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Summary

Over the last two decades privatization programs in different countries radically reduced the role of the State as a key player in the economic arena. We use agency theory to discuss the theoretical relationship between changes in the firm's principal-agent structure following privatization, and incentives to invest in R&D and to patent. We compare the pre and post privatization R&D effort and patenting behavior of 35 companies that were fully or partially privatized in 9 European countries through public share offering between 1980 and 1997. Results show that, after controlling for inter-industry differences, privatization processes negatively affect different measures of R&D commitment. Moreover, the shift from public to private ownership leads to a significant increase in the quantity of patents granted and in their quality, measured by citations' intensity.

Keywords: Privatization, R&D investments, patents, inventions

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INTRODUCTION

Privatization – the transfer of productive assets from public to private sector – has been one of the defining economic changes of the 1980s and 1990s. During the period 1977-1997, approximately 1.850 privatization actions took place worldwide, generating more than $750 billion revenues. According to recent estimates, the number of firms to be privatized in the future is still high at around 1.500 and likely to generate revenues of $750 billion (Siniscalco, Bertolotti, Fantini & Vitalini, 1999).

The economic and welfare consequences of privatization processes have been widely studied, showing a strong evidence for positive firm level effects such as efficiency gains, increased productivity and higher profitability. These effects are stronger when privatization plans are accompanied by liberalization processes (D'Souza & Megginson, 1999; Galal, Jones, Tandon & Volgesang, 1992; Megginson, Nash & Van Randenborgh, 1994; Vickers & Yarrow, 1988). The performance improvements of privatized companies are theoretically supported by property rights theory (Bös, 1991; De Alessi, 1980; Vickers & Yarrow, 1988) and public choice theory (Buchanan, 1972; Niskanen, 1971). According to property rights theory, private ownership proves to be superior to public ownership in providing effective managerial incentives and supporting more effective monitoring schemes (Vickers & Yarrow, 1988). Public choice theorists argue that State-owned firms are inherently less efficient than private ones, since managers are subject to pressures by politicians to pursue political objectives rather than efficiency (Niskanen, 1971; Shleifer & Vishny, 1994). Both theoretical and empirical studies of privatization processes, however, have adopted a comparative static perspective, underscoring the analysis of dynamic efficiency gains associated, for example, with R&D investments (Parker, 1998). This shortcoming is surprising for at least two reasons.

Empirically, one can observe that, in many countries, State-Owned Enterprises (SOE) have played a fundamental role in directing and enhancing the technological and economic evolution of different industries, and of the economic system as a whole (Katz, 2001; Nelson, 1993). In many cases, SOE' R&D facilities and programs have intentionally lead the development of the national base of competences in technological areas of strategic importance for the whole country. In these conditions is not clear how State divestments are likely to influence the national innovation system and if they should be accompanied by specific policy measures targeting R&D investments.

Theoretically, scholars studying the relationship between corporate governance and strategic decision making have analyzed the consequences of institutional changes on corporate control structures (Keck & Tushman, 1993; Tushman & Romanelli, 1985; Virany, Tushman & Romanelli, 1992). For instance, during time of environmental stability, executive teams tend to be characterized by higher stability and homogeneity, which in turn drive to further inertia and incremental change (Keck & Tushman, 1993; Tushman & Romanelli, 1985). On the contrary, organizations facing relevant technical or institutional discontinuities are more likely to present higher heterogeneity and change in executive teams, which in turn are more likely to promote strategic reorientation and organizational renewal. Under a neo-institutional perspective, Haunschild (1993) demonstrates that strategic decision related to corporate acquisitions are significantly influenced by interlocking relationships of board members with firms that have previously made acquisitions. In this sense, the replacement of top management team and board of directors after privatization can play a fundamental role in promoting entrepreneurship and strategic change, through the adoption of more risk-oriented behavior and the imitation of private sector strategic decision-making (Zahra, Ireland, Gutierrez & Hitt, 2000).

In this paper, we theoretically model the impact of the State as a sole or principal shareholder on firm's commitment to invest in R&D activities and to protect the results of the innovation process. Drawing on agency-theory, we hypothesize that privatization processes negatively affect firm-level R&D investments, and positively affect appropriability concerns.

To test our hypotheses, we analyze a panel-data set of 35 companies, operating in 11 different industries, and fully or partially privatized through public offering in 9 European countries during the period 1980-1997. First, we use an event-study approach to compare pre- and post- privatization R&D efforts and patent quantity and quality. We then explore possible differences emerging between the privatization announcement and its actual implementation, relatively to trends in the precedent and in the following periods. We argue that, over this time-window, a significant restructuring can affect the allocation of resources to R&D activities and their organization, given the priority to maximize the value of the company to increase the financial returns for the government from the public offer. Finally, we use a fixed effects regression model to control for alternative explanations (e.g. industry effects, scale effects) in assessing R&D and patent behavior of firms facing privatization.

The results support our hypotheses, showing a significant reduction of R&D intensity at the firm level, controlling for industry and time effects. Differences emerge with regard to the amount of shares being transferred, to the level of technological opportunities and to the degree of liberalization of the industry. At the same time, our findings document an increase in patenting by privatized companies. Moreover, using citations to measure patents quality, we find that the rise in patenting activity following privatisation is not accompanied by a decline in the quality of the awards, which remains constant or even increases in some cases. These two results combined suggest an improvement in terms of R&D productivity of privatised firms. We conclude by discussing the implications of these results for future research and for public policy decisions to proactively address possible under investment risks in R&D accompanying privatization process.

THEORETICAL BACKGROUND

The differences between State owned and private firms in terms of objectives, effort and outcomes of the innovation process have not been assessed in the literature in a direct and systematic way. However, several studies analyzed the relationship between governance and ownership systems and different aspects of the innovation process, such as the propensity to invest in R&D (Baysinger, Kosnik & Turk, 1991; Graves, 1988; Hansen & Hill, 1991), the propensity to patent (Hitt, Hoskisson, Ireland & Harrison, 1991; Ahuja & Katila, 2001), or the development and introduction of new products or production processes (Hitt, Hoskisson, Johnson & Moesel, 1996; Kochhar & David, 1996; Zahra, 1996). These results are particularly interesting in the context of privatization, since government divestment impacts consistently on the principal-agent relationship. More precisely, the change in the allocation of property rights from public to private sector impacts upon the objectives of the principal and, as a consequence, upon agent's incentives structure (Vickers and Yarrow, 1988). These changes may present significant implications for innovation processes and outcomes.

Corporate Ownership Structures and Innovation

The decision to carry on R&D activities inherently involves high agency costs, since R&D projects are typically risky, unpredictable, long-term oriented and multi-stage, labor intensive and idiosyncratic (Holmstrom, 1989). Innovation is therefore a potential arena of acute conflicts of interest between executives and shareholders, whose characteristics may influence management's decision to pursue or not risky R&D projects. Different empirical studies document a positive relation between stock-ownership concentration and R&D spending (Hill & Snell, 1989; Baysinger & al., 1991), suggesting that large stockholders are more effective at closely controlling management's decision and at reducing their potential risk-aversion.

