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Firm ownership, quality of government and innovation

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Abstract

Despite the wave of privatisation in recent decades, Enterprises under government control still account for a large part of assets and employment in several countries and particularly continue to play a key role in certain network industries. We explore the potential role of State-Invested Enterprises (SIEs) as investors in innovation, with particular interest in that played by the institutional environment. We focus on the telecommunication industry, which has been affected by fundamental technological and organisation change, including liberalisation and privatisation, over the last decades but where public ownership still retains a major role. We draw on a longitudinal data set of 707 telecom companies from 85 countries over the 2007-2015 period and show that public ownership is positively correlated to innovation activity. We also find that - for both state-invested and private companies -improvements in institutional quality are positively associated with firm-level innovation, and that such a relation is stronger under public ownership. We offer an interpretation of these findings which shed new light on the role of SIEs as patient investors.

1. Introduction

The role of innovation in modern growth theory has been firmly established since the contribution by Arrow (1962) who, as opposed to the neoclassical tradition of Solow (1956, 1957) and Swan (1956), identified learning and R&D as an endogenous driver of change. Subsequent developments of this theory (e.g. Romer 1986, 1990; Aghion and Howett 1992) established a potential role for government support for R&D when firms are unable to attain the optimal quantity of investment in knowledge creation. R&D by firms is constrained by two market failures: the uncertainty of returns

to R&D (Foray 2004) and externalities due to knowledge spillovers (Griliches 1979, Grossman and Helpman 1990). A traditional view to counteract any externality consists in government intervention (Atkinson and Stiglitz, 1980) in different forms. Examples of government interventions to support R&D include subsidies to private firms (Busom 2000; Salter and Martin 2001; Trajtenberg 2002), collaboration between public universities and firms (Bergman 1990; Mansfield 1991, 1998; Veugelers and Cassiman 2005; Segarra-Blasco and Arauzo-Carod 2008), public procurement for innovation by Big Science (Castelnovo et al 2018; Florio et al 2018), and combined demand and supply-side policies (Wonglimpiyarat 2006; Guerzoni and Raiteri 2015). More recently Mazzucato (2013, 2016) has promoted the view that the government's role goes beyond the correction of market failures as it supports technological breakthrough, which in turn creates entirely new markets. Mazzucato (2017, 2018) advocates a governmental mission-oriented innovation policy to address big societal challenges.

In this paper, we explore another mechanism of government support for innovation: the potential role of enterprises under public control as active players in knowledge creation. We focus on the telecommunication industry, which has been affected by fundamental technological and organisation change, including liberalisation and privatisation, over the last decades but where the public ownership of major players is still important.

Existing evidence on the relation between firms' ownership and innovation outcome at firm level is far from being conclusive (Sterlacchini 2012; Belloc 2014; Fang et al. 2016; Rong et al. 2017; Demircioglu and Audretsch 2017). A strand of literature points to the inferior innovation capability of enterprises under public control due to their internal governance structure, lack of adequate monitoring and market incentives and risk of political capture. On the other side, one may argue that public enterprises might have a better attitude towards innovation. In fact, both ownership concentration and stability, and the departure from short-term goals may reduce the risk-aversion associated with an activity which exchanges current and certain returns for future and uncertain ones.

The relevance of this issue is motivated by evidence that, despite the wave of privatisation that affected the world economy in recent decades, enterprises under government control still account for a large part of assets and employment in both developed and developing economies, and continue to play a central role in network industries (e.g. telecommunication, oil & gas, railway,

power generation)[1]. Moreover, although there is consistent evidence on public ownership under-performance compared to private companies in terms of efficiency, productivity and profitability (e.g Shleifer, 1988, Shleifer and Vishny 1994, Megginson and Netter 2001, Dewenter and Malatesta 2001), major market-oriented reforms have increasingly exposed them to a new set of incentives. Markets have been widely liberalised and former public monopolists have been brought to compete against private enterprises (Khandelwal et al. 2013; Koske et al. 2015). Traditional State-owned enterprises (SOEs) have undergone major governance reforms as well. Their proprietary structure has faced radical changes: many governments have partially divested from them and, while continuing to maintain the residual right to appoint the relative majority of the board, have opened their shareholding structure to private equity (Bortolotti and Faccio 2009). In light of these transformations, enterprises under public control are increasingly referred to mixed enterprises of State-invested enterprises (SIEs) (Christiansen and Kim 2014). Various SIEs have been listed on a stock exchange where they currently compete with private enterprises in the collection of financial resources (Pargendler et al. 2013). The consequence of these reforms has been a deep transformation in their internal governance and management organisation, resulting in an improvement in their financial accountability and economic performance (Musacchio and Lazzarini 2018). Thus, the question of whether contemporary SIEs differ from their private competitors in terms of innovation arises . This is our first research question.

This paper further contributes to the existing literature by investigating the issue of ownership and innovation through the lens of institutional economic theory (Williamson 1985; North 1990). Our second research question is whether SIEs' innovation-oriented attitude, compared to private companies, is likely to be differentially affected by the quality of government and of institutions in general. Indeed, governments can appoint the SIEs' managers, thus directing them on the objectives to achieve, and are likely to influence SIEs' internal governance, monitoring and incentives mechanisms, and ultimately its innovation capability. Consequently, we contend that the relationship between firm-level innovation and ownership nature varies depending on institutional quality. Our approach is motivated by the recognition that the efficiency of the firm – and its ability to innovate – crucially depends on institutional quality (Sala-i-Martin, 2002; Tebaldi & Elmslie 2013).

[1] For a review see PWC (2015), Christiansen and Kim (2014), European Commission (2016). According to the OECD, in the telecom sector, the major market player is still controlled by the government (by means of a majority or minority of shares) in the following countries: Austria, Belgium, France, Germany, Japan, Luxembourg, Norway, Slovak Republic, Slovenia, Sweden, Switzerland, Turkey, China, India, South Africa, Cyprus, Latvia and Romania (Koske et al. 2015).

We argue that this relation is stronger under public ownership because, in this case, institutions affect both the quality of the external environment where firms perform their economic activity and the quality of SIEs' internal governance and management mechanisms.

In the present paper, we address these issues by analyzing a comprehensive dataset comprising information on companies operating all around the globe in the telecommunication industry. To the best of our knowledge, no studies have focused on the relation between ownership and innovation for: (i) a sector (i.e. telecommunication) involving firms that have undergone major transformations in their ownership nature and competitive environment; (ii) companies operating in widely different geographical areas, thus entailing a large variance in the quality of the institutions of the home country.

