Innovation at State Owned Enterprises*

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Abstract

We investigate the impact of state ownership on the innovativeness of firms, as measured by the number, quality, and value of the patents produced. In a sample of listed European firms, we find that minority government ownership increases investment in research and development, especially for financially constrained firms and during "normal" macroeconomic conditions. Yet, government control leads to the opposite effect, by imposing myopic goals and complicating access to private equity markets. Overall, state owned enterprises (SOEs) produce fewer patents per dollar invested and about 10% fewer patents in absolute terms. When comparing SOE patents to private-sector patents, we find no difference in patent quality as measured by the number of citations received per patent or by the market reaction at patent publication. Furthermore, we find no increase in the number of patents focused on sustainable technologies, suggesting that SOEs do not emphasize innovation that produces public goods or social spillovers.

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1. Innovation at state owned enterprises

The past two decades have seen both an increase in government ownership of firms, following a previous wave of privatizations in western markets, and substantial changes in the dominant type of state ownership model.[1] In contrast to the old model of state-led entrepreneurship, in which the state owned and ran sprawling industrial conglomerates and monopolistic national champions, today the most common incarnation of government ownership is the holding of minority stakes in publicly traded firms (Bortolotti and Faccio, 2009; Megginson and Fotak, 2015). The impact of government stakes on publicly traded firms has accordingly attracted substantial interest.[2] We investigate the impact of state ownership on an aspect of corporate behavior that has so far been ignored by the literature on government ownership: the innovativeness of firms. Our aim is to explore how government ownership affects investment in research and development (R&D), the R&D efficiency of firms, and the ultimate output of the R&D process, as measured by the number, quality, and value of patents generated by the firm.

There are various ways in which government ownership could affect the investment in innovation by state-owned enterprises (SOEs). First, extant literature emphasizes the lack of incentives for SOE managers, which could lead to under-exertion of effort and excessive risk-aversion.[3] This "quiet life" channel would imply a lower level of effort in general, and lower levels of investment in risky activities such as R&D. In addition, government ownership could impose short-term social and political goals (Kahan and Rock, 2010; Shleifer, 1998), such as the support of high levels of employment that divert firm resources away from investments with a long-term payoff, such as R&D. This "myopic government" channel also implies a lower level of investment in R&D.

On the other side, there are well-documented constraints on investment in R&D that government ownership could help relax. First, extant research on innovation finds that managerial risk-aversion and short-termism (due to pressures from investors) lead to underinvestment in R&D

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[1] Borisova et al. (2015) report that, "contrary to public perceptions and despite the worldwide success of state privatizations, from 2003 to 2013 governments have acquired more assets through stock purchases ($1.52 trillion) than they have sold through privatizations ($1.48 trillion)."

[2] Dewenter, Han, and Malatesta (2010), Kotter and Lel (2011), Knill, Lee, and Mauck (2012), and Bortolotti, Fotak, and Megginson (2015) discuss the impact of a prototypical type of sovereign minority investor, the sovereign wealth fund, on firm behavior and valuation. Borisova et al. (2015) investigate the impact of government shareholding on the cost of debt of publicly traded firms.

[3] Boubakri, Cosset, and Saffar (2013) examine the role of state ownership in corporate risk-taking, using evidence from privatizations. They find strong and robust evidence that state ownership is negatively related to corporate risk-taking.

(Lerner and Hall, 2010). The long investment horizons of governments and the stable availability of financing provided by state-owned banks allow state-owned enterprises (SOEs) to focus on long-term projects, including R&D, providing insulation from short-term market pressure. In short, while there is a risk that governments impose their own short-term, myopic goals, privileged access to finance for SOEs might relax short-term pressures from the financial sector. Second, the high opacity and long-horizon of R&D investment lead to well-documented underfunding. Government ownership, by providing implicit debt guarantees and access to state owned banks, could relax financial constraints and allow for larger investment in R&D.[4] Yet, government ownership is potentially a double-edged sword, as it could also increase financial constraints of firms by preventing access to equity markets.[5] Third, Arrow (1951) and Debreu (1959) find that private agents underinvest in goods that produce high levels of social-benefit spillover and have low commercial value, as they are unable to fully internalize the benefits of such investments. Accordingly, privately held firms underinvest in technology (Arrow, 1962; Lerner and Hall, 2010). Yet, governments and affiliated SOEs share some of those social goals and are thus better posed to internalize the benefits produced by innovation. This would imply higher levels of investment in R&D, with a particular bias towards innovation with social spillover.

The above arguments point to conflicting predictions in regards to the relation between government ownership and R&D investment. Our empirical analysis aims at shedding light on the issue—yet, we are only able to document the predominant, net effect. On the other side, extant literature documents that government-owned and mixed-ownership firms are less efficient than private enterprises, due to conflicting objectives (Kahan and Rock, 2010; Shleifer, 1998), lower managerial incentives (Borisova et al., 2012), and politicians extracting rents from firms, either to

[4] O'Hara and Shaw (1990), Faccio, Masulis, and McConnell (2006), Borisova and Megginson (2011), Iannotta, Nocera, and Sironi (2013), Acharya, Anginer, and Warburton (2016), and Borisova et al. (2015) all find that government ownership leads to implicit debt guarantees, which lower the cost of capital of state owned enterprises.

[5] Stulz (2005) shows that firms subject to the "twin agency" problems, where the threat of insider expropriation is compounded by that of government expropriation, face a higher cost of capital. Ben-Nasr, Boubakri, and Cosset (2012) find government ownership to be associated with a higher cost of equity due to the threat of political interference. Chen, Wang, Li, Sun, Tong (2015) find that SOEs underprice IPOs more than private-sector firms, suggesting difficulties in rising equity capital. D'Souza and Nash (2017) find that listed firms with majority government ownership face agency problems (due to conflicting priorities of the government and minority shareholders) that hinder access to foreign capital markets. Jiang, Lee, and Yue (2010) and Cheung, Rau, Stouraitis (2010) find evidence of government owners extracting rents from minority investors.

reward supporters or themselves (Jiang, Lee, and Yue, 2010; Cheung, Rau, Stouraitis, 2010).[6] Hence, we expect government shareholding to lead to lower efficiency. To investigate this issue, we test whether government ownership is associated with fewer patents per unit of invested capital. Lower efficiency could manifest not only in a lower patent count per unit of capital invested, but also in patents of lower quality. Accordingly, we aim at testing whether government ownership is associated not only with the sheer number of patents produced, but also with the quality of the patents—which we proxy, as in extant literature, by the number of citations received from other patent filings.