Studies on the association between institutional ownership and innovation offer conflicting evidence, with some reporting a positive relationship (Baysinger et al., 1991; Hansen & Hill, 1991) and others reporting a negative one (Graves, 1988). These differences can be reconciled by considering that institutional investors are heterogeneous in terms of investment horizons and behavior, as a consequence of differences in their goals and objectives. Zahra (1996) finds that those institutional investors with long-term horizons, such as mutual, pension and retirement funds, are more likely to promote innovation and venturing, whereas short-term institutional owners, such as investment banks and private funds, seem to discourage executives to invest in activities with a long pay-off period. Similar results are found by Kochhar and David (1996), who categorize institutional owners by their ability to influence firms in which they have an ownership stake. Their findings suggest that pressure resistant institutions (i.e. public pension funds, mutual funds, foundations) have a more positive influence on firm innovation than pressure-sensitive institutions (i.e. banks or insurance companies).

Studies in the corporate control tradition have also addressed the impact of corporate restructuring activities on companies' decisions to invest in R&D and innovation output (Ahuja & Katila, 2001; Hall, 1990, 1994; Hitt et al., 1991; Hitt et al., 1996; Lichtenberg & Siegel, 1990). As stated by Hall (1990), two different arguments were advanced to explain why we should expect to see a change in the investment horizon towards the short-term in the case of firms subject to corporate restructuring. The first explanation views financial markets as efficient and recalls the conflict of interest between principal and agent within the agency framework (Jensen, 1993; Jensen and Meckling, 1976). Under this perspective, corporate restructuring, such as the one following a hostile take-over, provides a better discipline to managerial choices and ultimately brings efficiency gains, for instance by terminating waste in the allocation and use of resources, excessive diversification and sub-optimal strategies in terms of risk. In this sense, we should expect a reduction in R&D expenditures especially in relatively mature industries, characterized by limited technological opportunities (Hall, 1990). On the contrary, the second explanation assumes that "myopic" financial markets are not able to value correctly long-term investments, like R&D, because of high information asymmetries, so that managers tend to avoid this kind of investments (Porter, 1992; Stein, 1988). Under this perspective, even R&D projects with potentially high returns can therefore be eliminated.

The empirical studies on the consequences of corporate restructurings focused on changes in R&D intensity within firms subject to leveraged-buy out (Hall, 1990; Lichtenberg & Siegel, 1990) or management buy-out operations (Smith, 1990), hostile take-overs (Bhagat et al., 1990), or mergers and acquisitions (Hall, 1990). As to their conclusions, in her survey Hall (1994) states that the majority of restructuring in the U.S manufacturing sector in the 1980s didn't have a significant impact on managerial investment choices. Rather, the observed reduction in R&D effort seems to depend on the use of debt as a way of financing, especially among relatively mature and stable industries.

The Government as a Principal: Implications for Corporate R&D Choices

State owned enterprises present important peculiarities as to the objectives of principal, the management incentive system, the amount of information available to principals and agents, and their risk-profile. Privatization brings a shift in the objectives of principals and hence a different structure of incentives for management (Vickers and Yarrow, 1988).

First of all, it is important to consider whether and how the objectives of the State as owner of firms diverge from those of private shareholders relatively to R&D investment. State-owned enterprises are set up - or nationalized - to achieve a wider set of objectives, targeted to the maximization of social welfare through the control of possible market asymmetries, which would generate inequality in the distribution of (or access to) not only the revenues coming from the activities controlled, but also their physical or non physical output (Vickers and Yarrow, 1988; Ramamurti, 2000).

Therefore, while private shareholders are mainly interested in private returns to innovative activities, SOE’s mission on the R&D side is not only to pursue business-specific objectives, but also to support the advancement of knowledge and the creation of public goods. As a consequence, it is likely that SOE’s R&D laboratories tend to allocate substantial funds to long-term research projects and make specific commitments to scientific and downstream activities in order to diffuse their results to the more general national R&D system.

Overall, the presence of an institutional investor such as the government in companies engaged in R&D activity can generate profound differences not only at the more macro level of investments, but also at the more micro level of structures, processes and employee attitudes (Zahra et al., 2000). Given the peculiarities of this type of principal, expectations or manifestations of changes of its role and presence in the company would determine profound adjustments or reformulation of the agent’s mandate and, as a consequence, of the organization goals and processes.

After the divestiture of the State, private shareholders seek to maximize their expected financial returns from the company. The firm has no more implicit or explicit obligation to act in the interest of the public welfare or of the overall industry, carrying out research programs going far beyond its own immediate business needs. For this reason, managers within privatized company, under a tighter control of the capital market, may have more incentives to reduce investment in long-term, high-risk projects and to focus on short-term results. This should push the management to reconsider the scope of R&D projects undertaken, by focusing on those most closely linked to the needs of the core business.

This concept is clearly summarized by a former Director of Procurement and Technology of British Telecommunications (BT), privatized in 1984 by the Thatcher’s Government: “For Research and Techology the first priority must be the BT Operating Divisions and the Corporate Hedquarters. Recognizing BT’s public sector background it has been emphasized that this first priority does not include “British Industry”, the “UK Government”, or even the “National Good” except where BT’s interests coincide” (Rudge, 1990). Qualitative studies on privatization process offer evidence consistent with this claim, for instance in the case of the telecommunications and energy sectors in the United Kingdom or in the steel industry in Italy (Munari, Roberts & Sobrero, 2000).

According to public choice theory (Buchanan, 1972; Niskanen, 1971), the reduction of resources devoted to R&D can also be interpreted not as a shift from national interest objectives, but rather as a consequence of the elimination of wastes and duplication of resources characterizing the company under State ownership. Under this perspective, in the absence of an effective control system, SOE's managers have more freedom to pursue their particular interests, for example by inflating budgets or defending their personal position. Privatization should produce an increased alignment of managerial incentives with firm financial performance, ultimately promoting a more efficient use of resources. Indeed, most of the studies on the economic consequences of privatization generally show consistent efficiency gains and improvements in productivity after the divestiture of the State (Galal et al., 1994; La Porta and Lopez de Silanes, 1997; Megginson et al., 1994; D'Souza and Megginson, 1999).

Obviously, the process of privatizing a company doesn't occur overnight, since a government faces different important and interrelated decisions, such as which method to choose (e.g., share issue or direct sale), how to transfer control, how to price the offer and how to allocate the shares, if and how to anticipate State divestments with new market regulatory frameworks (Ramamurti, 2000; Siniscalco et al., 1999; Vickers and Yarrow, 1988). In most of cases, the announcement of privatization by the Government considerably precedes the actual divestiture. For instance, in the case of the British privatization program, the period between the date of announcement and the date of sale on average amounted to 2.5 years (Cragg and Dyck, 1991).

Thus, it is likely that the hypothesized reduction on R&D resources occurs in a more general restructuring of the company beginning well before the State divestment. In this sense we view privatization as a process and we expect that its effects on the firm's commitment to innovate start before the date of the selling. This leads us to the following hypothesis:

Hypothesis.1: Ceteris paribus there is a negative relationship between firm's privatization and its R&D investment levels.