We considered patents as an empirical proxy of knowledge creation by firms and we modeled the interaction between ownership and institutional quality as our variables of interest after controlling for firm-level and time and geographical characteristics. Our investigation relied on three data sources: information from the Orbis dataset on economic characteristics and ownership structure at the firm-level; detailed patent-level information from PATSTAT; World Bank's Worldwide Governance Indicators (WGI) database for data on countries' institutional quality. Our final sample comprises 707 telecom companies from 85 countries over the 2007-2015 period, for a total of 4,858 firm-year observations.

Our main finding is that, firstly, government ownership *per se*, along with other firm-level characteristics (such as size and being listed) positively correlates to patenting activity. Secondly, while improvements in institutional quality are positively associated with firm-level innovation in general, such a relation is stronger under public ownership. In fact, in countries with high-quality government and institutions, SIEs show better patenting performance than private firms, while the reverse occurs in countries with a low-institutional profile. We interpret this main result in the following way: SIEs are more effective in terms of innovation output when they benefit from improved internal governance mechanisms and when they depart from the short-term profit goal of private enterprises. This is true, however, only in countries with high-level institutions. When corruption is at a minimum level, accountable governments are likely to adopt transparent selection procedures and effective monitoring mechanisms and commit the SIE's management on long-term valuable social goals (such as those related to connectivity and the digital agenda). Conversely, in countries with corruption problems, the SIEs' controlling governments are likely to

put the short-term private interests of politicians and other stakeholders before social ones and do not implement sound management strategies, thus bringing SIEs to underperform compared to private peers in terms of innovative outcome.

The paper is structured as follows. Section 2 provides a brief review of the core contributions addressing the relationship between public versus private ownership structure and firm performance, with a focus on innovation performance. The section concludes by formulating a set of research questions pertaining to the effect of ownership structure, type of control and institutional quality on innovation activity at the firm level. Section 3 presents the dataset and describes the sample, variables and method that were employed for the present empirical analysis. Section 4 presents the results of the econometric analysis and robustness checks. Section 5 summarises the main findings and discusses some implications of our study.

2. Literature Review and research questions

Ownership of the firm is increasingly recognised as a factor that affects its capacity to develop technological innovation (Choi et al. 2011; 2012; Lazzarini et al. 2016). Indeed, the firm's internal organisation, governance mechanisms, and the goals that managers are instructed to achieve crucially depend on the nature of the owner retaining residual rights of control over the firm. Building on the career concern hypothesis formulated by Holmstrom (1999), Aghion et al. (2013) find that, among listed companies, those in which institutional owners participate (hedge and mutual funds) are associated with more innovation. The authors argue that managers may be reluctant to undertake R&D investments with an intrinsic probability of failure, especially when the principal does not develop the monitoring mechanisms that are required to understand whether a potential failure of the project is due to the manager's incompetence or other reasons. To contrast this risk, by implementing effective monitoring and incentive mechanisms, institutional owners lower information asymmetries and reduce managers' career risk in association with projects with uncertain returns. This encourages an increase in managers' attitude towards innovative projects.

Other studies have investigated this issue, finding different and potentially conflicting channels through which the ownership nature of the firm affects its capacity to innovate (Belloc 2014). An established stream of literature points to the lower efficiency of traditional public ownership compared to private companies (Vining and Boardman 1992; Shleifer 1998). Following this line of

argument, the main source of their inefficiency is traced back to the government's inability to (i) effectively monitor managers' behavior and to (ii) design an adequate set of incentives aimed at reducing principal-agent problems by aligning owners' and managers' objectives (Holmstrom and Milgrom, 1991, Laffont and Tirole 1993). Other reasons behind public ownership inferior efficiency refer to the lack of hard budget constraints and the absence of a takeover threat (Vickers & Yarrow, 1991; La Porta et al. 1998), as low replacement risk fails to give public managers the adequate incentives to run the firm efficiently and improve its performance. A final important source of inefficiency is the risk of political interference and capture by private interests (Shleifer and Vishny, 1993, 1994; Mauro 1995). Bad governments may use their controlled enterprises as a vehicle to pursue private goals at the expenses of social well-being, causing the misallocation of resources. By hindering efficiency and productivity, these constraints are likely to negatively affect the traditional SOEs' dynamic efficiency and capability to develop successful innovations. This argument is confirmed by recent evidence from China on the inferior innovative performance of SOEs compared to private firms (Hu and Jefferson 2009; Boeing et al. 2016, Fang et al. 2016). Notably, Rong et al. (2017) find that the positive impact of institutional ownership on innovation (Aghion et al. 2013) is not significant when institutional owners hold a minority of stakes in firms that are controlled by the State where managers are likely to be appointed according to their political connections rather than their business competences.

Contrary to this dominant view, there is evidence suggesting that enterprises under public control can actually perform similarly to private enterprises (Szarzec and Nowara, 2017) or even better in some sectors and countries (Borghi et al., 2016; Florio, 2013); in some circumstances they exhibit certain internal features that may provide a comparative innovation advantage with respect to private companies. A first argument relates to the risk of short-termism that may affect profit-maximizing private enterprises. It has been argued that pressure for immediate results induces managers to redirect financial resources from R&D activities to more conventional and short-term oriented activities (Porter 1992; Stein 1988). Evidence of short-termism has been found when looking at private enterprises listed on the stock market (Ferreira et al. 2013), especially when they are participated by speculating investors (Bushee 1998, 2001), and when enterprises are acquired through excessive means of financial leverage. On top of this argument, the traditional public economics literature stresses the difference in the objective functions between private and public enterprises that allow the latter to adopt strategies and investments with long-term returns that private investors looking for high and fast returns are not willing to undertake. When activities

entail positive externalities that cannot be fully monetised, private enterprises might be reluctant to undertake optimal investments, while this market failure is less likely to occur under public owership (Atkinson and Stiglitz 1980; Kaldor 1980).

Another relevant issue for the firm's capacity to innovate is its internal stability. Ownership concentration is found to be positively associated with R&D expenditures and innovation (Francis and Smith 1995). The propensity and capacity to develop long-term R&D projects is likely to benefit from a stable environment. Conversely, managers under a continuous threat of replacement may increase their preference of conventional projects with a lower probability of failure (Stein, 1988; Kaplan et al. 2012; Sapra et al. 2013).