In empirical analysis, we focus on a sample of publicly traded European state-owned enterprises (SOEs), including firms that majority-, and minority-owned by governments. We adopt here a broad definition of the term "state-owned enterprise" encompassing every firm with a domestic government stake greater than zero, even if such stake is a small minority holding. We restrict our analysis to European firms to benefit from a uniform intellectual-property regime (so to allow for comparability in the number of patents registered by firms), while still benefitting from a wide range of ownership structures. We obtain data on government ownership from the BvD Orbis database for the years spanning 1999 to 2016. We define a firm as a "state-owned enterprise" (SOE) if the government owns any share of voting rights in the firm. Aside from a binary indicator variable identifying the presence of a government shareholder, we further construct a continuous variable identifying the total size of the stake owned by the government, both direct and indirect. We restrict our analysis to domestic government ownership and focus on firms headquartered in one of the twenty-eight countries that are member of the European Union as of December 2016.[7] We analyze publicly listed firms so that we can obtain data on research and development expenditures, as well as other financial data from Thomson Reuter's Worldscope database. Finally, we obtain data on patents from the European patent office's (EPO) PATSTAT database. Our sample covers 5,171 firms, of which 1,363 are SOEs, and 3,808 have no government ownership at any point in our sample ("non-SOEs"). Of the government-owned firms, 291 have an average

[6] Extant privatization finds that the efficiency of state-owned enterprises increases post-privatization. The early literature on privatizations is surveyed by Megginson and Netter (2001) and Djankov and Murrell (2002). More recent evidence includes Sun and Tong(2003), Boubakri, Cosset and Guedhami (2005), and Estrin, et al. (2009), among others. Empirical evidence of inefficiency in mixed-ownership enterprises is provided by Eckel and Vermaelen (1986), Boardman and Vining (1989), and Chen, Firth and Xu (2008). Borisova, Brockman, Salas, and Zagorchev (2012) document that ownership by central and local governments is associated with worse corporate governance.

[7] While we include all twenty-eight countries in our data filter, we find usable observations for firms in twenty-six countries only. Further detail on the distribution by country is presented in Table 2.

government stake exceeding fifty percent, while the rest (1,072) have minority government ownership stakes.

Our final sample contains 34,192 firm-years with complete data. Of those, 30,384 are non-SOEs while 3,358 are SOEs, with average government ownership of 6.83%. Univariate statistics reveal important differences. SOEs are larger (greater total assets), more profitable (higher ROA) and display greater leverage. We exclude financials from our sample. The SOE sample is more heavily tilted towards manufacturing, while the sample of non-SOE firms has a higher fraction of service firms. As expected, the fraction of transportation firms and public utilities is also higher in the SOE sample. Due to those differences in industrial distribution, we control for industry-level characteristics with industry (and industry-year, where feasible) fixed effects, except when including firm fixed effects. More importantly, SOEs display a larger investment in R&D when scaled by size, at 2.29% of total assets, compared to 1.86% for private-sector firms. SOEs are also much larger on average. Hence, the absolute dollar investment in R&D by SOEs is almost three times as large as for non-SOEs (USD 13.6 million vs. USD 5.2 million). This translates into a higher number of patents for SOEs: the mean number of patents per year is 9.25 for SOEs, vs. 5.01 for the non-SOE sample. SOE patents receive about the same number of citation per patent (0.06-0.07). Overall, the comparison reveals that SOEs invest substantially greater amounts in research and development (both as a proportion of total assets, but especially in absolute terms) and consequently generate a higher number of patents. Yet, the increase in R&D for SOEs is relatively greater than the resulting increase in patent count, pointing to lower efficiency of the R&D process, or a lower count of patents "per dollar of R&D."

We investigate more formally the relationship between R&D expenditure, as a proportion of total assets, and government ownership in a multivariate regression setting. We control for country-year and industry-year fixed effects, but also for time-variant firm characteristics. We find that the presence of a government shareholder is associated with greater R&D expenditure. The results are both statistically and economically significant, with the presence of a government shareholder increasing investment in R&D by about 5.55% (while the increase is estimated at 0.1% of total assets, the average R&D expenditure for firms in our sample is about 1.8% percent of total assets). Yet, when we control for the size of the stake owned by the government shareholder, we find more nuanced results. While the presence of a government shareholder is associated with a higher expenditure in R&D, a large, controlling stake is associated with a decline in R&D expenditure. Our results are consistent with the conjecture that the presence of a government shareholder encourages expenditure in R&D by providing access to cheap external funding, presumably via state-owned banks, while a controlling government stake leads to the imposition of myopic, short-term goals similar to Shleifer (1998).

To further investigate this interpretation, we add to our models variables identifying financially constrained firms and firm-years affected by financial crises—and interactions of these variables with metrics of government ownership and control. We use an indicator variable based on the Laeven and Valencia (2013) dataset to identify financial crises at the country-year level. We identify financially constrained firms by computing the Hadlock and Pierce (2010) (HP) index for each firm, at a yearly frequency. We find that the increase in R&D investment associated with the presence of a government shareholder is even stronger in capital constrained firms, consistent with the hypothesis that the presence of a government shareholder relaxes financial constraints. Further supporting this interpretation, we find that the effect is weaker during a financial crisis, as state-owned banks are likely to face other priorities and funding constraints during times of macro-economic distress. On the other side, the interaction between firm-level financial constraints and government control points to an additional decline in R&D expenditures. This result suggests that government control (as opposed to government minority ownership) increases financial constraints, presumably by discouraging access to equity capital markets. This is consistent with a large literature that documents that equity issuances by government-controlled firms are slower, more complex, and more expensive processes that a simple seasoned equity offering by a private-sector firm, leading to a higher cost of private-sector equity capital (Ben-Nasr, Boubakri, and Cosset, 2012; Chen et al., 2015; D'Souza and Nash, 2017).

Clearly, one of the challenges in our setting lies in the fact that government ownership is not random—and even the univariate statistics indicate that SOEs tend to be larger, more profitable, and more highly levered. This leaves open the potential for confounding effects due to omitted variable biases induced by unobservable firm characteristics. Accordingly, in robustness tests, we first re-estimate the same regression models with firm fixed effects, to control for time-invariant unobservable firm characteristics. We find that our main findings regarding government presence and control are unaffected. On the other side, we do not find significance in the interaction between measures of firm-level financial constraints and government ownership, possibly due to the low variation in time after absorbing cross-sectional difference with firm fixed effects.

As an additional test, we employ a two-stage model to control for the possibly endogenous nature of government ownership, mimicking the approach by Borisova et al. (2015). In the first stage, we instrument government ownership and control using variables that have been found to be related with government ownership, but which are unlikely to affect firm-level R&D expenditures directly: political orientation of the ruling executive (left vs. right-wing), an identifier for civil-law legal systems, the level of investment in the country, scaled by GDP, and the country-level unemployment rate. Once more, we confirm our main findings.

Yet, we are interested, ultimately, in innovation output. Accordingly, we similarly analyze the relationship between the number of patents produced by a firm, scaled by the amount invested in R&D, and government ownership. In a multivariate setting, we analyze the impact of patent production over varying time horizons (from one to three years), while controlling for industry-year and country-year fixed effects, but also for time-variant firm characteristics. We find that the presence of a government shareholder is negatively related to the number of patents produced by SOEs over the following years. Our results point to a 10.2% decrease in the production of patents scaled by R&D expenditure. However, government control (as opposed to simply minority ownership) does not appear to affect the efficiency of intellectual property production. These results are robust to the inclusion of firm fixed effects.

