evaluated by the stock market (Griliches, 1981). Consistently with previous literature (Cockburn and Griliches, 1988; Hall, 1993a, 1993b), we use two alternative measures of K : annual R&D investments (RD) and R&D capital (RDC), that are calculated as explained in the previous section. The coefficient b is the market valuation of firm's total assets and reflects its differential risk and monopoly position (Griliches, 1981), whereas the coefficient g_K measures the market valuation of K relative to the tangible capital A . Under the theoretical assumptions of the model, g_K depends on the expected impact of K on the firm's expected economic performance.

Scaling both the members of equation [1] by A and taking the natural logs, we obtain the following expression:

$$[2] \quad \ln(V_{it}/A_{it}) = \ln b + \ln(1 + g_K K_{it}/A_{it})$$

where V/A is a form of Tobin's q . In most of previous work on this subject, the term $\ln(1 + \mathbf{g}_K K_{it}/A_{it})$ has been approximated by $\mathbf{g}_K K_{it}/A_{it}$ (Griliches, 1981; Cockburn e Griliches, 1988; Hall, 1993a, 1993b; Blundell et al., 1999), so that the following linear regression model where the dependent variable is the natural log of Tobin's q has been derived:

$$[3] \quad \ln q_{it} = \ln(V_{it}/A_{it}) = \ln b + \mathbf{g}_K K_{it}/A_{it} + e_{it}$$

The following set of control variables has been added:

- I/A
- D/A
- $\ln S$
- year dummies
- country dummies

The ratio I/A appears as explanatory variable to account for eventual differential impacts of non R&D-related intangible assets on the firm's market value. Consistently with the previous work of Demsetz and Villalonga (2001), the inclusion of the ratio D/A , representing the share of firm's assets financed through debt, serves to capture eventual value enhancing or value destroying effects related to the exposure of the firm to interest rate variations in the observed period. The natural log of S is included to control eventual size effects on the market value. Full sets of year and country dummies are added to account for time- and country-specific effects. We initially estimate equation [3] through plain OLS.

4.2 Fixed- and random-effects

The estimation of equation [3] through OLS does not account for the eventual unobserved firm-specific heterogeneity v_i . Assuming that this component is constant over time, this problem can be eliminated recurring to the fixed-effects estimator, that subtracts the individual mean from each variable.

However, even though the fixed-effects estimation accounts for unobserved firm-specific heterogeneity, it drastically reduces the degrees of freedom. For this reason along with the fixed-effects model, we run a random-effects regression, as done by previous studies on similar topics (Bortolotti et al., 2002). In this case, the latent variable \mathbf{n}_i is treated as a random variable with mean $\bar{\mathbf{n}}$ and variance \mathbf{S}_n^2 . The random-effects estimator is then obtained by

computing a ratio q of the relative importance of within and between variation of the total disturbance ($\mathbf{n}_i + \mathbf{e}_{it}$) and using this ratio to combine fixed-effects estimator and between estimator optimally.

The random-effects is more efficient than fixed-effects estimator because it uses both within and between information. However, in order to have consistent results more conditions are required for the random-effects than for the fixed-effects estimator. In particular, the terms v_i and x_{it} must be uncorrelated. In fact, if they were correlated, the estimator could not determine how much of a variation of the dependent variable has to be assigned to \mathbf{b} or to v_i . In order to check the assumption of no correlation, we use the Hausman (1978) specification test of the null hypothesis that there are no systematic differences between fixed-effects and random-effects coefficients. The logic underpinning the test is that fixed-effects estimator is consistent under both null and alternative hypothesis, whereas random-effects estimator is consistent only under the null hypothesis. Therefore, only in case the null hypothesis can not be rejected, a random-effects specification can be adopted.