The departure from short-term profits, features of internal long-term stability and ownership concentration are likely to characterise firms under government control and may put public managers in a better position to deal with long-term innovative projects characterised by uncertain and time-deferred returns. These arguments are supported by the empirical evidence that privatisation has been associated with a decline in R&D activity (Munari and Oriani 2005; Sterlacchini 2012; Xie 2012), and that privatisation through leveraged buyout has reduced R&D intensity and investments in innovation (Zahra and Fescina, 1991; Long and Ravenscraft's, 1993).

Following the discussion above, earlier literature has found contrasting results, thus preventing the development of any unambiguous prediction on the impact of ownership on innovation. We believe that these apparently conflicting views are due to an important omission in the analysis and can be reconciled within a broader general conceptual framework once the role of institutions is properly taken into consideration. Notably, we argue that institutions are linked to the ownership of the firm by a double relation. One is external to the firm itself and affects both private and public enterprises, the other is internal to the firm and mainly involves enterprises under governmental control.

Institutions govern economic and social interactions within a country and can be defined as the broad set of formal and informal rules shaping the environment where citizens interact in society and where firms carry out their economic activity (North 1990). It is widely recognised that the quality of institutions affect firms' strategies, performance and, ultimately, economic growth (Mauro 1995; Rajan and Zingales 1998; Acemoglu et al. 2001; Helpman 2004, Rigobon and Rodrik

2004). The certainty of the rule of law[2]; the strengths and effectiveness of law enforcement, judicial and correctional procedures; the degree of government effectiveness, transparency and accountability; the absence of corruption: all these elements contribute to determining the quality of institutions within a country. They constrain the firms' endowment of resources, affect their production costs and consequently shape their strategies and decision-making processes. Previous research shows that the linkage between institutional quality and firms' performance (Baumol 1990, Dollar et al. 2005; Commander and Svejnar 2011) positively affects the process of knowledge accumulation (Sala-i-Martin, 2002; Gradstein, 2004; Rodriguez-Pose & Di Cataldo 2015). Boschma and Capone (2015) find that institutions affect the direction of the diversification process and their industrial evolution. Tebaldi & Elmslie (2008, 2013) provide empirical evidence that the absence of corruption, the protection of property rights and the effectiveness of judiciary systems impact on the economy's rate of innovation and are significant in explaining cross-country patenting variations.

Building on this extensive literature, we firstly argue that the positive relation between institutions and firm dynamic efficiency is external to the firm itself and does not depend on their ownership nature. Both public and private firms benefit from a safe environment and their propensity towards innovative but risky investments increases with their confidence in the quality of the underlying institutional framework. However, we also argue that there is a second channel linking institutions and enterprises. As opposed to the previous one, this relation is internal to the firm and is more relevant for SIEs than for private enterprises. The quality of the government (e.g. transparency, accountability, absence of corruption) is likely to affect public management appointment procedures, SIEs' internal governance and monitoring mechanisms, and the objectives that SIEs are instructed to achieve.

The phenomena of political capture, orientation towards immediate personal objectives, and misallocation of resources are more likely to take place in countries characterised by low quality institutions. Enterprises under the control of a malevolent government are brought to bargain short-term private returns at the expense of long-term social goals. Thus, we expected that a bad

[2] The rule of law has been defined as a principle of governance in which "all persons, institutions and entities, public and private, including the State itself, are accountable to laws that are publicly promulgated, equally enforced and independently adjudicated, and which are consistent with international human rights norms and standards. It requires, as well, measures to ensure adherence to the principles of supremacy of law, equality before the law, fairness in the application of the law, separation of powers, participation in decision-making, legal certainty, avoidance of arbitrariness and procedural and legal transparency" (United Nations Secretary-General 2004, par. 6)

institutional quality is detrimental to SIEs' innovation performance compared to private enterprises. Conversely, SIEs that are located in countries with high quality institutions are more likely to rely on internal stability, transparent monitoring and selection procedures and clear commitment towards long term socially valuable goals. Therefore, we expected high institutional quality to have an incremental positive effect on SIEs' capacity to innovate compared to private enterprises.

In light of these considerations, our empirical analysis explicitly considered both external and internal dimensions linking institutions to enterprises in order to understand firms' drivers of innovation. Notably, based on the conceptual framework outlined above, we predicted the following relations to hold. First, according to the recognition of the positive effect that good institutions exert on economic growth and industrial evolution, we anticipated a positive relation between institutional quality and innovation at the firm level. Second, given the direct positive effect of institutional quality on SIE's internal governance and management, we expected that, as institutional quality improves, innovation will increase at the margin more in SIEs than in private enterprises. These arguments bring us to expect SIEs to be inferior enterprises in their innovation performance compared to private enterprises under a poor institutional framework. When the quality of institutions is high, SIEs are expected to outperform private enterprises in their capacity to innovate.

3. Data and variables

We focus on the global telecom industry[3]. There are several reasons why this represents an interesting setting to address our research questions. First, this is fast evolving industry where innovation represents a key-determinant for enterprises to grow, expand their business and increase profits (Davies, 1996; Godoe, 2000; Lam and Shiu, 2010)[4]. Second, in past decades the telecom industry has undergone an important pattern of reforms. Traditional SOEs that used to

[3] A firm is considered to operate in the telecom industry when, according to the NACE rev. 2 classification, it belongs to sector 61 "Telecommunications", which includes wired (61.10), wireless (61.20), satellite (61.30) and other (61.90) telecommunication activities. This includes: operating, maintaining or providing access to facilities for the transmission of voice, data, text, sound and video using a wired, wireless and satellite telecommunications infrastructure; purchasing access and network capacity from owners and operators of networks and providing telecommunications services using this capacity to businesses and households; provision of Internet access by the operator of the wired wireless and satellite infrastructure; provision of specialised telecommunications applications, such as satellite tracking, communications telemetry, and radar station operations; telecommunications resellers (i.e. purchasing and reselling network capacity without providing additional services).

[4] The introduction of breakthrough technologies has brought to an increasing consumption pattern and, more in general, to radical changes in our daily life and to how people interact in society. Some of the most relevant technological changes in the telecom industry are the Global System for Mobile communications; the World Wide Web; triple-play "telephony, television, and internet access" offer; high-speed wireless communication for mobile phones and data terminals; Long-Term Evolution Networks

operate under a legal monopoly have been widely brought to compete in liberalised markets and underwent a process of privatisation, with different degrees of intensity across different countries (Clifton et al. 2011; Florio 2013). This ensures a high level of heterogeneity in corporate ownership among telecom enterprises. Third, the global perspective we adopt allows us to exploit the high institutional heterogeneity characterizing the countries where telecom firms operate. The fact that telecom SIEs are located both in high-quality OECD countries (e.g Swisscom in Switzerland, Deutsche Telekom in Germany, Alcatel and Orange in France, NTT in Japan, Telenor in Norway or Teliasonera in Sweden) and in less developed countries with a lower institutional setting (e.g.Telecom Egypt in Egypt, Rostelecom in Russia, China Telecom in China, CANTV in Venezuela) allows to integrate the institutional perspective into the analysis of ownership as a determinant of innovation.