Given that our main findings indicate an increase in R&D expenditure (at least for firms with minority government ownership and during non-crises periods), but a decrease in research efficiency (fewer patents per dollar invested in R&D), the net impact on firm innovativeness is a matter ripe for empirical analysis. Accordingly, we re-estimate similar regression specifications with the number of patents (or log of the number of patents) per firm-year as a response variable. Overall, we find that the presence of a government shareholder is associated with a 10% decline in the number of patents. The effect is, however, weaker (approximately a 3% decline) in financially constrained firms, as those appear to benefit from a greater investment in R&D thanks to access to capital via state-owned banks. These results, as before, are robust to the inclusion of firm fixed effects.

Given that governments have different goals than private-sector shareholders, we hypothesize that government ownership could affect not only R&D investment and the quantity of innovation but also the quality of innovation. Extant literature finds that one of the reasons for underinvestment in innovation by private-sector actors is the inability to fully internalize the value of a technological breakthrough. Early-stage technologies are the ones that provide the most technological spillover—and whose value is the hardest to fully internalize. Early-stage patents would likely generate higher citation counts, as they lead to derived inventions. On the other side, government ownership might lead to inefficiencies that, in turn, lead to investment in low-impact innovations. Such low-impact innovation could be associated with a low citation count. Given such conflicting predictions, we investigate the impact of government ownership and control on the number of citations per patent produced. We regress the number of citations per patent per R&D dollar spent against variables identifying government ownership and control and the usual interactions with variables identifying financially constrained firms and financial crises. After controlling for time-variant firm characteristics, country-year fixed effects, industry-year fixed effects, and in robustness tests firm fixed effects, we find no evidence of an impact of government ownership on the average citations per patent. This suggests that SOE patents do not differ in terms of quality from private-sector patents.

Another indirect measure of patent quality is the commercial value of the patent itself. While we cannot observe patent value directly, similar to Kogan et al. (2017), we proxy its quality by measuring the stock price reaction of the patenting firm at the announcement of a patent's application. If SOE patents are more oriented towards social, rather than commercial, objectives, then the average market reaction at announcement should be weaker, reflecting a lower patent commercial value. In a series of event studies, we find that the publication of a patent leads to an abnormal return of about 0.67% over the 21-day window surrounding the patent publication. In comparison, the related figure is 0.64% for the benchmark sample of private-sector patents. Tests for significance of the difference in abnormal returns reveal that the difference is not statistically significant, nor does it appear economically relevant. We find robust results over different event-time windows. Overall, our results indicate that SOE patents have substantial commercial value, increasing firm valuation by approximately 0.67% at announcement, which is not different from the impact of private-sector patents.

The different priorities of government owners, as compared to private-sector shareholders, could also lead to a greater focus on new technologies that can provide benefits to society at a large. Such technologies have value that cannot be fully captured by the commercial value of the patent. For that reason, socially beneficial technologies will likely be underfunded by the private sector. Governments, on the other hand, are in a position to prioritize patents with such high social value. We identify a set of "sustainable patents" related to technologies aimed at climate change mitigation and, in broader terms, related to clean energy sources. Our prior is that SOEs, given their greater concern for patents with social value, are more likely to pursue innovation aimed at such sustainable patents. Yet, in empirical tests, we find no significant relation between the presence of a government shareholder, the size of the stake owned by the government, nor government control and the number of sustainable patents produced by the firm. This confirms that government ownership does not affect the type of innovation pursued by the firm. Our manuscript contributes to two streams of the empirical corporate finance literature. A stream of recent papers examines the effect of government shareholding on listed firms (Dewenter, Han, and Malatesta, 2010; Kotter and Lel, 2011; Knill, Lee, and Mauck, 2012; Borisova and Megginson, 2011; Bortolotti, Fotak, and Megginson, 2015; Borisova et al., 2015). Within the literature on government ownership, we fill an important gap by showing that state ownership has a deleterious impact on innovativeness, despite the fact that it helps financially constrained firms obtain credit and increase R&D investment. While this result has been often predicted in theoretical discussion on state ownership, our manuscript is the first, to our knowledge, to provide robust empirical evidence in regards. This deleterious impact translates into a lower number of patents, both in absolute terms and scaled by the amount of funds invested in R&D. On the other side, we do not find evidence of an impact on patent quality (as measured by the number of cites) or commercial value (as measured by the market reaction at announcement).

We also contribute to the growing literature on corporate innovativeness. There are multiple works that examine firm characteristics that influence innovation such as firm boundaries (Seru, 2014), corporate governance (Meulbroek et al., 1990), and executive characteristics (Chemmanur et al., 2015). A growing literature on the availability of financing suggests that while equity capital may be preferential for the funding of risky projects (Lerner and Hall, 2010), firm innovation output can still be influenced by the availability of access to debt markets (Amore et al., 2013; Cornaggia et al., 2015). If debt markets are indeed important for the financing of innovation, state ownership may provide another mechanisms for firms to access debt when traditional financial intermediaries fail to fund innovative activities. Other works examine the role private institutional owners play in driving innovation. Aghion et al. (2013) find that institutional owners encourage more innovation allowing managers to "swing for the fence" instead of encouraging myopic, short-term decisions based on career concerns. This is similar to the failure tolerant culture venture capitalist can create to spur innovative output (Tian and Wang, 2014). While it is possible that sovereign owners may create a similar long-horizon culture within the firm, SOE's balance other non-revenue maximizing objectives like job creation which may run counter to the results in Aghion et al. (2013). A large portion of the innovation literature focuses on intellectual property in the United States. More recently, Ayyagari et al. (2011) examine innovation, broadly defined, in emerging economies and finds that new product lines and new technology development can be hampered by controlling state ownership. Cao et al (2016) find that state ownership improves innovative efficiency through the relaxation of financial constraints in Chinese owned firms. Similar to these latter studies, we examine investment and patenting efficiency outside the United States to take advantage of the diverse sovereign ownership in European firms. Accordingly, we examine firms across 26 countries which allows us to address endogenous concerns that may be driven by country specific effects and more broadly address the influence of state ownership on innovation and investment.

2. Data and univariate statistics

In each of the sections below we describe the sources from which we draw our data. In Table 1, we define the various variables used in the tests that follow and the data source used to create each variable. Table 2 provides summary statistics for the industry composition, country composition, full sample of firm-year observations, and univariate t-tests comparing firm characteristics for the SOE and non-SOE firms.