The impact of privatization on firms' performance is likely to be highly dependent on how SOE are privatized, in particular with regards to government's residual ownership after privatization and the kind of private capital they attracts (Ramamurti, 2000). Governments' decision to retain a majority or a minority stake - or no stake at all - has a direct influence on the distribution of control over the company after the public offering, as well as on the lasting presence of the same principal. Restructuring following privatization is more likely to occur when private shareholders get control rights, since privatized firms' objectives become independent from politicians (Boycko, Shleifer & Vishny, 1996). Thus, selling voting control to outside private investors leads more directly to efficiency improvements after privatization. D'Souza and Megginson (1999) compare the performance changes following State divestments of 85 companies from 28 countries, privatized through public offer during the period 1990 to 1996, distinguishing between when voting control is sold (companies privatized for more than or equal to 50 percent) or retained (companies privatized for less than 50 percent). Their findings show that the post-privatization increase in real sales and sales efficiency (sales to total employment) is significantly higher for the first group, whereas post-privatization changes in return on sales, dividend pay-out, capital expenditures, leverage and total employment don't differ significantly between the two groups. We would therefore expect the following, *Hypothesis 2: Ceteris paribus, the lower is the amount of shares retained by the government after privatization, the stronger is the pressure on R&D investments.*

Privatization may also affect R&D outcomes. The shift from public to private ownership influences significantly firms' propensity to patent, since it induces a series of mutually reinforcing changes leading to an increase in patent production. First, it is likely that, under State control, R&D facilities pay less attention to control mechanisms against information leakage and know-how spillover, as a consequence of their status as national laboratories and their explicit or implicit mission to maximize social returns to R&D activities. On the contrary, after privatisation the company has no more obligation to act in the interest of public welfare and can focus on the maximization of private returns. Therefore, the appropriability concerns become critical. Second, the increase in patenting may also reflect a major shift in the orientation and balance of research portfolio towards more applied work and development activities at expenses of fundamental research, given the new priority to focus on research projects offering more direct and faster commercial application (Roberts, 1995).

Finally, we can argue that after privatisation the firm manages R&D activities in a more efficient way, so that any currency unit invested in R&D could have a higher impact in terms of inventions realized. In this sense, an increase in the number of patents issued should be ascribed to higher productivity of research efforts, rather than to a shift in the firms' propensity to patent. This explanation is consistent with the findings of the empirical literature on privatisation suggesting that the switch from public to private ownership is associated with improvements in operating performance (D'Souza & Megginson, 1999; La Porta & Lopez de Silanes, 1997; Megginson et al., 1997). Ultimately, these three different but interrelated explanations support the expectancy of a rise in patent production following privatisation.

Hypothesis 3: Ceteris paribus, there exists a positive relationship between firm's privatization and its patenting activity.

However, considering the simple count of patent as an output indicator of inventive activity presents widely known limitations, because: "[N]ot all inventions are patentable, not all inventions are patented, and the inventions that are patented differ greatly in quality" (Griliches, 1990). Since patents significantly vary in their technological and economic value (Giliches, 1990; Trajtenberg, 1990), it seems necessary to capture the impact of privatization on the average quality of the inventions which are patented, not only on their overall quantity. Indeed, it is possible that the expected rise in patent production within privatized companies is due to a lower threshold adopted in the decision to patenting.

Henderson, Jaffe and Trajtenberg (1998) suggest that a similar pattern can be traced for U.S. university patenting after the changes in federal law in the early 80s. Although patenting by universities has risen dramatically over this period, it seems that there has been no significant improvement in patent quality measured by the number of citations received. On the contrary, Jaffe and Lerner (1999) document that after similar reforms at the beginning of the 80s the quality of the national laboratories patents has remained constant or even increased as patenting has risen.

Following the findings of Henderson et al. (1998), we hypothesize the following:

Hypothesis 4: Ceteris paribus there exists a negative relationship between firm's privatization and its average patent quality.

RESEARCH DESIGN

Sample and data

We started our data collection from the lists of privatized companies reported in the two articles by Megginson et al. (1994) and D'Souza and Megginson (1999). The initial sample thus includes 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), we adopted a definition of privatization that includes any measure that transfers some or all of the ownership and/or control over SOE to the private sector. Moreover, we decided to consider only companies privatized through public sale, in order to collect comparable, publicly available pre and post privatization financial information.

We then recurred to other sources to further integrate this initial sample, more precisely: (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 after this first phase included 182 firms from 32 countries.

We then decided to select from this group only those firms which were privatized in Western European countries from for several reasons. First, the vast majority of privatization programs that occurred worldwide over the last twenty years took place in Western European countries. Using a database compiled by *Privatisation International* including 1.867 privatizations in 113 countries between 1977 and 1997, Siniscalco and colleagues (1999) conclude that privatizations in Western European countries account for around 30% of all operations and around 50% of global privatization revenues

Second, it is extremely difficult to gather accounting and financial data from publicly available sources for privatized companies not operating in Western European countries, especially with regards to data on research and development 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, and take into account in our analysis the potential effects of contextual variables in affecting firms' incentives to invest in R&D over-time, as we describe later on.

We then identified all the R&D performing firms in Western European countries from the initial sample, and kept only those reporting R&D expenditures in their financial figures at least once in the period –3 to –1 and in the period +1 to +3, where the year of privatization is defined as year 0. In the end of this process, we were left with a final sample of 35 privatized companies operating in 9 Western European countries and 11 different industries.[2]

Financial figures on these firms were drawn from Datastream, Worldscope and company annual reports, and converted to constant (1990) U.S. dollars to ensure standardization within the

[2] A list of the sample firms is available from the authors.

sample Industry country level R&D data were collected from the ANBERD database published by OECD, reporting information on R&D activities carried out in the business enterprise sector on a consistent basis across the main OECD countries since 1973, regardless of the origin of funding, and including the R&D performed by SOE. The data are reported at country level, using an industrial disaggregation based on the second and third revision of the International Standard Industrial Classification (ISIC, Rev.2 and ISIC, Rev.3), which covers 58 sectors. We then matched the R&D data with information on gross output (production) at industry and country level from the OECD STAN dataset, which is compatible to ANBERD, to calculate the ratio of business enterprise R&D to output for each industry and each country in our sample.

Turning to patent data analysis, we adopted a sample of privatized companies that differs slightly from the precedent ones, since some of the companies that were included in latter didn't realize any patenting activity over the period analyzed. The procedure we used to select this second sample is straightforward: starting from the initial sample taken from Megginson et colleagues (1994, 1999), we kept only those European companies that were assigned at least one patent at the United States Patent Office (USPTO) in the period –5 to –1 and in the period +1 to +5, where the year of privatization is defined as year 0. We ended up with a set of 33 companies, operating in 12 industries and 9 Western European countries. In 27 cases out of 33, the companies of this second sample coincide with those included in the one we consider in the R&D commitment analysis. Following other studies using patent data on international samples (Ahuja & Katila, 2001; Stuart & Podolny, 1996) we decided to employ U.S. patent data in order to maintain comparability.

Patents data were provided by Chi Research. For each company in the sample, we obtained information on the total number of patents assigned at the USPTO in any given year, as well as on the average number of citations per patent received by following patents, over the time-window year – 5 to year + 5, where we define as 0 the privatization year.