4.3 Simultaneous equations and instrumental variables

To address the potential problem of the eventual simultaneity of R&D investments and Tobin's q , we estimate a model of two simultaneous linear equations through the two-stage least squares (2SLS) method, similarly to previous empirical analyses on corporate governance and market value (Loderer and Martin, 1997; Cho, 1998; Demsetz and Villalonga, 2001). The first equation is the corporate value equation described by [3] and the second is a linear equation of either RD or RDC on the following regressors:

- $\ln q$
- $\ln S$
- D/A
- $RDIND$

The natural log of Tobin's q is included to take into account the effect of economic incentives to invest in R&D, consistently with previous analyses (e.g., Blundell et al., 1992). To control for scale effects in R&D investments, we consider the firm's size in any given year as measured by the log transformation of S . Following the evidence provided by Hall (1990b), which shows a negative association between firm's debt level and R&D investments, we also add a leverage variable, calculated as the ratio D/A . The underlying

notion views debt financing as inappropriate for funding R&D investments, given that servicing a debt typically requires a stable stream of cash flows which can be deviated from innovative projects. Finally, we take into account the fact that the level of technological opportunities in an industry is an important determinant of the managerial decision to invest in R&D (Cohen and Levin, 1989). For these reasons, we include the variable *RDIND* to control for industry-, country- and time-specific factors influencing firms' R&D investments.

The use of the 2SLS method addresses the question of the endogeneity of R&D investments to Tobin's *q*, but could still lead to inconsistent results because of the previously discussed problem of simultaneity between the two variables, caused by their dependence on the exogenous change in the corporate governance regime. In this case, it can be appropriate to estimate an instrumental variables (IV) model, where R&D investments are regressed on a set of variables not related to firm-specific characteristics. In particular, consistently with previous studies (Jaffe, 1986; Lev and Sougiannis, 1996), we regress *RD/A* and *RDC/A* on two industry-level instruments: *RDIND* and *INDGR*. The first variable intends to assess the technological opportunities and the second the economic incentives affecting individual firms' choices on the level of R&D investments.

5. Results

5.1 Descriptive statistics and correlation

Descriptive statistics of the variables are reported in Table 2. They show that privatized firms present slightly lower mean values of *RD/A*, *RDC/A* and Tobin's *q* (respectively .051 vs. .063, .219 vs. .253 and 1.017 vs. 1.540) and a higher mean value of *D/A* (.411 vs. .336). Furthermore, they are larger than matched firms in terms of average total sales (14,100 vs. 6,630 millions of Euros) and total tangible assets (10,500 vs. 3,837 millions of Euros).

--- Insert Table 2 about here ---

However, it results more interesting and informative to explore the patterns of *RD/A* and Tobin's *q* over time for privatized firms, as reported in Figure 1. To this respect, we first focus on the case of privatized companies, and notice that the average *RD/A* ratio initially declines after the public offer, whereas Tobin's *q* increases. The valuation of privatized firms

by the market thus incorporates the positive effects brought by the new ownership and governance structure on expected profitability. Moreover, the pattern of Tobin's q during the first two years clearly diverges from the one of RD/A . Thus, the market valuation of privatized companies does not seem to respond negatively to the decreasing level of R&D activities. On the contrary, the higher value attributed by the market reflects positive expectations that the management may be more able to generate profits from the firm's tangible and intangible assets.

--- Insert Figure 1 about here ---

In table 4 we report the correlations among all the variables for the samples of privatized and matched firms. No serious problems of multicollinearity seem to emerge. For privatized firms there is a high negative and significant correlation between $\ln S$ and $\ln q$ (-.50), a result that may require a more detailed inquiry with respect to the R&D investments equation in the simultaneous equations model. In the case of matched firms, I/A is positively correlated RD/A and RDC/A (.38 for both variables), suggesting that the two variables might be jointly influenced by some exogenous factors.