2.1 Intellectual property

Our patent data comes from two sources. The initial patent information is taken from BvD Orbis, which provides granted patent data in addition to raw citation counts for each individual patent. BvD Orbis reports patents across 41 different patent offices and draws its patent information from the EPO's PATSTAT database. BvD Orbis has disambiguated the patent information and thus provides a link between granted patents and firm accounting and ownership information. We take the intellectual property data from BVD Orbis and aggregate the total number of granted patents across all European Patent Convention (EPC) member offices for each firm-year. As is custom in the literature, we use the year of application to associate the patent with its most likely time of invention, i.e. when the firm was most likely to expend effort and investment to produce the invention. While BvD Orbis provides raw citation data, it is important to adjust for citation truncation issues as noted in Hall et al. (2000). Because BvD Orbis only provides raw citation information, we also gather patent data from the EPO's PATSTAT product. PATSTAT contains patent applications and grant information for the EPC member offices and the European patent office in addition to citation data for each patent. Following Hall et al. (2000) and Levine et al. (2015) we calculate the citation truncation adjustment for each industry patent class (IPC) and grant lag of the citation distribution.[8] We report the citation lag distribution for each IPC class in the appendix Table A1. Because we include patent counts and citations across different European patent offices, we calculate the citation truncation adjustment for multiple individual patent offices and perform a patent office specific truncation adjustment where there is enough data to form the citation lag distribution. Figure A1 compares the citation adjustment factor for industry patent classification (IPC) A: Human necessities across multiple patent offices. The coordinating

[8] Similar to Levine et al. (2015) we estimate the citation lag distribution over a 30 year window for each grant year and patent class in the window 1976-1985. We then average the citation lag distribution for each industry class over the 10 years to generate an average citation lag distribution for European patents.

adjustment factors are reported in Table A2. As shown in Figure A1 and Table A2, there is some significant heterogeneity in the citation accumulation timing across the different patent offices, necessitating office specific adjustments when possible. When there is not enough time series information to generate an office specific truncation adjustment, we use the aggregate patent data across all EPC offices to generate an average citation lag distribution reported in Table A1.

2.2 Sovereign ownership

We obtain data on government ownership from the Bureau van Dijik Orbis database for the years spanning 1999 to 2016.[9] We define a firm as a "state-owned enterprise" (SOE) if the government owns any share of voting rights in the firm. Aside from a binary indicator variable identifying the presence of a government shareholder, we further construct a continuous variable identifying the total size of the stake (as a proportion of voting rights) owned by the government. We restrict our analysis to domestic government ownership, direct or indirect. "Indirect" ownership is defined as ownership through controlled entities (any stake owned by an entity in which the government owned a majority of voting rights would be included in our definition of "government stake"). We focus on firms headquartered in one of the twenty-eight countries that are member of the European Union as of December 2016. We exclude financials and firms for which we have incomplete accounting data (as discussed in the following section). Our final sample covers 5,171 firms, of which 1,363 have non-zero government ownership at some point during the time interval of interest, and 3,808 have no government ownership at any point in our sample. Of the government-owned firms, 291 have an average government stake exceeding 50%, while the rest (1,072) have minority government ownership stakes.

In addition to data on government ownership, we obtain firm level primary SIC codes, to identify the main industry in which the firm operates, and a variable identifying the country of headquarters. We report the industrial distribution of the firms in our sample in Table 2, Panel A. Both SOEs and non-SOE samples contain a large proportion of manufacturing firms (46% of the SOE sample and 39% of the non-SOE sample) and firms in the service industry (21% and 30%). "Transportation and Public Utilities" constitute about 13.5% of the SOE sample and 9.5% of the

[9] Our choice is restricted by data availability in the Orbis database. The version of the dataset we employ is via an online platform made available in the summer of 2016 as part of a transition to a new database ("Orbis historical"). It contains the data that was previously available only in CDs, including historical data for both listed and delisted firms. Data coverage prior to 1999 is available, but scarce—hence our choice of starting year.

non-SOE sample, while "Retail Trade" and "Mining and Construction" each constitute about 10% of both the SOE and non-SOE sample.

2.3 Accounting data

We obtain financial data from Thomson Reuter's Worldscope database. We match firms between Orbis and Worldscope by using International Securities Identification Numbers (ISINs), which are available in both datasets. All data is as of December 31 of the year of interest and in USD—at yearly frequency. We download metrics for firm size (total assets), profitability (return on assets), leverage (debt over total assets), capital expenditures, property plant and equipment, and investment in research and development. We further obtain dates of first addition in the database (as rough proxies for firm age) and dates of last updates. We drop all observations following the date of last update (as Worldscope stores the last available data for all subsequent years). All values are expressed in USD. Continuous variables are winsorized at the 1% tails, to mitigate the impact of outliers and bad data points. In the descriptive tables, we report numbers unadjusted for inflation; in empirical analysis, we adjust all monetary values to the base-year 2004, using the Consumer Price Index (Urban) data from the St. Louis Federal Reserve.

In empirical analysis, we test whether government ownership relaxes financial constraints of firms. In order to identify financially constrained firms, we construct the Hadlock and Pierce (HP) index, as described by Hadlock and Pierce (2010). In particular, following their formula, we compute the index as:

$$\textit{HP index} = (-0.737 \times \textit{Size}) + (0.043 \times \textit{Size}^2) - (0.040 \times \textit{Age}) \quad (1)$$

Where *Size* is the log of inflation adjusted (to 2004, as in the original formulation) total assets, and age is the number of years the firm has been listed in the Worldscope database. As in the Hadlock and Pierce formulation, size is replaced with log ($4.5 billion) and age with 37 years, if the actual values exceed those thresholds. We further identify financially constrained firms as firms whose *HP index* is below median and construct a binary variable, *Constrained*, equal to 1 for every firm-year for which the HP index is below median, and 0 otherwise.

2.4 Descriptive statistics

Our final sample contains 34,192 firm-years with non-missing data. Of those, 30,848 are non-SOEs while 3,358 are SOEs (firms with a government stake greater than zero), with average government ownership of 6.83%. Approximately 4% of firms with government stakes are government controlled (with a government stake exceeding 50%). Univariate statistics, reported in Table 2, reveal important differences between the SOE and non-SOE samples. SOEs are much larger, with total assets over USD 6.4 billion, compared to USD 1.9 billion for non-SOEs. Further, SOEs are more profitable, with higher ROA, have higher leverage and a higher proportion of tangible assets (PPE) as a proportion of total assets. SOEs and non-SOEs do not differ significantly in capital expenditures. SOEs are slightly less capital constrained, as measured by the *HP index*.

SOEs invest more in R&D than non-SOE, both in absolute terms (SOEs invest on average $13.6m in R&D, non-SOEs $5.2m) and as a proportion of total assets (2.2% for SOEs vs. 1.8% for non-SOEs). SOEs produce, on an average, 9.25 patents in each year, versus 5.02 patents for non-SOEs, but fewer patents "for each dollar invested": SOEs produce 0.17 patents for each $1million invested in R&D, while non-SOEs produce 0.19. SOEs and non-SOEs do not differ significantly in the average number of cites per patent (0.060 for SOEs and 0.068 for non-SOEs), but do differ substantially in terms of the average number of cites per patent scaled by R&D investment: SOEs generate 6.35 cites per patent for each $1billion invested in R&D, while non-SOEs generate over ten times as many, at 66 cites per patent per $1billion in R&D.