In order to control for more general trends across time and industries in the propensity to patent and cite we collected the same kind of patent indicators (average number of patents granted per company and average cites per patent) at the industry level as well. A major difficulty in collecting patent data at the industry level descends from the fact that they are classified by the Patent Office into many technological classes, and the development of a concordance between the patent class and industry classification is inherently ambiguous (Griliches, 1990). We adopted the concordance developed by Chi Research, which categorizes all patents into 26 industry groups, roughly corresponding to the 2-digit SIC coding scheme. Under this classification, our sample companies were assigned to 8 industries (aerospace, automotive, chemical, energy, machinery, metals, pharmaceuticals, telecommunications).

Measures

Critical events. Several studies in different fields showed the relationship between organizational adaptation to critical events and the actual materialization of critical events (Ghemawat, 1991; Tushman & Keck, 1993), pointing to the importance of conceptually and empirically separating the critical event itself from the moment chosen by the organization to prepare for the event. In our case this means to consider the time window between the announcement and the actual materialization of privatization, which we have previously called the preparation time, during which the pressure towards restructuring and reorganization efforts may be strongest. It must be noted, in fact, that changes in corporate governance are very often anticipated by changes in strategy and organization, which can start well before the actual selling of the company, and are promoted by Governments in order to maximize the value of the company and by that the financial returns from the divestiture (Cuervo & Villalonga, 2000).

In our sample we had complete information on both events in 21 cases out of 35. In these cases the period between the announcement and the public offering is on average equal to 2 years. Such value was confirmed by anecdotal evidence collected from press releases on some of the countries observed in our sample. We therefore decided to consider as the critical event in our analysis the announcement date and use a 2 year window before the public offer as an indirect way of identifying the event for all our observations. To further validate our analysis, we also coded our data using a second time-window of 1 year only, and a third one of 3 years.

R&D and patent indicators. We use four different dependent variables in our analysis to measure firms' commitment in R&D activities. First, we use the log transformation of R&D expenditures in any single fiscal year, converted to constant (1990) U.S. dollars, to control for the skewness in the distribution of the variable. Second, we compute the R&D intensity at the firm level, defined as total R&D expenditures divided by total sales in any given year. Third, we compute "industry-adjusted" R&D intensity to control for industry influences, by subtracting average industry R&D intensity from the R&D intensity of each firm in the sample. The target industries were the dominant industries of each firm as reported in Worldscope and defined using four-digit Standard Industrial Classification (SIC) system. As described above, we define the industry R&D intensity as the ratio of business enterprise R&D to output in each industry and each country. Since the coverage of service sectors is very limited in the statistics provided by OECD, we were able to completely compute this indicator over the analyzed period only for 10 manufacturing industries, corresponding to 24 companies in our sample. For the remaining ones, we decided to recur to the average value of R&D intensity for the whole manufacturing sector at the country level. Finally, we calculate our fourth indicator as the ratio of firms' "industry adjusted" R&D intensity to the average industry R&D intensity, in order to compare the marginal change of the individual firm with respect to the industry average.

To measure firms' patenting activity we used three indicators. First, we used the number of patents assigned at the USPTO in each year of observation. Second, we constructed "industry adjusted" patent count for each company in any given year, calculated as the difference between the actual number of patents received by the company and the average number of patents assigned per company within the industry in the same year. Third, we used a second normalized indicator calculated as the ratio of "industry adjusted" patent count (the difference described above) to the average number of patents granted to companies within the industry, to control for differences across industries and time in the propensity to patent.

Following previous studies (Henderson et al., 1998; Jaffe & Lerner, 1999; Trajtenberg, 1990), we considered the number of citations per patent received by following patents as a measure of patent quality. The underlying assumption is that a large number of citations received by a patent indicates that it has lead to numerous following technological improvements. The literature has confirmed that the intensity of citations received by company's patents is strongly associated with patents' technological and economic value (Trajtenberg, 1990) and with companies' market value (Hall, 1999).

To measure the quality of patents assigned to each company in our sample, we therefore calculated two normalized citation intensity indicators, to control for variations in the propensity to cite across time and industries, and for the truncation in time of citations, given that - *ceteris* *paribus* - older patents are likely to receive more citations. The first one is computed as the difference between the average number of citations received per firm's patent and the industry citation intensity. This last one is defined as the average number of citations per patent received by the firms operating in the same industry in a given year. The second indicator is the ratio of the normalized citation intensity (as described above) and the industry citation intensity.

Independent variables. The study's first independent variable is a dummy variable that takes for each company a value of 0 for the pre-privatization estimation period and 1 for the post-privatization period, including the year of the divestiture by the State. However, this simple variable doesn't permit to capture the extent and credibility of government divestiture, since in many cases governments privatize SOE without selling the full amount of shares in their possession. We therefore decided to control for these asymmetries and compute for each company the total amount of shares owned by the private sector in any given year.

Control variables. To include in our analysis the results of previous studies on the relationship between R&D expenditures and corporate governance (Baysinger et al., 1991; Hall, 1990; Hansen & Hill, 1991; Zahra, 1996), we use four controls. First, to control for scale effects in R&D investments, we consider the firm's size in any give year as measured by the log transformation of total sales. Second, following the evidence provided by Hall (1990), showing a negative association between R&D investments and firm's debt level, for each firm in each year of observation we calculate leverage as total debts divided by total assets.

In addition to firm-level control variables, we also tried to assess the potential effects of industry-level variables that can influence managers' decisions to invest in R&D. Zahra (1996) showed that the level of technological opportunities in the industry has a moderating effect on the association of governance and ownership with corporate entrepreneurship. Similarly, Chan, Martin and Kensinger (1990) showed that the market response to R&D investment was positive in the case of firms operating in high tech industries, but not for firms operating in low tech industries. We therefore partitioned our sample into two categories and used a dummy variable (LOW-TECH) to separate firms operating in low-technology industries (1) from firms operating in high-technology ones (0). The categorization into high-technology or low-technology groups is based on the classification provided by the OECD.

Although privatization (the transfer of ownership) and liberalization (the opening up of markets to competition) are distinct concept, they are very often intertwined and contemporaneous processes, especially in the case of public utilities. Vickers and Yarrow (1988) clearly state that in those cases new ownership arrangements are contingent to the competitive structure of the industry in which the firm is operating and the regulatory constraints it faces. To this purpose, similarly to other studies on privatization effects (Cragg & Dyck, 1991; D'Souza & Megginson, 1999; Megginson et al., 1994;), we use a dummy variable (REGUL) to separate companies operating in noncompetitive industries (1), for instance public utilities which used to act in a monopoly regime under the State ownership, by those operating in more competitive industries (0). Following D'Souza and Megginson (1999), we define competitive firms as those operating in industries subject to international product market competition, whereas noncompetitive firms are relatively free of product market competition. Consequently, we include public utilities in the latter group, such as telecommunications carriers or energy utilities, and we classify all other firms in the competitive group.

EMPIRICAL ANALYSIS

Descriptive Statistics

While almost all sectors were affected by privatization processes worldwide, the majority of revenues came respectively from public utilities and manufacturing (Siniscalco et al., 1999). Our sample reflects this distribution with 12 public utilities, such as energy or telecommunications service providers, and 23 manufacturing companies, from both high-technology industries, such as pharmaceuticals, aerospace or telecommunications equipment, and low-technology industries, such as steel or oil distribution.