We combined data from three different sources. The first source is the ORBIS database managed by the Bureau Van Dijk, which contains yearly information on the financial, accounting and corporate characteristics of a large number of international companies. From this data source, we retrievde information related to investments in tangible assets, investments in intangible assets and market shares, firm geographical location, operating revenues, year of incorporation, and whether the firm is listed on a stock market. ORBIS also contains relevant information relating to the patenting activity of companies. Bureau Van Dijk has extended the OECD HAN database (Harmonised Applicants' Names) (Thoma et al. 2010b) and provides a reliable matching of patent assignee names (and the corresponding publication numbers) with ORBIS firms. Therefore, our second source of data refers to firm innovation activity. Following previous studies in the analysis of innovation in the telecommunication sector exploiting patent data (see, among the others, Calderini and Scellato, 2005; Nambisan, 2013; Bekkers et al., 2002), we relied on the Worldwide Patent Statistical Database (PATSTAT) to retrieve information on the names of the assignees, publication number, filing dates and number of citations. Finally, we relied on the World Bank's Worldwide Governance Indicators (WGI) database for data on countries' institutional quality. We combined the information collected from the three data sources described above, and we restricted our sample to telecommunication companies (Sectors 61.10, 61.20, 61.30 and 61.90 of NACE Rev. 2) with complete information on their variables of interest over the 2007-2015 period, thus attaining an unbalanced panel comprising 707 firms from 85 countries (4,858 firm-year observations).

As discussed in the preceding sections, we are interested in explaining the innovative activity of firms in the telecommunication sector. Our key outcome variable is the number of patent applications filed by each company in our sample.[5] While being an imperfect proxy of innovation activity at the firm level, patents are publicly available documents that are collected on a regular basis and measure the direct outcome of the innovation process while allowing for international comparison (Griliches, 1990). We also tested the robustness of our results by controlling for the quality of the patents that are filed at the firm level. To this end, we used the number of granted and quality-weighted (using 3-years and 5-years citations' timeframes) patents.

Our first explanatory variable refers to whether the firm is state owned or not. A firm is considered a SIE when it is ultimately owned by a government or public authority[6]. This criterion encompasses both enterprises under direct public control, where the government is the top shareholder[7], and indirect public control, where the government is the ultimate owner through a chain of upstream ownership relations while it does not figure as the SIE's top shareholder[8]. During the 2007-2015 period under analysis, the ownership nature of the firm was very stable (less than 3% of companies shifted from public to private property, or vice versa), thus lowering the risk of our results being biased by a potential problem of reverse causality (e.g. the possibility that the performance of the firm affects its probability of being privatised or nationalised).

Around 72% of the sample (3485 firm-year observations) comprises private companies (e.g. Vodafone and British Telecom (UK), Telecom Italia (IT), America Movil (MX), Telefonica (ES), Verizon and AT&T (US), Vivendi (FR)). The remaining 28% of the sample (1372 firm-year observations) is composed of firms controlled by a government.

The second explanatory set of variables refers to the quality of the government in the country where each firm is located. To measure institutional quality, we followed a consolidated literature and used the World Bank's Worldwide Governance Indicators (WGI) (Kaufmann and Kraay 2008; Kaufmann et al. 2010). In light of our specific interest in the quality of the government controlling

[5] We restrict/limit our analysis to patents filed in the main patent offices (USPTO, EPO and JPO). On top of ensuring higher quality, stringency and transparency in the evaluation procedure, they grant wider geographical IP protection in the most relevant markets.

[6] The ownership of a company is determined by adopting the following procedure. For each year of the 2007-2015 period, we extracted information on the firm's top shareholder from ORBIS. The former refers to the owner of the largest share of equity in the company, so we proceeded in a recursive manner until the ultimate controller is identified, especially when such an entity is a governmental body.

[7] This includes, for instance Swisscom (CH), Orange (FR), China Mobile (CN) Nippon Telegraph and Telephone (JP), Temasek (SG), Teliasonera (SE), MobiFone (VT).

[8] e.g. Fastweb (IT) is controlled by Swisscom, a private shareholder which, in turn, is controlled by the Swiss government; as regards Hellenic Telecommunications (GR) the top shareholder is Deutsche Telekom, a private shareholder which in turn is controlled by the German government.

the SIEs, we decided to focus our attention on the Control of Corruption (CC) indicator, which captures “the extent to which public power is exercised for private gain, including both petty and grand forms of corruption, as well as "capture" of the state by elites and private interests” (pag 223, Kaufmann et al., 2011). Nevertheless, the CC indicator is highly correlated with the other WGI indicators, thus pointing to a high degree of overlapping of these measures (the correlation coefficients range between 0.7 and 0.9). Moreover, our main results are broadly confirmed when we consider other WGI indicators, such as government effectiveness (GE); rule of law (RL) and regulatory quality (RQ), or voice and accountability (VA).

We also included a set of variables recognised as relevant to explain innovative activity at the firm level: investment in tangible and intangible assets, the firm’s total assets, operating revenues, the firm’s age, industry concentration and whether the company is listed on a stock market. Investments in firms’ assets have been found to be an important factor when explaining their innovative activity (Thornhill, 2006). Although investment in intangible assets is an imperfect measure of R&D investment at the firm level, it has been often used as a proxy of R&D investment when data on R&D expenses is not available or affected by self-selection bias as in our case (Leoncini et al, 2018; Marin, 2014). Investment in tangible (intangible) assets is calculated as the yearly net acquisition of tangible (intangible) assets plus the amortisation (Grazzi et al., 2015). Building upon the extensive literature investigating the determinants of a firm’s innovative activity, we control for firm size (measured as the yearly amount of total assets), profitability (operating revenues), age, and firm-level transparency constraints and financial accountability (stock market listing). We also include a popular measure of industry concentration, as the latter has been found to play a relevant role with respect to firms’ innovation performance (Breschi et al., 2000). A four-firm concentration ratio was computed as the market share of the four largest firms in terms of operating revenues at 2-digit NACE Rev. 2 industry codes each year.