3. Empirical Analysis

The first step in our analysis is to estimate the impact of government ownership and control on the investment in R&D at the firm-year level. There are various ways in which government ownership could affect the investment in innovation by SOEs. First, SOE managers might face weaker incentives. SOE compensation tends to be less responsive to performance, because government ownership tends to isolate firms from the threat of a takeover (in turn increasing managerial job security). Also, managers may be less incentivized because sovereign owners are weaker monitors than other institutional blockholders. These weaker incentives could lead to under-exertion of effort and excessive risk-aversion, implying a lower level of effort in general, and lower levels of investment in risky activities such as R&D. In addition, government ownership could impose short-term social and political goals (Shleifer, 1998; Kahan and Rock, 2010) that divert firm resources away from investments with a long-term payoff such as R&D. On the other hand, government ownership could help by relaxing constraints on investment in R&D. This could be driven by multiple things. First, the long investment horizons of governments and the stable availability of financing provided by state-owned banks allow SOEs to focus on long-term projects, including R&D. Second, the high opacity and long-horizon of R&D investment lead to underfunding. Government ownership, by providing implicit debt guarantees and access to state owned banks, could relax financial constraints and allow for larger investment in R&D (O'Hara and Wayne, 1990; Faccio, Masulis, and McConnell, 2006; Borisova and Megginson, 2011; Iannotta, Nocera, and Sironi, 2013; Acharya, Anginer, and Warburton, 2014). Yet, while relaxing constraints on debt financing, government ownership could also increase financial constraints of firms by preventing access to equity markets (Ben-Nasr, Boubakri, and Cosset, 2012; Chen, Wang, Li, Sun, Tong, 2015; D'Souza and Nash, 2017). Finally, Arrow (1951) and Debreu (1959) find that private agents underinvest in goods that produce high levels of social-benefit spillover and have low commercial value, as they are unable to fully internalize the benefits of such investments. Accordingly, privately held firms underinvest in technology (Arrow, 1962; Lerner and Hall, 2010). Yet, governments and affiliated SOEs share some of those social goals and are thus better posed to internalize the benefits produced by innovation. This would imply higher levels of investment in R&D.

These conflicting predictions point to the need to formally investigate the impact of government ownership on investment in R&D. We do so by means of regression analysis in the following sections.

3.1 Government ownership and R&D investment, base regressions

As a starting point of our analysis, we model R&D investment, scaled by total assets, in a regression framework. As explanatory variables, we include observable characteristics that can influence research and development investment such as firm size (total assets), profitability (return on assets), leverage (debt-to-assets), capital expenditures (scaled by total assets), and property-plant and equipment (scaled by total assets). All metrics are as of December 31 of the previous year, to avoid issues related to simultaneity. We also include the previous-year expenditure in R&D, similarly scaled by total assets, as R&D can be a relatively persistent process. R&D investment can also vary widely by industry type with newer industries like healthcare and telecommunications demanding higher levels of R&D to remain competitive. To control for such industry specific trends we include industry-year fixed effects. There may also be unobservable differences in the tax treatment of R&D investment at the country level that would encourage firms to systematically report R&D differently by country. We include a full set of country-year fixed affects to address concerns with such omitted variables.

Our sample consists of firm-year observations from 1999 to 2015. Because the global environment at that time included multiple macro-financial crisis periods that may influence firm level investment, we include a financial crisis indicator representing the country-years identified as experiencing a financial crisis, as in Laeven and Valencia (2013). All firm level variables are expressed in USD, where relevant and winsorized at the 1st and 99th percentiles, to mitigate the impact of outliers or bad data points. The main variable of interest in our base model is the binary variable identifying the presence of a government shareholder, *SOE*. Using the specification below we test to see if R&D investment is associated with the presence of a sovereign owner:

$$R\&D/TA_{i,t+1} = \beta * SOE_{i,t} + \vec{\gamma} * \overrightarrow{Firm}_{i,t} + \gamma * FinCrisis_{j,t} + Country_j * Year_t + Industry_k * Year_t + \varepsilon_{i,t} \text{ (2).}$$

Results for this base model are presented in the first column of Table 3. The coefficient estimate associated with the main variable of interest, *SOE*, is positive and statistically significant at the 10% level, and equal to 0.001. Accordingly, our estimates indicate that the presence of a government shareholder is associated with an increase in R&D expenditure equal to 0.1% of total assets. Given that the average R&D expenditure in our sample is about 1.8% of total assets, this represents a 5.5% percent increase in R&D investment. While, for brevity, we refrain from discussing coefficient estimates associated with the other control variables in detail, we note that they are roughly consistent with expectations based on prior literature. For example, results indicate that capital constrained firms invest less in R&D.

Yet, a simple toehold might not reveal the full impact of government ownership. The imposition of social or political goals might be instead associated with larger stakes, allowing politicians to exercise a greater degree of influence and control over the firm. Accordingly, in a second model, we add a variable measuring the size of the government stake in the firm, *Gov Stake*. Coefficient estimates from this second model, presented in Column 2 of Table 3, indicate that, while the presence of a government shareholder is associated with an increase in R&D spending, larger stakes are associated with a decline in R&D. We confirm this finding with estimates from a third model, presented in Column 3, in which we replace the continuous variable *Gov Stake* with a binary variable, *Gov Control*, set equal to one when the size of the government stake exceeds 50%, and zero otherwise. In both cases, the coefficient estimate associated with *SOE* is positive and significant at the 5% level, while coefficients of *Gov Stake* and *Gov Control* are negative and statistically significant at the 5% and 10% levels, respectively. These findings suggest that, while a minority government stake increases R&D investment, presumably by relaxing financial constraints that are associated with underinvestment in innovation, a large or controlling stake decreases it, by imposing social and political priorities of a short term-nature, consistent with the "myopic government" hypothesis. This is consistent with the findings of D'Souza and Nash (2017), as they document potential agency conflicts between the state and minority shareholders when the state holds a majority stake in a listed firm.

We note that, if the presence of a government shareholder acts by relaxing financial constraints, the impact should be stronger on firms that are facing high financial constraints a priori. We accordingly identify financially constrained firms by computing the HP index, as discussed in Section 2.3. Each year, we label firms with an HP index above the median as financially constrained and construct a binary variable, *Constrained*, set equal to one for financially constrained firms and zero otherwise. We further interact this variable with *SOE* and *Gov Stake*. If the presence of a government shareholder reacts mainly via the relaxation of financial constraints, we expect the coefficient estimate associated with the *SOE* × *Constrained* interaction to be positive. We similarly interact *SOE* and *Gov Stake* with the binary variable identifying a financial crisis, *Fin Crisis*. As governments remove financial constraints via access to state-owned banks, we expect such impact to be weaker during a financial crisis, when bank capital is scarce and possibly directed to more short-term priorities. The results, presented in Column 4 of Table 3, are consistent with our expectations. The coefficient associated with the *SOE* × *Constrained* interaction is positive and significant at the 10% level, indicating that a government minority stake increases R&D investment by a larger amount in financially constrained firms. On the other side, the coefficient on the *SOE* × *Fin Crisis* variable is negative and statistically significant at the 10% level. Its magnitude is equal to the coefficient associated with *SOE*, but of opposite sign, suggesting that government minority stakes relax financial constraints by increasing R&D expenditures by about 10% during non-crises, but have no impact during financial crises. The increase for capital constrained firms, during non-crises, is even more dramatic, at about 20%. As before, a larger government stake is associated with a decline in R&D expenditures, with the effect being particularly strong for capital constrained firms. This suggest that, while minority government ownership relaxes financial constraints by providing access to state-owned banks and cheaper debt due to implicit debt guarantees (Borisova et al,. 2015), a controlling stake could hinder access to private equity markets due to the threat of conflict between the government and minority shareholders (D'Souza and Nash, 2017, find that firms with majority government ownership are less likely to raise capital abroad, via cross-listings).