Table 1 presents descriptive statistics. Firms average annual sales are $12,088 million, with a maximum of $70,969 million and a minimum of $424 million. They spend between $0.2 million and $2,603 million on R&D, with an average of $105 million.

--- Insert Table 1 about here ---

On average, R&D intensity of our sample companies is equal to 2.51. Firms operating in a low technology industry have an average R&D intensity ratio of 1.27%, while the value increases to 4.9% for firms operating in high technology industries. For firms operating in highly regulated industries, such as the telecommunications or energy utilities, the ratio of R&D intensity is equal to 1.07% and it becomes 3.59% in the case of competitive industries. In 79% of the observations for which data on industry R&D intensity are available, the average firm in the sample is 60% less R&D-intensive than the average firm in the industry.

Turning to patent data, the mean patent count is 40, although it presents a very high variability (the standard deviation is equal to 50). Our sample companies generate a lower number of patents per year than the average firm in the industry, as suggested by the negative values of the normalized patent count indicator, (– 24 in absolute terms and – 27% in relative terms). To this purpose, we should bear in mind than Chi Reserch keeps patent tracks only for companies that present a patent activity above a threshold of about 10 patents per year, so that companies included in the industry samples are generally very active in patenting. The normalized citation intensity indicator is – 1.17, suggesting that our sample patent are less frequently cited by subsequent patent that the ones included in the industry benchmark.

Pre and Post Privatization Cumulated Differences

To measure company level changes in R&D investments after privatization announcements we adopt an event study methodology, and assume that the announcement precedes the public sale by two year. To control for possible biases in the exact definition of our critical date, we have conducted a sensitivity analysis of our results, by considering that privatization announcements may precede the public offering respectively by one year, by two years and by three years. However, the results don't vary significantly in the three cases.

We partitioned all our observations at the firm level in two subgroups, representing data relative to the pre-privatization and the post-privatization period. We then treated our observations as two independent samples with unequal variance and used a corrected t-test to statistically compare the mean value of the four different measures of R&D investments. Tables 1 reports the means, the t-tests and the corresponding p-values. We use one-tailed tests because we are *ex-ante* expecting a directionality of the effect. More restrictive two-tailed tests, however, do not change significantly the magnitude of our results.

--- Insert Table 2 about here ---

In all cases, contrary to our expectations, we observe an increase in the overall amount of R&D investments. In the first case we record a shift from an average annual value of the log transformation of R&D expenditures of 17.30 before the privatization to 18.50 after the privatization. In the second and third case, the pre- and post-privatization values for the log transformation of R&D expenditures are respectively 17.55 and 16.94, and 18.27 and 18.35.

The analysis of the relative percentage of R&D spending over the total firm sales, on the contrary, offers opposite results. In all three cases, in fact, the ratio decreases and the differences are statistically significant. If we look at this result in conjunction with the previous one, a possible explanation lays in the changes experienced by the observed firms not only at the numerator (the absolute amount of R&D spending in any given year), but also at the denominator (the firm's sales). As the first one clearly increases significantly over time, the lower value of the ratio signals a more than proportional increase in the denominator as well.

These observations are confirmed by taking a closer look at the firm level R&D intensity with respect to the overall industry average. We observe R&D intensity values that are slightly higher than the industry average before privatization and then become lower. These differences are all strongly statistically significant and particularly interesting as they control for inter-industry differences, which might have gone unnoticed in the previous analyses.

One objection to these results could be that the firms in our sample have been generally underinvesting in R&D, regardless of their ownership structure. To control for this possibility, we used our fourth and last variable, which is the ratio of the difference in R&D intensity to the industry average R&D intensity. The data reported in Table 2 confirm an overall tendency of the firms observed to reduce the commitment to R&D activities with respect to the industry average following the announcement of privatization.

We replicate this analysis using patent data. In this case, it is important to bear in mind that we employ the number of patent *granted* as a measure of innovation output. Given that there exists a delay between applying for and granting a patent of about two years, it is likely that changes in the R&D overall effort and shifts in the focus from basic to more applied research, that may begin during the preparation time, will be reflected in a different number of patent granted with a consistent time-lag. In the previous analysis we singled out the privatization announcement as the critical event and assumed that it took place on average two years before the divestment. To account for delays that may occur in granting a patent, we now consider the year of privatization as the turning point to partition all our annual patent observations in two subgroups.

We calculated the mean of each patent variable over the pre- and post- privatization period (pre privatization: - 5 to –1 and post-privatization 0 to +5) and then use a t-test to examine whether significant differences exist between the two subsample groups (see Table 3). The number of patents granted at the USPTO goes from an average 35.8 value during the pre-privatization period to 45 patents granted in the post-privatization period. However, if we compare this trend to the average patent production in the industry, the increase tends to shrink and becomes statistically insignificant: following privatization, the sample firms reduced the gap in patent production from the industry average, since the negative difference passes from 25 patents to 22 patents (from 28% to 26% in terms of marginal change with respect to industry average patent frequency).

--- Insert Table 3 about here ---

To test if the surge in the propensity to patent may lead to a decline in patent quality after privatization, we then examine the changes in the mean values of citations per patent. Results in Table 4 show that sample firms patents are on average less frequently cited by subsequent patents than industry ones, but this difference tends to decline following privatization. Prior to divestment, our sample firms patents had 1.6 citations less than industry ones, whereas, by the year of privatization, the difference in normalized citations intensity reduced to – 0.8 citations per patent (from – 21% to – 13% in terms of marginal change with respect to industry average citation intensity per patent).

The Privatization Period Effect

Similarly to research on the effects of public announcements on companies' share value (Chan et al. 1990), in the previous analysis we singled out a specific instant of time as a marker between two distinct moments of organizational life. As well as in case of publicly traded stocks, however, the observation of our variables of interests too early or too far away from the critical date might carry some unobserved variance, which could not be properly accounted for in the model. Moreover, in our case, we are interested in a critical period, more than in a single critical event. This period is the time during which the state assets are being prepared to be sold on the market. If we limit our analysis to the comparison of pre and post privatization data, we underscore the role played by the transition period, which is also the area where the impact of government measures accompanying privatization could be the greatest. To account for these elements we therefore decided to distinguish three different periods: the period preceding the privatization announcement, the period from the announcement to the public offering and the period after the public offering.

We used ANOVA to compare between group differences in the average values of our four indicators of R&D investments in the three periods for the whole sample. The F-test derived from the ANOVA statistically support (or not) the presence of a difference in the means observed. It does not, however, provide any information on the directionality of the effect observed. To test for a decreasing level of R&D investments in the three periods observed, we therefore decided to calculate a linear contrast test, with coefficients set equal to 1 for the first period, 0 for the second period, and –1 for the third period. As the length of the three periods and the number of observations in each period differ, we computed the test assuming unequal variance in the three distributions.