Table 1 reports descriptive statistics for the innovative performance, institutional quality and other relevant firm characteristics described above for SIEs and non-SIEs. SIEs tend, on average, to apply for a higher number of patents compared to private companies. The difference between private and public companies in the number of patent applications is likely to depend on the degree of heterogeneity within the private firms’ group. This group includes small companies that have been historically found to have a low propensity to patent the results of innovation activity (Andries and Faems, 2013). When we removed the companies that had not applied for any patent from the

descriptive statistics, we found that the average values increase, but the difference between SIEs and private enterprises (POEs) persist. In our sample, private enterprises are, on average, larger in size (in terms of both total assets and operating revenues) and show higher investment in tangible and intangible assets compared to SIEs. The high value of standard deviation shows that this pattern might be driven by some relevant outliers among private companies (notably US telecom enterprises, e.g. AT&T, Verizon, Centurylink). If we focus on median values, SIEs invest more in tangible assets compared to POEs but have lower operating revenues. Concentration ratio values show that telecom companies mainly compete in oligopolistic markets and that, on average, SIEs operate in more concentrated markets than private companies.

It is interesting to observe that 48% of the private companies are listed on a stock market, while this percentage increases up to 55% for SIEs. This suggests that, despite being controlled by a public entity, many SIEs have improved their financial accountability and are increasingly exposed to market incentives through stock market listing. Table 1 also shows that, compared to private companies, SIEs are relatively more concentrated in countries characterised by lower institutional quality (mainly non-OECD countries). The higher standard deviation in institutional quality measures for SIEs suggests that institutional quality is more heterogeneous under public ownership. SIEs can be found both in countries belonging to the lower tail of institutional quality distribution (Egypt, Indonesia, Kazakhstan, Serbia, Russian Federation, Ukraine, Venezuela, Vietnam) as well as the upper tail (Austria, Germany, Finland, France, Japan, Norway, Sweden, Switzerland).

[TABLE 1 AROUND HERE]

4. Estimation strategy and results

As discussed in Section 2, we are interested in examining the effect of state ownership, country institutional quality and their interplay on innovative activity at the firm-level. Section 4.1 contains a discussion of our empirical strategy, while Section 4.2 presents our main results on the relationship between ownership type and firm patenting. In the same section we analyse how this relation varies depending on the quality of institutions.

4.1 Model specification

To study the relationship between firms' ownership and its patenting activity, and given the count nature of the dependent variable (number of patents) containing positive and integer values, we rely on a Poisson specification to model the number of patents (*y*) a firm applies for:

$$\Pr(Y = y) = \frac{e^{-\mu}\mu^{y}}{y!}$$

with $E[Y] = var[Y] = \mu$

Adopting a Poisson regression model, we specify the conditional mean in the following formula:

$$E\left[PAT_{i,t}\right] = exp(\alpha + \beta SIE_{i,t} + X'_{i,t}\gamma + \delta Z_i + \theta Y_t) \quad (1)$$

where the dependent variable is the expected number of $PAT_{i,t}$, the number of patents filed by firm *i* in year *t*. $SIE_{i,t}$, takes the value of 1 when the firm is controlled by a government and zero otherwise. The vector $X_{i,t}$ includes the set of control variables described in Section 4 which have been log-transformed for estimation purposes. As for firm-level controls, the size of the company is proxied by its operating revenues. Tangible assets measure the firm's capital expenditures; intangible assets are used as a proxy for internal R&D effort, since data on R&D expenditures are missing for most of the firms composing our sample. We also considered the age of the firm and whether the firm is listed on a stock exchange. As for country level controls, we included the concentration ratio CR_4, which measures the market share of the four largest firms in terms of operating revenues for each year and country. Time and geographical fixed-effects were added to control for potential confounding factors and for correlated unobserved heterogeneity. Year fixed-effects Y_t capture time-dependent common shocks including macroeconomic exogenous shocks (2007-2015), while Z_i controls for time-invariant differences in patenting activities across 85 countries.

Given the positive-skewed distribution with a long right tail, we first adopted the Poisson model as the main estimation approach with standard errors being robust to heteroskedasticity. Although our dependent variable shows a departure from the assumption of equi-dispersion (i.e. the mean and variance of our dependent variable are significantly different) characterising Poisson regression models, recent work has consistently shown that the Poisson regression model has several advantages compared to alternative regression models (e.g. negative binomial). The Poisson regression model provides consistent estimates of coefficients of interest even when the underlying

distribution of the dependent variable is not Poisson but the conditional mean is correctly specified (Gourieroux et al., 1984; Wooldridge, 1999)[9]. Moreover, the Poisson regression model is robust to a number of misspecifications such as over-dispersion (it can be accommodated by using robust standard errors), the presence of an excessive number of zeros, and to dependence over time as well as cross-sectional dependence (Bertanha and Moser, 2014).

Then, we extended the baseline model by adding institutional quality measures and interacting them with the ownership variable (equations 2). This allowed us to assess whether the change in institutional quality differentially affects the patenting activity of private companies compared to SIEs.

$$E\left[PAT_{i,t}\right] = exp(\alpha + \beta SIE_{i,t} + \mu INST_{QUALITY_{i,t}} + \vartheta SIE_{i,t} * INST_{QUALITY_{i,t}} + X'_{i,t}\gamma + \delta Z_i + \theta Y_t) \quad (2)$$

4.2 Results and discussion

Table 2 contains the results from the model 1 above. Column 1 reports the baseline knowledge production function excluding market and ownership variables. Results show that the number of patents is positively and significantly associated to the size of the firm (measured by the log of operating revenues), the intensity of R&D internal effort (proxied by the log of intangible assets) and firm age. Being listed on a stock market is positively associated to patenting activity (Column 2 Table 2). Listed companies manage to attract a larger amount of private equity and become more financially accountable. Both phenomena contribute to explaining this result. Market competition is also found to be positively associated with firm-level patenting activity, as an increase in the market concentration index is associated with a reduction in the number of patents (Column 3 Table 2). This pattern (low market concentration, high firm size and innovative role of established companies) resonates well with the taxonomy of patterns of innovation for the telecommunication sector (Malerba and Orsenigo 1994, 1996) which cannot be entirely assimilated to a "Schumpeter Mark I" or to a "Schumpeter Mark II" pattern of innovation.

[9] The same does not hold for the Negative Binomial, i.e. when the dependent variable is not gamma distributed, the coefficient of interest is not consistently estimated even if the conditional mean is correctly specified.