To add insight into the impact of a large government stake, we estimate a last model, replacing *Gov Stake* and its interactions with *Gov Control*. We find largely consistent results. Minority government stakes are associated with larger R&D investments, particularly for capital constrained firms, but not during financial crises. Controlling government stakes are associated with a decline in R&D investment, supporting the myopic government hypotheses. Even more, the significant interaction between *Gov Control* and *Constrained* suggests that a controlling stake does not simply impose short-term priorities, but increases financial constraints as well. This is consistent with government-controlled firms having more difficulty accessing financial markets, particularly equity markets (Ben-Nasr et al., 2012; Stulz, 2005). Stulz (2005). Finally, the coefficient estimate associated with the interaction between *Gov Control* and *Fin Crisis* is negative and statistically significant, indicating that government controlled firms cut R&D investment during financial crises, which is again consistent with the myopic government hypotheses.

3.1.1 Government ownership and R&D investment, firm fixed effects

It is likely that government ownership is non-random—the descriptive statistics of our sample indicate that SOEs tend to be larger, more profitable, and more highly levered than private-sector firms. As a consequence, the relation between government ownership and firm's investment in R&D could be confounded by an omitted-variable bias induced by unobserved firm characteristics. As a first attempt at mitigating such problem, we substitute industry-year and country-year fixed effects for year and firm fixed effects. This allows us to control for time-invariant unobserved firm-characteristics and thus mitigate the potential biases driven by fixed firm characteristics.

We estimate the same models discussed in the previous section, now with firm and year fixed effects (but without the industry-level fixed effects, which are redundant in this context). Coefficient estimates and related test-statistics are presented in Table 4. Results are somewhat weaker in this specification, reflecting the fact that we are only capturing the time-series variation in government ownership and ignoring the more significant cross-sectional differences. In the first three models, respectively with *SOE*, *SOE* and *Gov Stake*, and *SOE* and *Gov Control*, none of the estimated coefficients is statistically significant. Yet, when we add the relevant interactions with *Constrained* and *Fin Crisis*, the coefficient on *SOE* is positive, statistically significant at 10%, and of the same magnitude as in the base model (without firm fixed effects). The coefficient on *Control* is negative and statistically significant at 10%, and the coefficient on the interaction *SOE* × *Fin Crisis* is negative and significant at 5%. Overall, these results are consistent with the findings without firm fixed effects, but statistical significance is weaker. The lower power of time-series tests, after absorbing firm fixed effects, is not surprising, given that government ownership varies more in the cross-section, than over time.

This firm fixed effects approach mitigates selection issues related to government ownership, but does not fully solve them, as it cannot account for time-variant firm characteristics. Accordingly, we present further robustness tests in the following section by implementing an instrumental variable approach.

3.1.2 Government ownership and R&D expenditures, instrumental variable approach

We use two-stages least square instrumental variable models, mirroring the approach in Borisova et al. (2015). The initial selection equation is fit using models describing the characteristics associated with the presence of government owners. The first-stage equations include firm-specific variables present in the second-stage outcome equation and industry-year fixed effects as well as variables that predict the presence of government ownership and are exogenous to the R&D outcome we intend to model in the second stage. Specifically, we employ two binary variables, also at the country level: *Civil law* (from Djankov, Hart, McLiesh, and Shleifer, (2008)) and *Left-wing* (from Beck, Clarke, Groff, Keefer, and Walsh, (2001)), which describe the legal system origin and the political party of the nation's chief executive in a given year, respectively. We anticipate a positive relation between government ownership and *Civil law*, as state owners could more easily divert resources towards social and political goals in a legal environment providing less protection to minority shareholders. Bortolotti and Faccio (2009) find higher government control in nations governed by left-wing political parties, who are more likely to pursue social goals via economic intervention, and a positive relation is predicted between *Left-wing* and state presence. We also use the annual country-level measures *Total investment* and *Unemployment rate* from the firm's home nation. These values are collected from the International Monetary Fund (IMF). A larger *Unemployment rate* suggests a higher likelihood of government investment with a goal of job preservation. Higher national values of *Total investment* indicate higher availability of funding to the government for investment purposes, and greater state holdings are possible in these cases. Yet, when total investment declines, as during macroeconomic crises, governments tend to step-in and bail struggling firms, possibly leading to an increase in government ownership. Accordingly, the relation between total investment and government ownership is a matter for empirical investigation. While we expect these country-level factors to predict government ownership, they are not likely to directly influence a firm's level of investment in R&D. For a further discussion of the relevance and exclusion criteria related to those instruments, and related test statistics, we refer interested readers to Borisova et al. (2015), noting that both their sample of interest and ours are comprised by European publicly traded firms with minority or majority government ownership stakes.

In the first model, we only include the instrumented binary variable identifying the presence of a government shareholder (and the usual set of controls) in the second stage. The first-stage coefficient estimates indicate that government shareholding is more likely in civil law countries and in environments with high levels of unemployment, consistent with our priors. The level of investment, scaled by GDP, is negatively related with government shareholding, suggesting that, when private-sector investment is lagging, the government might increase ownership, perhaps via bailouts. The surprising result is the coefficient estimate associated with the left-wing dummy variable, indicating that government ownership is less likely in left-wing countries. This result is puzzling and contrary to our priors. It could be an economic artifact, as we note a high level of correlation between the civil-law binary variable and the left-wing dummy. Or it could be an historical accident: during the timeframe we investigate in our sample, multiple European nations that have had a long left-wing tradition and substantial government-owned sectors have seen centrist parties come to power.

In the second stage, while the coefficient estimate associated with the instrumented variable *SOE* is positive and of approximately the same magnitude as in the previous-discussed estimates, it is not statistically significant. Yet, we obtain statistically significant results in the second two-stage model we estimate, including instrumented variables identifying both the presence of a government shareholder and the size of the stake owned. In this model, we confirm our previous findings—the presence of a government shareholder increases investment in R&D, while government control has the opposite effect.

We further attempt two-stage models including interactions between government presence and control and metrics of firm-level financial constraints and financial crises. Following Wooldridge (2010), we include interactions of the same exogenous variables with the financial crisis and with the binary variable identifying financially constrained firms to instrument our interaction term of interest. Second stage results indicate that minority government stakes are associated with greater investment in R&D, while controlling stakes are associated with a decline in R&D investment. We find no robust results on the interactions.