Table 4 reports the results of this analysis, which offer additional support for the hypothesized negative relationship between privatization processes and R&D investments. In addition to that, they also highlight the specific role played in this process by the period dedicated to the preparation of the SOE to the market investors. The value of the log transformation of R&D expenditures before the privatization announcement is on average equal to 17.18 and it significantly increases during the time between the announcement and the public offering. However, if we look at the rough and industry adjusted R&D intensity indicators, we notice a decreasing tendency, which starts during the preparation period and continues after the public offering, signaling the continuation of a significant restructuring effort, initiated by the State and carried forward by private investors.

--- Insert Table 4 about here ---

We repeated the same analysis for patent variables. As before, we assume that changes in the organization of R&D activities, which are likely to begin after the privatization announcement, will traduce in changes in number of patents granted with a lag of around two years, in order to consider the delay between the request for and the grant of a patent. Therefore we now distinguish three different period: the period before the public offering, the period which goes from the public offer to two years later, and the period which follows.

The results of the ANOVA analysis reported in Table 5 highlight that changes in patenting behavior may have begun before privatization, since there exist significant differences across the three periods in terms of patent assigned at the USPTO. The number of patents per year before privatization on average is 35.80 and it significantly increases during the two following periods. However, these differences tend to disappear once the trends in patenting activity within the industry are considered, given that the industry adjusted patent count remains stable. Contrarily to our expectations, the citations received per patent seem to increase significantly over the three periods as compared to industry trends in citations intensity.

--- Insert Table 5 about here ---

Regression Model

Changes in ownership structure could not be the only reason for changes in the attitude towards R&D investments. In the previous sections we have controlled for possible inter-industry differences by adopting "industry adjusted" R&D indicators and have found consistency in our results. To consider the influence of additional variables that may impact on R&D investment decisions according to previous research, we estimated the following regression model:

$$R\&D_{it} = \alpha + \beta_1 \text{ Log } (Size_{it}) + \beta_2 Priv_{it} + \beta_3 Privshare_{it} + \beta_4 Leverage_{it} + \varepsilon_{it}$$

where *i* denotes firms, *t* years. Firms' size is measured by the log transformation of total annual sales. Priv is a dummy variable that takes the value 1 in the estimation period following the public offering, including the year of the divestiture, and the value 0 in the pre-privatization period. Privshare is the proportion of firm's share not owned by the government in any given year. Leverage is defined as the ratio of total debts to total assets in any given year. For each firm *i*, we used all the available observations. We have performed a sensitivity analysis by considering the observations for a shorter time window around privatization, and have included observations up to three years prior the privatization and for three years after the years in which the privatizations were completed. However, the changes in the time window used did not generate any relevant change in the estimates obtained.

We adopted a fixed-effect (within group) estimator to take into account the effects of unobserved heterogeneity, or the possibility that unobservable individual firm specific effects lead to permanent differences in the amount of R&D investments across firms. The fixed-effect approach takes the unobserved individual effect to be a group specific constant term in the regression model (Green, 1993). This technique essentially transforms the data into deviations from individual means and by that it drops the time-invariant terms out of the final estimating equation.

Table 6 reports the results for the four models estimated, each one using a different measure for the dependent variable. In this model, the dummy variable that measures the post-privatization period has a significant positive relationship with the dependent variables in all the models. On the contrary, PRIVSHARE, which captures the percentage of shares owned by private shareholders, has a negative relationship which is highly significant in the models with "simple" and "industry-adjusted" R&D intensity as dependent variables. This suggests that the higher is the transfer of control, the higher becomes the change in the investment horizons of the companies and the discontinuity with the precedent practices. Company size has a statistically positive effect only on the log transformation of annual R&D investments, offering mixed results with respect to the presence of scale effects. Finally, the evidence on firm's leverage values offers some mixed support to the results provided by Hall (1990).

--- insert Table 6 about here ---

To empirically investigate the interaction of privatization with industry-level variables in affecting R&D investment, we then investigated a regression model including direct and interaction terms which refer to the level of technological opportunities and the intensity of competition within the industry. Under this specification, our estimation equation takes the following form:

$$R\&D_{it} = \alpha + \beta_1 \, Log(Size_{it}) + \beta_2 \, Priv_{it} + \beta_3 \, Privshare_{it} + \beta_4 \, Leverage_{it} + \\ + \beta_5 \, Low\text{-}tech_{it} + \beta_6 \, Regul_{it} + \beta_7 \, (Low\text{-}tech_{it} * Priv_{it}) + \beta_8 \, (Regul_{it} * Priv_{it}) + \varepsilon_{it}$$

where the coefficients β_5 , β_6 and β_7 , β_8 respectively pick up the direct and interaction effects of the level of technological opportunity and of the intensity of competition. As described above, Low-tech is a dummy equal to 1 for low-tech firms, and 0 for high-tech firms, whereas Regul is a dummy equal to 1 if firm *i* operates in regulated/noncompetitive industries and 0 if it operates in competitive industries. However, it should be stressed that it won't be possible to separately identify the linear effect of these two variables in the "within-group" regression model, since this estimator doesn't permit to obtain estimates of any time-invariant explanatory variables (Bloom & Van Reenen, 2001). The within-group transformation, in fact, not only removes the unobserved individual effects but also the effects of any observed variable that is time-invariant.

Looking at the results in Table 7, we note that the technological opportunity-privatization interaction term is negative in the last two model, but insignificant at conventional level, suggesting only a limited decrease of R&D effort after privatization as compared to industry average in the case of low-tech industries. This confirms only partially the results obtained by Chan et al. (1990). On the contrary, for all of the four models, privatization leads to a negative impact on R&D investment for noncompetitive firms, as in the case of public utilities, as suggested by the negative and significant coefficients of the regulation-privatization interaction term. We interpret this observation in the light of the simultaneous process of market liberalization that very often accompanies the divestiture of the State in the case of public utilities. Our results suggest that in these industries the pressure of competition on the product/service market further encourage the reduction in R&D commitment, a trend which is confirmed by anecdotal evidence stemming from different countries (Munari et al., 2000).

--- insert Table 7 about here ---

Turning to patent analysis, the number of patent assigned to a company in a given year, the first dependent variable of our analysis, is a typical example of count data, since they have a non-negative discrete nature and generally present small values and excess of zeros. In this context, a Poisson regression approach results appropriate. Consequently, we decided to adopt the following Poisson regression model:

$$Patent_{it} = \exp(\beta_1 \text{ Log } (Size_{it}) + \beta_2 Priv_{it} + \beta_3 Privshare_{it} + \beta_4 Leverage_{it} + \beta_5 Indpat_{it} + \varepsilon_{it})$$

where $Patent_{it}$ is the number of patents assigned to company *i* in year t, and the explanatory variables are the same adopted in the R&D investment model, except for $Indpat_{it}$, that measures the average number of patents assigned per company in the industry. However this simple model doesn't permit to account for the presence of unobserved heterogeneity. The standard approach to consider the problem of not observed heterogeneity in panel data with count model is the Poisson conditional maximum likelihood estimator proposed by Hausman, Hall and Griliches (1984), separating persistent individual effects by conditioning on the total sum of outcomes over the observed years.