--- Insert Table 4 About here ---

5.2 Regression results

We first estimate equation [3] using pooled OLS (Table 5). In model (1) we include the ratio RD/A , whereas in model (2) we substitute the annual R&D expenditures (RD) with the R&D capital (RDC). Table 5 reports the results of the regression on the two different samples. Consistently with previous research (Hall, 1999), the regression analysis shows a significant positive effect of R&D investments on $\ln q$, even though the R&D coefficient in model (1) is not statistically significant for privatized firms. It is interesting to notice that in the case of privatized firms the magnitude of the relationship is consistently lower than in the case of matched firms. This result holds for both the models that have been estimated. In model (1), the RD/A coefficient takes the value of 1.286 for privatized companies and 7.504, almost six times bigger, for publicly held companies. When we substitute RD with RDC in

model (2), we have that the coefficient of RD/A for publicly held firms (1.917) is almost five times bigger than the same coefficient for privatized firms (.386).

With respect to the control variables, it has to be remarked that the ratios I/A and D/A have a positive impact on Tobin's q for both the samples, but their coefficients are statistically significant only for privatized firms. Moreover, $\ln S$ has a negative and significant effect on $\ln q$ for privatized firms, indicating that smaller privatized firms have a higher market valuation. Finally, the significantly higher value of the constant for privatized firms (1.985 in model (1) and 1.902 in model (2)) can be justified by the economic meaning of $\ln b$ that, as seen in previous section, represents the market valuation of all firm's assets and is linked to market power. Therefore, it is likely that in the early years after the State divestment, privatized firms still benefit from a high market power, especially in those industries not immediately opened up to competition.

--- Insert Table 5 about here ---

In Table 6 we report the fixed-effects (FE) and random-effects (RE) estimations of models (1) and (2). In line with our theoretical expectations, FE estimation shows that the stock market places a higher valuation on R&D investments of publicly-held firms vs. privatized firms (the coefficients are 2.524 vs. -1.088 for RD/A and .544 vs. .313 for RDC/A), but never produces statistically significant results with respect to both RD/A and RDC/A . RE estimation leads to similar results, showing a difference between market valuation of R&D investments, but in this case the coefficients of both RD/A and RDC/A for publicly-held firms are statistically significant, respectively at 5% and 10% level. Moreover, in all the models using the RE estimator, the Hausman test does not allow to reject the null hypothesis (the p -value is always bigger than .1) suggesting that the estimator is admissible.

--- Insert Table 6 about here ---

In Table 7 we report the results of the 2SLS estimation of the simultaneous equations model where $\ln q$ and RD/A in model (1) and $\ln q$ and RDC/A in model (2) are the endogenous variables. The $\ln q$ equation substantially confirms the results shown in Table 5 and Table 6. The coefficients of R&D investments are strongly positive and statistically

significant at 5% level for publicly-held firms (8.795 in model (1) and 2.027 in model (2)), whereas they are negative and not significant for privatized firms.

The joint estimation of the R&D investments equation provides some additional useful insights with respect to the control variables. In particular, the leverage D/A has a negative and significant impact on R&D spending for publicly-held firms (the coefficient is -.065 in model (1) and -.270 in model (2)), consistently with the traditional argument discussed in the previous section, it has the opposite effect for privatized firms, presenting a positive coefficient that is even statistically significant in model (2). This finding is coherent with the evidence reported by Dewenter and Malatesta (2001) showing that privatized firms are more leveraged than publicly held firms for two main reasons: the reluctance to issue new equity when they were under the State ownership and the existence of implicit or explicit loan guarantees allowing them to borrow at favourable rates. Therefore, while in publicly held firms a higher ratio D/A increases the external control and consequently reduces the propensity to invest in risky activities such as R&D, in privatized firms the debt is more likely to be an important source for R&D financing.

--- Insert Table 7 about here ---

Finally, the estimation of the IV model confirms previous results (Table 8). In particular, it is still possible to observe a positive and statistically significant effect of both RD/A and RDC/A on $\ln q$ for matched firms (the coefficients are respectively 7.456 and 1.966), whereas a negative and not significant effect emerges for privatized firms.

--- Insert Table 8 about here ---

6. Discussion and conclusions

In this paper we have discussed the impact of privatization on the private returns to a firm's R&D investments. Even though there exists a broad theoretical and empirical literature on the effects of privatization on the firm's economic performance, to our knowledge there are no contributions studying in depth the specific implications for the results of R&D activities.