3.2 Government ownership and the number of patents

The previous analysis focuses on the inputs of the innovation process, that is, expenditure on R&D. Yet, we have reason to suspect that government ownership and control affect the efficiency of the process as well, as a vast literature finds that government ownership is generally associated with less efficient firm, due to a lack of monitoring by the government owners, and weaker incentives for managers. As a metric for how efficient the firm is in producing innovation, we compute the ratio of the number of patents produced scaled by R&D expenditure—effectively, a metric for the number of patents per dollar invested in R&D.

In a multivariate setting, we analyze the impact of government ownership and control over this efficiency metric. While we focus on the patent efficiency two years following the patent application date, we look at the impact over the next one, two, and three years, finding largely consistent results. The set of explanatory variables we employ in various models is the same as in the regression models estimates presented in Table 3, including country-year and industry-year fixed effects, but also for time-variant firm characteristics, and identifiers for financially constrained firms and for financial crises. As before, the variables of interests are *SOE*, *Gov Stake*, *Gov Control*, and their interactions with *Constrained* and *Fin Crisis*. The results presented in Table 6 refer to the two-year impact: so the response variable *Pat Count over R&D* is the patent count as of December 31 of year *t divided by the R&D expenditure of year t-2*, while all explanatory variables are as of December 31 of year *t*-2.

In all models, the presence of a minority government stake is associated with a decrease in the number of patents scaled by R&D investment. The coefficient estimates are statistically significant in models 1, 2, and 3, at the 5% level, but not in models 4, and 5.

Consistent with our univariate analysis, we find that the presence of a government shareholder is negatively related to the number of patents produced by SOEs over the following years, with results significant over all time horizons. The coefficients on *Gov Stake*, *Gov Control*, and all interactions are not statistically significant, indicating that the inefficiencies associated with government ownership are unaffected by the size of the stake, by capital constraints, or by financial crises.

3.2.1 Government ownership and the number of patents, firm fixed effects

As before, we are concerned about the non-random nature of government ownership. As a first attempt to mitigate the related potential biases, we re-estimate the same models with the inclusion of firm fixed effects, mirroring the approach employed when investigating the impact of government ownership on R&D expenditure. Our results, presented in Table 7, are largely consistent, indicating that the presence of a government shareholder is associated with a less efficient process, as measured by a decline in the number of patents scaled by R&D investment. Yet, in this set of results, we find that the effect is weaker for government-controlled firms and for financially constrained firms.

3.2.2 The overall impact of government ownership on patent counts

Our findings so far indicate that government ownership is associated with an increase in R&D spending, at least for minority government-owned firms during non-crises periods, and especially for financially constrained firms. Yet, we have evidence of lower efficiency in the process, with the number of patents per dollar invested in R&D subsequently declining, at least over one, two, and three year horizon windows. Which leaves open the question—how does government ownership affect the quantity of innovation ultimately produced by the firm, as proxied by the number of patents?

To answer this question, we estimate a new series of models, mirroring the same sets of explanatory variables, with the log of the number of patents as the response variable. As before, we estimate models over a one, two, and three year window, but, for brevity, present results related to the two-year event window only, in the more stringent model with firm fixed effects, in Table 8. The main finding is that the presence of a government shareholder decreases the count of patents by approximately 10%. Interestingly, the decline is of a smaller magnitude (only about 3%) in capital constrained firms, as the inefficiencies associated with government ownership are partially counterbalanced by a relaxation of financial constraints.

3.3 Government ownership and patent quality

The findings so far relate to the quantity of innovation (as proxied by the number of patents) that the firm produces. Yet, government ownership might affect not just the quantity of innovation, but also its quality. Inefficiencies could translate into not only fewer patents, but patents of lower overall quality. In addition, a greater orientation towards innovation with social and political spillover could lead to patents with lower commercial value. We investigate both issues in the following sections.

3.3.1 Government ownership and patent citations

To investigate the impact of government ownership on patent quality, we first focus on the number of cites per patent, which has often been employed as a standard metric of patent quality in the extant literature. We conduct empirical analysis via regressions. Our setup and list of control variables mirrors what we have first employed in Table 3 and, with the addition of firm fixed effects, in Table 4.

For brevity, we refrain from discussing individual model estimates. The overall picture paints a consistent set of results, as, in all cases, we fail to detect any impact of government ownership, either through minority or majority stakes, or with interactions with metrics of capital constraints or financial crises, on the average number of cites per patent. Our results strongly suggest that government ownership does not impact the average patent quality, at least as measured by the average number of cites per patent.

3.3.2 The commercial value of patents—event studies

Extant literature finds that the announcement of new patents leads, on average, to a positive market reaction, in the form of abnormal short-term returns on the stock prices of publicly traded firms (Kogan et al., 2017). This market reaction is a measure of increased firm value. Extant studies attribute this increase to the commercial value of the innovation being patented and, accordingly, interpret the abnormal market reaction as a measure of the commercial value of the invention. If SOEs produce patents with lower commercial value (and potentially higher social spillover or political benefits), we should observe a weaker market reaction at announcement.

To investigate the market reaction at loan initiation, we rely on event-study methodology. The main proxy for the impact of a new patent on firm value is the abnormal return at the time of the announcement of the patent approval. To estimate the abnormal market reaction at announcement, we obtain daily total return indices, adjusted for dividends and splits, in USD, for the primary common equity issue for each firm in our sample. We also obtain local market indices, similarly adjusted for dividends and splits and denominated in USD. All data is from Thomson Reuter's Datastream database. Cumulative abnormal returns (CARs) are computed by subtracting the total market return from the patenting firm's stock total return over various intervals on and around the day on which the loan is initiated (day 0). We present results for various short-term window spanning from one-day (day 0) to twenty-one days (-10,+10), to capture the effect of possible leakage of information or delayed disclosure. Results for SOEs are presented in Table X, Panel A, while results for private-sector firms are presented in panel B. We are able to compute ten-day (twenty-one-day) abnormal returns for 21,162 (63,179) patent announcements by SOEs (private-sector firms). Observations are excluded from the analysis if return data is missing during the event window. We find a mean abnormal return of 0.67% over the twenty-one day event window, and a median abnormal return of 0.63%. We test the statistical significance of mean abnormal returns using the standard Patell's z (Patell, 1976) test and the skewness-adjusted t-test described by Hall (1992) to correct for the skewness of abnormal returns, and employ a generalized sign test for medians. All tests are highly statistically significant, well below the 1% level. Over shorter event windows, the magnitude of the estimated effect declines, but the statistical significance of the estimate results remains robust.

When applying the same methodology to the sample of private-sector patent announcements, we find very similar results. The magnitude of the estimated impact is slightly smaller, with a mean (median) abnormal return of 0.64% (0.60%) over the twenty-one day event window, but the difference in means (medians) is economically negligible. We estimate and report two-sample *t*-test statistics for the significance of the difference in abnormal returns between the SOE and private-sector samples, but, for all event window, fail to reject the null hypotheses (that the difference is zero) at any conventional level of significance.