We have therefore adopted this estimator in our regression model. Table 8 reports results from the conditional Poisson specification in Column 1. The variable PRIV, which captures the post-privatization period, has the expected positive sign, but it is statistically insignificant. On the contrary, PRIVSHARE, which measure the percentage of stake held by private shareholders is positive and significant, suggesting that the more credible is State divestment and the transfer of control to private sector, the higher is the increase in patent productivity. Among the control variables, firm size and especially the level of patenting activity in the industry (INDPAT) are significant.

A major shortcoming of the conditional Poisson is the underlying assumption of equality between the variance and the mean. To assess the problem posed by overdispersion in the data, we then adopted a fixed effect version of the negative binomial model proposed by Hausman et al. (1984). The estimates from the negative binomial specification are reported in Column 2 of Table 8. The estimate of the coefficient of the post-privatization period is still positive and greater (0.23) than the estimate in the Poisson model (0.01), and it is now statistically significant, a result that confirms the increase in patenting activity after privatization. On the contrary, the coefficient of PRIVSHARE is now negative, although not significantly. Moreover, the control variables we introduced in the model are all statistically significant.

--- insert table 8 about here ---

We then turned to the citation intensity regression, to test our hypothesis that the increase in patenting after privatization, emerging also in the regression analysis, may negatively affect average patent quality. The dependent variable, the difference between sample company citation intensity per patent and mean industry citation intensity, is now a continuous variable. Accordingly, we adopt a fixed effects (within-group) specification to account for permanent differences in behavior across individual firms. Column 3 of Table 8 provides the regression estimates for the citation intensity regression, where the explanatory variables are the same of the patent count model. The coefficient of PRIV has now a negative sign, as we would have expected, whereas the share of private ownership has a positive sign. However, both of the variables capturing the transfer of ownership don't result statistically significant. Thus, it is not possible to draw any strong conclusion from the citation intensity regression about the association between privatization and an increase in the value of inventions patented. Among the control variable, firm size, leverage and the level of patent production in the industry are all significantly associated to citation intensity. The last relationship suggests that patents that are assigned to companies operating in industries with high patenting activity are more likely to be cited by subsequent patent, as it is logical to expect.

CONCLUSIONS

Over the last two decades, privatizations programs have profoundly transformed the economies of a variety of countries, consistently reducing the role of the State as a major owner of productive assets. However, the literature on privatization has mainly focused on assessing its consequences on static efficiency, while dynamic efficiency gains, involving investments, R&D and innovation, have been relatively ignored.

In this paper, using an event-study methodology, we investigated the consequences of privatization processes on the incentives to invest in R&D and innovation output. Our findings support the hypotheses of a negative association between privatization processes and R&D investments. We document significant decreases in the mean levels of R&D intensity after privatization, even relatively to industry trends, and highlight the impact of prior restructuring undertaken by the government to maximize firm value and thus achieve a greater price from the sale. Moreover, the amount of shares being sold to private shareholders, the level of technological opportunities and the degree of market competition of the industry seem to affect significantly R&D commitment within privatized companies.

Since R&D is just a measure of innovative input, we also assessed the impact of privatization on patenting activity. We document a rise in the average number of assigned patents after the State divestment, which is largely in line with the trends in patenting occurring contextually within the industry. At the same time, patent quality, measured by citations received by subsequent patents, doesn't seem to decrease significantly. This last result contrasts with the hypothesis we advanced, regarding a possible lowering of the threshold adopted in the decision to patent following privatization. On the contrary, it suggests that the switch in ownership induce privatized companies to produce more patent, by reorienting their research activities towards areas with more direct commercial applicability. This is coherent with the findings of Jaffe and Lerner (1999) on the impact of legislative reforms of the early 80s on patenting and technology transfer activities at U.S. national laboratories.

Taken together, these findings suggest that privatization may lead to an overall improvement in R&D productivity and the innovative outcomes deriving from restructuring process may be considered positive from the perspective of private investors. These results are consistent with the literature on the impact of privatization, which on average document significant improvements in financial and operating efficiency of privatized firms (D'Souza & Megginson, 1999; Galal et al., 1994; La Porta & Lopez de Silanes, 1997; Megginson et al., 1994).

Besides directly contributing to the literature on the consequences of privatization, our study supports precedent research which examined the relationship between governance structures and innovation (Hall, 1990; Hitt et al., 1991, 1996; Hoskisson et al., 1994; Kocchar and David, 1996; Zahra, 1996). More precisely, it confirms that the nature of the institutional owner - in our case the State - ultimately affects the firms' propensity to invest in R&D activities. Our findings are in line with previous studies (Zhara, 1996; Kocchar and David, 1996) showing that the differences in institutional investors objectives leads to differences in their investment behavior and ability to influence corporate innovation outcomes.

Our study presents several implications from a public policy perspective. First, we find that private-owned companies are unlikely to make the same long-term commitment as did State-owned enterprises, and that the barriers to private risk-taking vary across industrial sectors. We argue that this reduction is to be considered positive in terms of private interest, since it is driven by a better use and higher productivity of R&D resources. However, a critical situation arises when the abandoned R&D activities, of limited interest for the company at least in the short term, but important in a more general sense for the industry or for society as a whole, are not undertaken by other subjects, since in this case their abandonment can have a negative impact on social welfare. A typical situation of market failure emerges and the intervention of the State should be requested in forms that differ from ownership and control.

This should be opportune and in the interest of general welfare, but it is not always likely to happen. For instance, in the electricity sector in the United Kingdom the huge cuts in R&D expenditures by the successors of State-owned CEGB were not accompanied by a corresponding increase in spending by the government on energy research. As a consequence, research in important areas, such as environment protection, was negatively affected (Kenward, 1993). To this purpose, further research is needed to assess the impact of privatization on social returns to innovative activities.

Finally, it is important to acknowledge this paper's limitations, which indicate some fruitful avenues for future research. A first weakness derives from the limited number of companies constituting our sample, which is strictly related to the limited number of privatization programs of relevant size that have occurred worldwide over the last twenty years. 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 financial and innovation data on international companies. Second, 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 & Villalonga, 2000; Ramamurti, 2000). This was our main concern and we tried to control for different factors both at the firm level, for instance by separating the individual permanent effects in the regression models, and at industry level, by adopting industry adjusted indicators and by differentiating between competitive and non-competitive firms or between high-technology and low-technology firms. However, future studies may employ more sophisticated control variables (for instance to measure the level of competition within the industries) or research approach (such as matched-paired research designs) in order to account for these critical issues. Another limitations of this study derives from the use of patents as a measure of innovative output. We have addressed the problems of the high variance in the value of patents by considering citations-based measures to proxy patent quality. Future research might more directly tackle this issue by analyzing the impact of privatizations on the underlying economic value of innovations.

Despite these limitations, we believe that this study provides the first empirical evidence on the impact of privatization on innovation activities and contributes to deepen our understanding of long-term consequences of the decision to privatize public sector activities, a rich area for future research.