Arguments from property rights (De Alessi, 1987; Vickers and Yarrow, 1988) and public choice theory (Niskanen, 1971; Buchanan, 1972) suggest that privatization should be associated with a rise in R&D performance. However, different hypotheses can be advanced on the timing of the performance improvement. If privatization is considered a discrete event, we should expect the improvements to take place immediately after the ownership change. On the contrary, different factors operating at firm-level, such as deferred control transfer and organizational inertia, could significantly delay the positive effects of privatization on R&D performance.

We have advanced that the literature on innovation and firm's market valuation, as expressed by Tobin's q , inspired by the seminal contribution of Griliches (1981), can be an useful reference to address this issue. A major difficulty in the assessment of firm-level changes in performance after privatization regards the multiplicity of variables that typically intervene at different levels (firm, industry and country) and generate substantial noise around the ownership effect (Cuervo and Villalonga, 2000). This was our main concern and we tried to control for it by adopting a match-paired research design, as done by other works in the privatization literature (Cragg and Dyck, 1999; La Porta and Loperz-de-Silanes, 1999).

The results emerging from the different models show that the coefficients of R&D investments are positive and often significant for privately-owned firms, in line with the general findings of the literature on market value and innovation (see Hall, 1999; Oriani and Sobrero, 2002), whereas the evidence is less clear and the sign of the relationship is often negative in the case of privatized firms. Moreover, even when the sign is positive, the R&D coefficient is never significant (except for model (2) in the pooled OLS estimation) and it is always consistently lower than the correspondent value for privately-owned firms. The results are robust to our controls for firm-specific effects (FE and RE estimation) and endogeneity and simultaneity issues (2SLS and IV estimation).

This evidence strongly supports the hypothesis that the improvements in private returns to R&D investments are affected by firm-level factors and hence the idea that privatization can not be seen as a discrete event, at least with respect to the innovation activities. Our findings present important implications for the privatization literature. First, under the assumption of efficient capital markets, they support the view of low private economic returns to R&D activities of formerly publicly-owned enterprises, in line with evidence provided by recent qualitative studies (Munari, 2002; Munari et al., 2002). Second, they suggest that the performance improvements brought by private ownership may be not immediate as implicitly assumed by the economic literature studying the impact of privatization. This observation

highlights the importance of adopting a dynamic perspective in assessing the economic impact of the State divestment, given that the efficiency growth may be strictly contingent upon the time window considered. Third, consistently with previous theoretical arguments (Cuervo and Villalonga, 2000), our results confirm the importance of the firm-level factors for a better understanding of the privatization effects.

Finally, it is important to acknowledge this paper's limitations, which also highlight some fruitful avenues for future research. A first weakness is related to the small number of firms constituting our sample, which is strictly dependent on the limited number of privatization programs of relevant size that have occurred worldwide over the last twenty years and on the scarce availability of data on firm-level R&D investments for European companies. The possibility of considering larger samples in future research, for example by including firms privatized in developing economies, will largely depend on the objective difficulties of collecting reliable, publicly-available financial and innovation data on international companies. Second, there is a measurement issue, since in our analysis we computed the firm's commitment to innovative activities by means of R&D investments, that are an input variable. Further research could adopt alternative innovation measures, for instance the citation-weighted number of patents assigned, which have been demonstrated to correlate more strongly to market valuation when their relative quality is considered (Hall et al., 2000). Moreover, we confronted a serious endogeneity problem because both R&D investment choices and performance outcomes as measured by Tobin's q are likely to be jointly determined by exogenous and only partly observed changes related to the privatization event. We tried to address the potential endogeneity effect by estimating a simultaneous equations system and an IV model of corporate value and R&D investments. Here, the major difficulty was related to the choice of instruments for firm-level R&D investments.