In Column 4 of Table 2 we test our research question relating to the differential role of public ownership on firm-level innovation performance and controlling for major potential confounding factors. Variable $SIE_{i,t}$ has a positive and significant coefficient, suggesting that public ownership is associated with higher patenting activity compared to the private benchmark.

[TABLE 2 AROUND HERE]

Table 3 shows the results of our estimation of equation (3) when a measure for the quality of government is added to the knowledge production function. Results show that the "control of corruption" WGI indicator has a positive and significant coefficient, supporting the argument that improvement in the quality of institutions is positively associated with firm innovation performance (Column 1). This result is confirmed in the next version of the model, where the public ownership variable interacts with the institutional quality variable (Columns 2). When focusing on the ownership dimension of the firm, two interesting results emerge. First, the coefficient of the public ownership variable is negative and significant, pointing to a lower intercept for SIEs. This suggests that when looking at countries with lower institutional quality, SIEs innovate less compared to private companies. Conversely, the coefficients of the interaction between public ownership and institutional quality measures is found to be positive and significant. An increase in the level of institutional quality at the country-level contributed to innovation performance more for SIEs than for private companies. This result is consistent with our conceptual framework and we interpret it in the light of the double relation (internal and external) connecting the quality of institutions to SIEs. Under an improved institutional environment, both SIEs and private firms benefit from being located in a safer place where they can develop their business, but only SIEs seem to take advantage of an improved internal governance and organisational model for innovation purposes. Only in a high institutional setting are SIEs less prone to political capture, more likely to be managed efficiently, and committed to long term stringent social goals, resulting in a higher innovative performance. These results show that a firm's attitude towards innovation crucially depends both on its internal institutions, which are ultimately affected by ownership identity, and on the quality of the institutional environment where the firms operate.

[TABLE 3 AROUND HERE]

5. Robustness checks

As a first check, we also confirmed that our results are valid when other five different WGI measures of institutional quality are considered (Table 4). Results show that, irrespectively from the chosen indicator, the quality of institutions is always positively associated with firm innovation performance, with a differential impact across SIEs and private enterprises.

[TABLE 4 AROUND HERE]

We also checked the robustness of our results to several alternative specifications. For ease of exposition, the results are shown by the last specification of the model where the type of public control is specified and interacted with the Control of Corruption institutional variable although the results are broadly confirmed when adopting other correlated institutional quality indicators.[10]

The first set of robustness checks pertains to the nature of the dependent variable. Although the Poisson regression has demonstrated to be a specification that is quite robust to the excess of zeroes (as well as over-dispersion and departure from Poisson distribution - see Bertanha and Moser, 2014), we carried out an additional control for potential problems arising from a disproportionate number of zeros in our dependent variable (out of 707 companies, 595 have never applied for a patent in the considered period. The percentage of zero patenting increases up to 90% when considering firm-yearly observations). To this purpose, we ran our set of estimates, adopting both Zero-Inflated Poisson and Hurdle specifications (Cameron and Trivedi, 2005). While the former permits the decision to not patent in a mixture of Poisson and logit models, the latter keeps the decision to patent separated from the process generating the positive outcomes. Tables 5 and 6 present results for the two models, both of which confirm our main findings.

[TABLES 5 AND 6 AROUND HERE]

Second, in light of the low within variation of our main explanatory variable, we considered whether unobserved heterogeneity represents an issue in our estimates. We adopted a pre-sample mean estimator (Blundell et al., 2002) in which the inclusion of the firm's pre-sample mean of patent applications among the explanatory variables proxies for the unobserved difference among firms in

[10] Comparable results are obtained for the other model specification and are available from the authors upon request.

their ability to patent and allows us to control for possibly correlated, time-invariant heterogeneity. As expected, we find a positive and significant effect of patent pre-sample mean. More importantly, even after capturing the firm specific-effect through the pre-sample mean, our main results are confirmed. Improvements in institutional quality increase the innovative performance of SIEs at a faster pace compared to private firms. It is worth noticing that this latter result partially depends on the variable chosen to measure of institutional quality, i.e. it is confirmed when we use the "control of corruption" and the "regulatory quality" variables. Conversely, public and private enterprises do not differ in their innovation performance when other institutional quality variables are considered.

[TABLE 7 AROUND HERE]

Third, we evaluated whether our results are robust when the quality of innovation output, and not only the simple count of patent applications, is taken into consideration. To do so, we resorted to a consolidated literature that developed a number of indicators to proxy for the quality of patents companies apply for (Squicciarini et al., 2013; Lanjouw and Schankerman, 2004). For the purpose of our robustness check, we relied on three main indicators: the number of granted patents and the number of patent applications weighted by the number of citations received in forward 3- and 5-year windows. The results reported in Table 8 support our main results.

[TABLE 8 AROUND HERE]

We also considered whether our results are driven by some relevant outliers (e.g. firms with a particularly intensive patenting activity) given the long fat tails in the distribution of patent applications[11]. Therefore, we tested the robustness of our results by trimming the right tail of the patent distribution. Table 9 show that our results are also confirmed when yearly observations with more than 500 patent applications are excluded from our sample, leading us to 4810 firm-year observations.[12]

[TABLE 9 AROUND HERE]

[11] The Skewness/Kurtosis tests for normality reject the hypothesis that the patent-counting variable is normally distributed. While both values depart from those typical of a normal distribution, Kurtosis is much larger (around 500, compared to a value of 3), thus supporting the presence of fat tails in the patent distribution.

[12] Consistent results were also obtained when companies with more than 1000 patents were removed from the sample.

Finally, given the widespread geographical distribution of the enterprises and the resulting low number of observations that are obtained once country institutional variables are introduced, we wanted to exclude the possibility of our results being driven by particular enterprises located in particular countries. To address this issue, we also ran the previous regression: i) with institutional quality indicators aggregated in quintiles; and ii) by replacing them with a binary variable that allows enterprises located in the top 25 institutional countries to be distinguished from the others. The results are consistent with previous findings and available upon request.

6. Conclusions

This paper contributes to the current debate on the role of governments in supporting innovation by taking an innovative research avenue. While a wide and well established macroeconomic literature points respectively to the role of innovation and of institutions as facilitators of growth, we combined these intuitions in a firm-level frame of analysis. By considering patents as an empirical proxy of knowledge creation by firms, our findings confirm that the quality of government is indeed correlated with the innovation performance of major telecommunication companies worldwide. This is *per se* an interesting result because the telecommunication industry has been pivotal in changing modern economies through the transition from analogue telephony to digital information and the internet economy.