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TABLE 1
Summary statistics for all variables

	Mean	Standard deviation	Min	Max
R&D expenses (Log)	18.47	2.59	5.17	21.68
R&D intensity (R&D/Sales*100)	2.51	2.46	0.01	16.11
Industry adjusted R&D intensity [a]	- 0.28	2.15	- 11.22	3.93
Industry adjusted R&D intensity/Industry R&D intensity	.69	1.71	- 0.96	6.63
Patent count (number)	40.90	50.52	0	274
Industry adjusted patent count [b]	- 23.67	59.53	- 171.23	214.92
Industry adjusted patent count/Industry patent count	- 0.27	0.95	- 1	6.33
Industry adjusted citation intensity [c]	- 1.17	3.07	- 10.64	12.41
Industry adjusted citation intensity/Industry citation intensity	- 0.17	0.76	- 1	7.07
Dumpriv	.62	.48	0	1
Privshare (%)	54.66	38.16	0	100
Sales (Log)	9.09	1.15	6.05	11.17
Leverage	24.74	15.23	0	71.88

[a] The industry adjusted R&D intensity is the difference between firm R&D intensity (%) and industry R&D intensity (%).
[b] The industry adjusted patent count is the difference between the firm patent count and the industry average patent count.
[c] The industry adjusted citation intensity is the difference between firm average citations per patent and industry average citations per patent.

TABLE 2
Changes in R&D investments before and after the privatization announcement, assuming announcement occurs within 2 years from the public offer

	Pre	Post	T-test	p-value (one tail)
R&D expenses (Log)	17.55	18.27	-1.77	<.05
R&D intensity (R&D/Sales*100)	2.93	2.37	1.91	<.05
Industry adjusted R&D intensity [a]	0.10	-0.41	1.85	<.05
Industry adjusted R&D intensity/Industry R&D intensity	1.2	0.51	3.09	<.01

[a] The industry adjusted R&D intensity is the difference between firm R&D intensity (%) and industry R&D intensity (%).

TABLE 3
Changes in patent quantity and quality before and after privatization year

	Pre	Post	T-test	p-value (one tail)
Patent count (number)	35.83	45.01	- 0.l7	< 0.5
Industry adjusted patent count [a]	- 25.11	- 22.47	- 0.41	n.s.
Industry adjusted patent count/ Industry patent count	- 0.28	- 0.26	- 0.16	n.s.
Industry adjusted citation intensity [b]	- 1.63	- 0.80	- 2.50	< 0.01
Normalized citation intensity/Industry citation intensity	- 0.21	- 0.13	- 1.00	n.s.

[a] The industry adjusted patent count is the difference between the firm patent count and the industry average patent count.
[b] The industry adjusted citation intensity is the difference between firm average citations per patent and industry average citations per patent.

TABLE 4
R&D commitment: comparison of between group differences in the three periods for the whole sample

	Pre[a]	During[b]	Post[c]	F-test	Contrast t-test[d]
Ln R&S expenses	17.18	17.67	18.63	6.87	-1.48***
R&D intensity (R&D/Sales*100)	2.93	2.40	2.35	1.91	.57
Industry adjusted R&D intensity	0.17	-0.26	-0.50	2.84	.69*
Industry adjusted R&D intensity/Industry R&D intensity	1.24	0.63	0.44	6.28	.80***

[a] Until 2 years before the Public Offering
[b] From 2 years before to the Public Offering
[c] After the Public Offering
d Linear contrast coeficients 1, 0, -1
* p<.05, ** p<.01, *** p<.001

TABLE 5
Patent quantity and quality: comparison of between group differences in the three periods for the whole sample

	Pre[a]	During[b]	Post[c]	F-test	Contrast t-test[d]
Patent count (number)	35.80	41.00	47.12	1.74	5.57***
Industry adjusted patent count [a]	- 27.06	- 26.56	- 18.02	0.89	1.26
Industry adjusted patent count/ Industry patent count	- 0.27	- 0.27	- 0.26	0.99	0.01
Industry adjusted citation intensity [b]	- 0.19	- 0.22	- 0.10	0.47	0.06
Industry adjusted citation intensity/Industry citation intensity	- 1.48	- 0.93	- 0.92	1.42	- 6.06***

[a] Before the Public Offering

[b] From the Public Offering to two years after

[c] From two years after the Public Offering

d Linear contrast coeficients 1, 0, -1

* p<.05, ** p<.01, *** p<.001

TABLE 6
Estimates of the R&D Investment Model. Models with Fixed effects
(standard errors in parenthesis)

	Model 1	Model 2	Model 3	Model 4
Dependent variable	Log R&D	R&D intensity (R&D/Sales)	Firm R&D intensity vs. Industry average R&D intensity	Difference of firm R&D intensity over Industry average R&D intensity
Intercept	12.270***	4.332**	-3.985*	1.688*
	(.587)	(1.461)	(1.670)	(.826)
Log Sales	.657***	-.179	.432*	-.121
	(.066)	(.164)	(.190)	(.094)
Priv	.418***	1.238***	.662**	.307*
	(.086)	(.217)	(.237)	(.117)
Privshare	-.002	-.023***	-.012**	-.002
	(.001)	(.003)	(.004)	(.002)
Leverage	.013***	-.008	.001	.01
	(.003)	(.007)	(.008)	(.01)
R^2	.43***	.12***	.06**	.03**
N. of firms	35	35	33	33

* p<.05, ** p<.01, *** p<.001

TABLE 7
Estimates of the R&D Investment Model. Models with Fixed effects and Interactions
(standard errors in parenthesis)

	Model 1	Model 2	Model 3	Model 4
Dependent variable	Log R&D	R&D intensity (R&D/Sales)	Industry adjusted R&D intensity	Industry adjusted R&D intensity/Industry R&D intensity
Intercept	12.390***	4.202**	-3.596	1.885
	(.595)	(1.497)	(1.694)	(.835)
Log Sales	.648***	-.163	.402*	-.135
	(.067)	(.168)	(.192)	(.095)
Priv	.093	1.17***	.814**	.379*
	(.145)	(.250)	(0.275)	(.136)
Privshare	-.002	-.023***	.011**	.002
	(.001)	(.003)	(.004)	(.002)
Leverage	.012***	.009	.002	000
	(.002)	(.007)	(.008)	(.004)
Inttech	.057	.192	-.156	-.04
	(.104)	(.264)	(.293)	(.14)
Intregul	-.353**	-.142	-.668	.421
	(.130)	(.339)	(.401)	(.198)
R^2	.44***	.13***	.07**	.05*
N. of firms	35	35	33	33

* p<.05, ** p<.01, *** p<.001

TABLE 8
Estimates of the Patent Models
(standard errors in parenthesis)

	Model 1 Poisson model with fixed effects	Model 2 Negative binomial model with fixed effects	Model 3 Within group estimator
Dependent variable	Number of patents	Number of patents	Industry adjusted citation intensity
Intercept			7.68
			(4.22)
Log Sales	.036	.147***	- 1.08*
	(.040)	(.024)	(.48)
Priv	.010	.227*	- .04
	(.029)	(.094)	(.01)
Privshare	.001*	-.001	.32
	(.000)	(.001)	(.45)
Leverage	-.001	-.014**	.01*
	(.001)	(.004)	(.01)
Indpat	0.008***	.008**	0.03*
	(.001)	(.002)	(.01)
Log likelihood	- 1136.13	- 835.59	
R^2			.54*
N of firms	28	28	28

* p<.05, ** p<.01, *** p<.001

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