Despite these limitations, we believe that the evidence emerging from this study could stimulate new research and help to shed light on a topic of great importance for researchers, managers and policy makers. To this purpose, at least two potential avenues of development appear of particular relevance. First, as already mentioned above, it seems important to address the dynamics of R&D performance on a larger time span after privatization. The undervaluation of R&D investments of privatized companies could decrease and disappear over time, if privatized firms progressively succeed in gaining higher returns to their R&D investments. This would mean that the relation between R&D and Tobin's q of privatized firms should significantly strengthen over time. Second, we explicitly focused on the impact of privatization on the private economic returns to innovation activities, but ignored the issue

of the effects in terms of social returns. Since the seminal works of Arrow (1962) and Nelson (1959), the economic literature has highlighted the existence of a relevant gap between the social and the private returns to R&D investments, the former being significantly higher especially in the case of fundamental research activities. In the theoretical background section, we highlighted that, after privatization, the company can focus on the maximization of its business objectives, for instance by abandoning or outsourcing R&D activities more closely related to industry or national interest. As a consequence, the net effect of the divestment on social welfare could also be negative in the long run. If we recall the central role played by SOEs for the technological and economic evolution of several industries of both industrialized and developing countries (Nelson, 1993), assessing the impact of privatization on the long-term effects of innovation activities for social welfare emerges as a particularly relevant and promising task for future studies.

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Table 1 - Sample firms (privatized vs. matched firms)

<i>IPO year</i>	Privatized firm			Matched firm		
	<i>Name</i>	<i>Nat</i>	<i>Industry</i>	<i>Name</i>	<i>Nat</i>	<i>Industry</i>
1985	British Aerospace	UK	Aerospace & defence	BBA Group	UK	Motor Vehicles
1982	British Amersham	UK	Pharma	Glaxo	UK	Pharma
1986	British Gas	UK	Gas distribution	Burmah Castrol	UK	Oil&Gas
1982	British Petroleum	UK	Oil&gas	Shell	UK	Oil&gas
1988	British Steel	UK	Primary metal	Cookson Group	UK	Primary metal
1987	Rolls Royce	UK	Aerospace & defence	Westland Group	UK	Aerospace & defence
1986	Elf Aquitaine	FR	Oil&gas	Air Liquide	FR	Chemical
1986	Saint Gobain	FR	Stone, clay & glass	Valeo	FR	Motor Vehicles
1987	Alcatel-Alsthom	FR	Electronics & Tlc	Schneider	FR	Electrical
1993	Rhone-Poulenc	FR	Pharma	L'Oreal	FR	Soap & toiletries
1995	Pechiney	FR	Metal products	Fives Lille	FR	Machinery
1995	Usinor Sarcinor	FR	Metal Products	Legrand	FR	Electrical
1994	Renault	FR	Motor Vehicles	Peugeot	FR	Motor Vehicles
1997	Bull	FR	Computers	Compagnie des signaux	FR	Electronics & Tlc
1989	DSM	NE	Chemical	Akzo Nobel	NE	Chemical
1994	Kemira	FI	Chemical	Orion	FI	Pharma
1994	Outokompu	FI	Primary metal	Partek	FI	Machinery
1995	ENI	IT	Oil&gas	Montedison	IT	Chemical
1986	Nuovo Pignone	IT	Machinery	Magneti Marelli	IT	Electrical
1988	Volkswagen	DE	Motor Vehicles	Ford-Werke	DE	Motor Vehicles

Table 2. Variables description

Variable	Definition	Calculation (Datastream Code in Parentheses)
V	Total market value of the firm	Market capitalization at 12/31 (MV) + Loan capital (321) + Short-term borrowing (309)
RD	Annual R&D investments	Annual R&D investments (119)
RDC	R&D capital	Perpetual inventory of annual R&D expenditures (119)
A	Book value of net tangible assets	Total assets (392) – [Current liabilities (389) – Short-term borrowing (309)] – Total intangible assets (344)
I	Book value of other intangible assets	Total intangible assets (344)
D	Total financial debt	Loan capital (321) + Short-term borrowing (389)
S	Total sales	Total sales (104)
RDIND	Industry-level R&D intensity	2-digit ISIC annual R&D expenditures/ 2-digit ISIC output
INDGR	Growth of industry output	Annual growth rate of 2-digit ISIC output