Ownership of firms is *per se* an institutional arrangement, and the quality of firms' governance should be correlated to their performance, including their innovativeness. Previous literature largely supported the privatisation of state-owned enterprises by pointing to the low quality of their governance. The divestiture of British Telecom by the Thatcher government more than thirty years ago has been defined 'the mother of all privatizations' (Megginson and Netter, 2001). However, governments around the world are still the ultimate owners or top shareholders of major telecom companies, from Scandinavian countries to China. We find that the innovative performance of SIEs, while often inferior to that of their private counterparts, is strongly affected by the quality of government. We interpret this result in accordance to Borghi et al (2016) who suggest that while any firm may enjoy the benefits of good government in terms of a favourable external environment, there is an additional specific effect for SIEs. They directly benefit from quality of government in terms of being subjected to less political interference in the appointment of managers and of transparency of the public mission that is assigned to them.

For the first time in the literature, we empirically study to what extent public control of SIEs can reverse the traditional negative perception of SIEs in terms of innovativeness when the government is of high quality. In fact, we find that when the government of a country with good institutions (low corruption, high government effectiveness, high rule of law, good regulatory quality, good voice and accountability, high political stability) controls a major telecommunication company, this company is able to invest more in knowledge creation than its private counterpart. This novel and striking finding, which goes against a mainstream tenet about the low performance of SIEs, suggests that government ownership may act as a 'patient investor' mechanism against the short-termism of private ownership. This result matches very well with a recent stream of empirical literature that has found decreasing R&D expenditures in privatised firms. In fact, we find that there is no difference in the innovativeness of private and partially privatised telecommunication companies.

We do not want to draw any strong policy implications from our results. We are not claiming that SIEs are more innovative than their private counterparts, as in fact we find the opposite to be true when considering countries with poor institutional quality. Our findings underline that improvements in institutions and in SIEs' internal governance (see e.g. OECD 2015) can be an alternative to (full) privatisation in enhancing dynamic efficiency within a firm. Therefore, future research should explore this question: to what extent could a mission-oriented innovation policy in countries with high quality of institutions include reformed public enterprises in its scope, perhaps as an alternative or a complement to subsidies to the R&D of private firms or other public policies? In this perspective, the government's partial ownership of firms in some industries may enable it to take on the role of a patient investor, which is known to be favourable to corporate innovativeness.

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Table 1. Sample descriptive statistics categorised by ownership type

	Median	Mean	SD	Min	Max
			Operating Revenues (th. $)		
Private Enterprises	26,838	1,690,759	9,609,552	0	163,800,000
SIEs	21,315	696,792	2,130,091	0	17830,028
			Total Assets (th. $)		
Private Enterprises	59,439	3,415,506	20,700,000	0	402,700,000
SIEs	41,498	1,480,163	4,568,302	10	46,969,852
			Intangible Assets (th. $)		
Private Enterprises	3,243***	1,336,742	10,400,000	0	225,300,000
SIEs	2,592***	295,869	1,154,485	0	98,45,798
			Tangible Assets (th. $)		
Private Enterprises	9,535	1,198,763	7,411,236	0	124,500,000
SIEs	12,763	518,957	1,687,615	0	18,068,106
			Listed		
Private Enterprises	0.0***	0.48	0.50	0	1
SIEs	1.0***	0.55	0.50	0	1
			Year of incorporation		
Private Enterprises	1997	1990	24	1846	2014
SIEs	1995	1988	27	1852	2013
			Patent applications		
Private Enterprises	0.0***	6.6	61.7	0.0	1,571.0
SIEs	0.0***	55.1	375.4	0.0	4,035.0
			Control of Corruption^		
Private Enterprises	82***	73	23	2	100
SIEs	62***	63	26	1	100
			CR_4		
Private Enterprises	0.89***	0.84	0.17	0.32	1.00
SIEs	0.94***	0.88	0.15	0.32	1.00

*** Difference significant at 1 percent level according to Wilcoxon rank-sum test. ^ Institutional quality indicators refer to the country of the enterprise and are reported in percentile rank terms, ranging from 0 (lowest rank) to 100 (highest rank).

Table 2. Knowledge production function estimates: the role of ownership type

	(1)	(2)	(3)	(4)
Tangible Assets	-0.212***	-0.154***	-0.229***	-0.185***
	(0.044)	(0.046)	(0.053)	(0.040)
Intangible Assets	0.113***	0.053	0.150**	0.075*
	(0.042)	(0.044)	(0.059)	(0.045)
Operating Revenues	0.276***	0.276***	0.392***	0.357***
	(0.071)	(0.070)	(0.076)	(0.084)
Age	1.534***	1.247***	1.126***	0.831***
	(0.174)	(0.171)	(0.159)	(0.116)
Listed		1.580***	1.791***	1.833***
		(0.256)	(0.265)	(0.224)
Concentration Ratio			-5.073***	-5.596***
			(0.903)	(0.739)
SIE				1.702***
				(0.164)
Constant	-6.767***	-6.926***	-2.988**	-1.601
	(0.982)	(0.956)	(1.257)	(1.272)
Observations	4,858	4,858	4,858	4,858
Year and Country	YES	YES	YES	YES
r2_p	0.770	0.787	0.820	0.856
vcetype	Robust	Robust	Robust	Robust

*** p<0.01, ** p<0.05, * p<0.1; robust standard errors are reported in parentheses.

Table 3. The role of institutional quality and public ownership in firm innovation activity

	(1)	(2)
Tangible Assets	-0.175***	-0.171***
	(0.035)	(0.035)
Intangible Assets	0.001	-0.008
	(0.035)	(0.033)
Operating Revenues	0.232***	0.247***
	(0.065)	(0.066)
Age	0.833***	0.831***
	(0.102)	(0.101)
Listed	3.393***	3.498***
	(0.390)	(0.394)
Concentration Ratio	-5.242***	-5.538***
	(0.445)	(0.435)
SIE	2.965***	-2.600***
	(0.258)	(0.531)
Control of Corruption (CC)	0.078***	0.028***
	(0.005)	(0.007)
SIE *CC		0.063***
		(0.007)
Constant	-9.576***	-4.986***
	(1.181)	(1.101)
Observations	4,854	4,854
Year and Area	YES	YES
r2_p	0.699	0.707
vcetype	Robust	Robust

*** p<0.01, ** p<0.05, * p<0.1; robust standard errors are reported in parentheses. When country institutional quality indicators are introduced, we use 7 Macro-area dummies instead of country dummies, as the number of observations within cells tend to be low and this sometimes prevents the convergence of the maximum likelihood