Table 3 - Descriptive statistics for privatized and matched firms

	Obs	Mean	Std Deviation	Median
Privatized firms				
S (millions €)	103	14,100	13,800	9,836
A (millions €)	103	10,500	10,200	6,150
RD / A	103	.051	.045	.027
RDC / A	103	.219	.189	.125
I / A	103	.078	.129	.018
D / A	103	.411	.254	.378
Tobin's q	103	1.017	.492	.339
Publicly held firms				
S (millions €)	103	6,630	8,937	2,256
A (millions €)	103	3,837	5,555	1,310
RD / A	103	.063	.049	.049
RDC / A	103	.253	.195	.181
I / A	103	.112	.195	.028
D / A	103	.336	.221	.332
Tobin's q	103	1.540	1.274	.483

Table 4 – Correlations for privatized and matched firms

Privatized firms							
	ln q	RD/A	RDC/A	I/A	D/A	ln S	RDIND
ln q	1.00						
RD/A	.23**	1.00					
RDC/A	.24**	.95***	1.00				
I/A	.15	.07	.10	1.00			
D/A	.11	-.05	.00	.08	1.00		
ln S	-.50***	-.31***	-.28***	.22**	.27***	1.00	
RDIND	.07	.75***	.72***	.07	-.16	-.27***	1.00
Publicly held firms							
	ln q	RD/A	RDC/A	I/A	D/A	ln S	RDIND
ln q	1.00						
RD/A	.36***	1.00					
RDC/A	.32***	.98***	1.00				
I/A	.29***	.38***	.38***	1.00			
D/A	-.03	-.33	-.36***	.15	1.00		
ln S	-.01	.10	.10	.12	.23*	1.00	
RDIND	.18*	.31***	.34***	-.09	-.44***	-.40***	1.00

* significant at the ten percent level.

** significant at the five percent level.

*** significant at the one percent level.

Table 5 – Results of pooled OLS regression (dependent variable: ln q)

Variable	(1) Privatized firms	(1) Publicly held firms	(2) Privatized firms	(2) Publicly held firms
Intercept	1.985*** (.484)	-.025 (1.163)	1.902*** (.479)	-.117 (1.183)
RD / A	1.286 (.855)	7.504*** (2.451)		
RDC / A			.386** (.197)	1.917*** (.639)
I / A	1.113*** (.288)	.695 (.494)	1.097*** (.286)	.718 (.494)
D / A	.497*** (.180)	.496 (.360)	.489*** (.178)	.596 (.367)
ln S	-.133*** (.030)	-.010 (.064)	-.127*** (.030)	-.010 (.064)
Year dummies	YES	YES	YES	YES
Country dummies	YES	YES	YES	YES
R ²	.604	.378	.611	.375
N. of firms	20	20	20	20
N. obs.	103	103	103	103

* significant at the ten percent level.

** significant at the five percent level.

*** significant at the one percent level.

Table 6 – Results of fixed- and random-effects regression (dependent variable: ln q)

Variable	(1)	(1)	(1)	(1)	(2)	(2)	(2)	(2)
	Privatized firms FE	Privatized firms RE	Publicly held firms FE	Publicly held firms RE	Privatized firms FE	Privatized firms RE	Publicly held firms FE	Publicly held firms RE
Intercept		2.454*** (.725)		-.176 (1.341)		2.280*** (.746)		-.303 (1.358)
RD / A	-1.088 (1.419)	-.397 (1.017)	2.524 (3.484)	4.401** (2.217)				
RDC / A					.313 (.494)	.190 (.300)	.544 (1.038)	1.103* (.597)
I / A	1.179*** (.396)	1.037*** (.322)	.245 (.582)	.612 (.422)	1.104*** (.399)	.986*** (.325)	.229 (.592)	.591 (.431)
D / A	.211 (.263)	.270 (.201)	.413 (.441)	.304 (.364)	.206 (.264)	.252 (.202)	.393 (.441)	.310 (.369)
ln S	-.203 (.145)	-.189*** (.048)	-.291 (.290)	.041 (.091)	-.250* (.136)	-.180*** (.049)	-.256 (.294)	-.034 (.091)
Year dummies	YES	YES	YES	YES	YES	YES	YES	YES
R ²	.898	.330	.825	.253	.897	.342	.824	.236
σ^2_ε		.315E-1		.133		.316E-1		.134
σ^2_v		.894E-1		.251		.888E-1		.256
θ		.555E-1		.814E-1		.560E-1		.803E-1
Hausman test (p-value)		.149		.446		.160		.457
N. of firms	20	20	20	20	20	20	20	20
N. obs.	103	103	103	103	103	103	103	103

* significant at the ten percent level.
 ** significant at the five percent level.
 *** significant at the one percent level.

Table 7 – Results of 2SLS regression

Ind. Variables	Dep. Variable	(1) Privatized firms		(1) Publicly held firms		(2) Privatized firms		(2) Publicly held firms	
		ln q	RD / A	ln q	RD / A	ln q	RDC / A	ln q	RDC / A
Constant		2.361*** (.534)	.081* (.043)	-.282 (1.319)	-.062 (.063)	2.361*** (.536)	.367* (.209)	-.207 (1.300)	-.303 (.245)
RD / A				8.795** (3.965)					
RDC / A						-.094 (.292)		2.027** (.914)	
I / A		1.151*** (.296)		.543 (.616)		1.153*** (.298)		.669 (.575)	
D / A		.534*** (.185)	.019 (.013)	.523 (.366)	-.065*** (.023)	.534*** (.186)	.125** (.060)	.611 (.377)	-.270*** (.090)
ln S		-.159*** (.034)	-.005 (.003)	-.002 (.067)	.009** (.004)	-.159*** (.034)	-.022 (0.014)	-.007 (.067)	.038** (.015)
ln q			.001 (.013)		.051*** (.012)		-.030 (.058)		.179*** (.048)
RDIND			.316*** (.029)		.079 (.069)		1.284*** (.132)		.446* (.268)
Year dummies		YES	NO	YES	NO	YES	NO	YES	NO
Country dummies		YES	NO	YES	NO	YES	NO	YES	NO
R ²		.583	.590	.376	.133	.581	.530	.375	.182
N. of firms		20	20	20	20	20	20	20	20
N. obs.		103	103	103	103	103	103	103	103

* significant at the ten percent level.
 ** significant at the five percent level.
 *** significant at the one percent level.

Table 8 – Results of IV regression (Dependent variable: $\ln q$; Instrumented Variables: RD/A, RDC/A)

Variable	(1)	(1)	(2)	(2)
	Privatized firms	Publicly held firms	Privatized firms	Publicly held firms
Intercept	2.356*** (.534)	-.015 (1.293)	2.362*** (.536)	-.157 (1.297)
RD / A	-.381 (1.250)	7.456* (3.754)		
RDC / A			-.095 (.292)	1.966** (.909)
I / A	1.151*** (.296)	.701 (.597)	1.153*** (.298)	.697 (.573)
D / A	.534*** (.185)	.495 (.365)	.534*** (.186)	.603 (.377)
$\ln S$	-.159*** (.034)	-.010 (.067)	-.159*** (.034)	-.009 (.067)
Year dummies	YES	YES	YES	YES
Country dummies	YES	YES	YES	YES
Instruments	RDIND, RDGR	RDIND, RDGR	RDIND, RDGR	RDIND, RDGR
R^2	.583	.378	.581	.375
N. of firms	20	20	20	20
N. obs.	103	103	103	103

Figure 1 - RD/A ratio (left axis) and Tobin's q (right axis) for privatized firms (only 13 firms for which observations are available for all the years from year 0 to year 3 after privatization)