Table 4. The role of institutional quality and public ownership in firm innovation activity – alternative institutional indicators

	(1)	(2)	(3)	(4)	(5)
SIE	-3.250***	-2.191***	-1.646***	0.270	0.614
	(0.869)	(0.644)	(0.574)	(1.076)	(0.544)
Government Effectiveness (GE)	0.034***				
	(0.011)				
SIE*GE	0.069***				
	(0.011)				
Rule of Law (RL)		0.039***			
		(0.008)			
SIE*RL		0.059***			
		(0.008)			
Regulatory Quality (RQ)			0.027***		
			(0.008)		
SIE*RQ			0.055***		
			(0.008)		
Voice and Accountability (VA)				0.058***	
				(0.014)	
SIE*VA				0.033**	
				(0.014)	
Absence of Political Violence (PV)					0.022***
					(0.007)
SIE*PV					0.031***
					(0.008)
Constant	-5.246***	-5.348***	-4.859***	-6.220***	-4.561***
	(1.196)	(1.039)	(0.986)	(0.952)	(1.369)
Observations	4,854	4,854	4,854	4,854	4,854
Year and Area	YES	YES	YES	YES	YES
r2_p	0.673	0.696	0.662	0.716	0.666
vcetype	Robust	Robust	Robust	Robust	Robust

*** p<0.01, ** p<0.05, * p<0.1; robust standard errors are reported in parentheses. The following explanatory variables are included in the regressions although their coefficients have not been reported for space reasons: operating revenues; tangible and intangible assets; age of the firm; whether it is listed and concentration ratio. The sign of their coefficient is consistent with the results presented in Table 3. When country institutional quality indicators are introduced, we use 7 Macro-area dummies instead of country dummies as the number of observations within cells tend to be low and this sometimes prevents the convergence of the maximum likelihood

Table 5. Role of institutional quality and public ownership - Zero-inflated Poisson regression

	(1) Poisson	(2) inflate
SIE	-7.345***	-1.447***
	(1.159)	(0.521)
Control of Corruption (CC)	-0.036***	-0.037***
	(0.012)	(0.004)
SIE*CC	0.110***	0.009
	(0.014)	(0.006)
Constant	6.768***	6.213***
	(1.650)	(0.515)
Observations	4,854	4,854
Year and Area	YES	YES
vcetype	Robust	Robust

*** p<0.01, ** p<0.05, * p<0.1. Robust standard errors are reported in parentheses. The following variables are included in the regressions although their coefficients have not been reported for space reasons: operating revenues; tangible and intangible assets; age of the firm; whether it is listed; time and geographical fixed effects. When country institutional quality indicators are introduced, we use 7 Macro-area dummies instead of country dummies as the number of observations within cells tend to be low and this sometimes prevents the convergence of the maximum likelihood

Table 6. Role of institutional quality and public ownership - Hurdle Poisson model

	(1) logit	(2) poisson
SIE	-0.034***	-0.036***
	(0.003)	(0.012)
Control of Corruption (CC)	-0.750*	-7.353***
	(0.412)	(1.159)
SIE*CC	-0.001	0.110***
	(0.005)	(0.014)
Constant	6.406***	5.569***
	(0.494)	(1.568)
Observations	4,854	4,854
Year and Area	YES	YES
vcetype	Robust	Robust

*** p<0.01, ** p<0.05, * p<0.1. Robust standard errors are reported in parentheses. The following variables are included in the regressions although their coefficients have not been reported for space reasons: operating revenues; tangible and intangible assets; age of the firm; whether it is listed; time and geographical fixed effects. When country institutional quality indicators are introduced, we use 7 Macro-area dummies instead of country dummies as the number of observations within cells tend to be low and this sometimes prevents the convergence of the maximum likelihood

Table 7. Role of institutional quality and public ownership– Patent Pre-sample mean

	(1)
SIE	-2.397**
	(1.134)
Patent pre-sample mean	0.690***
	(0.030)
Control of Corruption (CC)	-0.010
	(0.009)
SIE*CC	0.026**
	(0.012)
Constant	1.477
	(1.603)
Observations	4,854
Year and Area	YES
vcetype	Robust

*** p<0.01, ** p<0.05, * p<0.1. Robust standard errors are reported in parentheses. The following variables are included in the regressions although their coefficients have not been reported for space reasons: operating revenues; tangible and intangible assets; age of the firm; whether it is listed; time and geographical fixed effects. When country institutional quality indicators are introduced, we use 7 Macro-area dummies instead of country dummies as the number of observations within cells tend to be low and this sometimes prevents the convergence of the maximum likelihood

Table 8. Role of institutional quality and public ownership

VARIABLES	(1) Granted Patent	(2) 3-year citations	(3) 5-year citations
SIE	-2.864***	-4.933***	-5.415***
	(0.772)	(1.027)	(1.118)
Control of Corruption (CC)	0.042***	0.026***	0.025***
	(0.007)	(0.006)	(0.006)
SIE*CC	0.037***	0.056***	0.060***
	(0.009)	(0.011)	(0.012)
Constant	-9.910***	-5.429***	-5.259***
	(0.822)	(0.746)	(0.745)
Observations	4,854	4,854	4,854
Year and Area	YES	YES	YES
vcetype	Robust	Robust	Robust

*** p<0.01, ** p<0.05, * p<0.1. Robust standard errors are reported in parentheses. The following variables are included in the regressions although their coefficients have not been reported for space reasons: operating revenues; tangible and intangible assets; age of the firm; whether it is listed; time and geographical fixed effects. When country institutional quality indicators are introduced, we use 7 Macro-area dummies instead of country dummies as the number of observations within cells tend to be low and this sometimes prevents the convergence of the maximum likelihood

Table 9. Role of institutional quality and public ownership– Trim of the right tail of patent distribution (>500 patents)

	(1)
SIE	-3.143***
	(0.589)
Control of Corruption (CC)	0.026***
	(0.007)
SIE*CC	0.040***
	(0.008)
Constant	-5.827***
	(0.869)
Observations	4,810
Year and Area	YES
vcetype	Robust

*** p<0.01, ** p<0.05, * p<0.1. Robust standard errors are reported in parentheses. The following variables are included in the regressions although their coefficients have not been reported for space reasons: operating revenues; tangible and intangible assets; age of the firm; whether it is listed; time and geographical fixed effects. When country institutional quality indicators are introduced, we use 7 Macro-area dummies instead of country dummies as the number of observations within cells tend to be low and this sometimes prevents the convergence of the maximum likelihood