Overall, our results indicate that patents produced by SOEs have substantial commercial value. The abnormal market reaction estimate indicates an increase in firm value of approximately 0.67% at patent announcement. In unreported robustness tests, we find even stronger estimates for sub-samples of high-quality patents: patents in the upper decile of citation count—an ex-post measure of patent quality—lead to an abnormal market reaction of approximately 4%. Yet, we find very similar results for private-sector patents, suggesting that SOEs pursue innovation with the same level of commercial value as their private-sector counterparties.

3.3.3 Sustainable innovation

Given that governments have different goals than private-sector shareholders, we hypothesize that government ownership could affect not only R&D investment and the quantity and quality of innovation, but also the type of innovation produced by the firm. In particular, new technologies can provide benefits to society at a large, which cannot be fully captured by the commercial value of the patent. Such innovation is likely to be underfunded by the private sector. Governments, on the other side, are in a position to prioritize patents with such high social value. In line with extant literature, we identify a set of "sustainable patents," using the Cooperative Patent Classification sub-groups by the European Patent Office. These are patents related to technologies aimed at climate change mitigation and, in broader terms, related to clean energy sources.[10] Our prior is that SOEs, given their greater concern for patents with social value, are more likely to pursue innovation aimed at such sustainable patents.

To test our hypothesis, we re-estimate the models in Table 9, but with a different response variable: we replace the total number of patents with a subset, the number of sustainable patents, at the firm-year level. In the various models, we identify government ownership with either *SOE*, *Gov Stake, Gov Control*, and we add their interactions with *Constrained* and *Fin Crisis*. Models are estimated with firm and year fixed effects and standard errors clustered at the firm level. In all cases, we find no significant relation between government ownership, government stake, nor government control (nor any of their interactions) and the number of sustainable patents produced by the firm. This is contrary to our priors and indicates, consistent with the event study and patent citation number analysis, that government ownership does not affect the quality or type of innovation pursued by the firm.

4. Conclusions

We study the impact of government minority and majority ownership on the innovativeness of publicly traded European firms. The analysis of investment in research and development reveals

[10] Each sub-group was devised in coordination with field experts using the United Nations Framework Convention on Climate Change and Intergovernmental Panel on Climate Change. For more information, please refer to Table 4 in the Appendix. The sub-group classification by the EPO is available at: https://www.epo.org/news-issues/issues/classification/classification.html

important insights into the impact of government ownership on inputs in the innovation process and points to a nuanced picture. A minority government stake increases R&D expenditures. These results are particularly strong for financially constrained firm, but weaken during financial crises, suggesting that the likely channel by which government ownership impacts investment in R&D is via a relaxation of financial constraints by providing privileged access to state-owned banks. Yet, government control leads to the opposite effect, both by imposing myopic goals and complicating access to private equity markets. Our results are robust to the inclusion of firm fixed effects and to the implementation of a two-stage instrumental variable estimation process.

In terms of outputs, we find that government ownership decreases the efficiency of the innovation process, by leading to fewer patents "per dollar of R&D" and, overall, a decline in the number of patents of about 10% for the average firm, and of about 3% for previously financially constrained enterprises. Finally, we find that the patents produced by SOEs do not differ significantly from private-sector patents, neither in terms of average number of cites, nor in terms of commercial value, as proxied by the market reaction at the announcement of a patent's application. On an average, announcement of a patent filing leads to an increase in firm value by about 0.6%, which is consistent for both SOEs and private-sector enterprises.

Some unexplored related questions point to possible extensions. We have not formally investigated whether SOE patents are more likely to focus on "socially beneficial" innovation—for example, are SOEs more likely to develop technologies in specific sectors, such as medicine or defense? We have looked at climate-related innovation, but that is a small subset of technologies with high public value. Related, we have not investigated possible spillover and the generation of derived innovation—if SOEs focus more on early-stage innovation, we could see more derived patents following SOE patents, in contrast to private-sector patents.

Our data covers publicly traded firms in European countries. Accordingly, one limitation lies in the exclusion of non-listed firms with partial government ownership and of firms that are fully government owned. While it is possible that the impact of full government ownership differs, qualitative and quantitatively, from that of partial ownership, data limitations do not allow us to test such effects directly. And, of course, our dataset is limited to European firms, thus leaving open the question whether the results would extend to regimes with substantially different financial systems, legal institutions, and cultural norms.

We should also note that our manuscript identifies only one channel by which governments can impact innovation—direct ownership of firms. Yet, governments can promote innovativeness via subsidized lending, via grants, by financing research via educational institutions or think thanks, and by enhancing the protection or intellectual property rights, amongst other channels.

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Table 1: Variable Definitions

This table provides definitions and data sources for the main variables of interest in our dataset.

Variable Name	Definition	Source
R&D $_{i,t}$	Investment in research and development scaled by total assets of firm *i* in year *t*.	TR Worldscope
Count $_{i,t+n}$	The number of (eventually) granted patents applied for by firm *i* in year *t+n*, We include patents across all patent offices in the sample.	BvD Orbis
SusCount $_{i,t+n}$	The number of (eventually) granted patents applied for by firm *i* in year *t+n* that fall within a Cooperative Patent Classification (CPC) sub-groups tagged as sustainable technologies. See Appendix Table 4 for list of CPC sub-groups.	EPO
Count$_{t+n}$/R&D $_{i,t}$	The number of (eventually) granted patents applied for by firm *i* in year *t+n* scaled by R&D ($ millions CPI adjusted with a base year of 2004) expenditures in year *t*. We include patents across all patent offices in the sample.	BvD Orbis
CpC$_{t+n}$/R&D $_{i,t}$	The average number of citations received by granted patents applied for in year *t+n* for firm *i* scaled by R&D ($ billions CPI adjusted with a base year of 2004) expenditures in year *t*. Citation numbers are adjusted for truncation bias based on the patent office of filing.	BvD Orbis (citation count, patent count) EPO PATSTAT (truncation adjustment)
SOE $_{i,t}$	Indicator that firm *i* has a domestic sovereign owner in year *t*.	BvD Orbis
GovStake $_{i,t}$	Percent of ownership in firm *i* belonging to a domestic sovereign owner in year *t*.	BvD Orbis
GovControl $_{i,t}$	Indicator that firm *i* has a domestic sovereign owner in year *t* with a percent of ownership greater than 50%.	BvD Orbis
ROA $_{i,t}$	Return on assets (%) of firm *i* in year *t*.	TR Worldscope
PPE $_{i,t}$	Book value of plants, property, and equipment scaled by total assets of firm *i* in year *t*.	TR Worldscope
Debt $_{i,t}$	Outstanding debt scaled by total assets of firm *i* in year *t*.	TR Worldscope
CAPEX $_{i,t}$	Investment in capital expenditures scaled by total assets of firm *i* in year *t*.	TR Worldscope

Assets $_{i,t}$	Total assets of firm *i* in year *t* scaled by the consumer pricing index with a base year of 2004.	TR Worldscope
Constrained $_{i,t}$	Indicator that firm *i* has an HP-index above the median HP-index in year *t*. HP-index is calculated from Hadlock and Pierce (2010) using the firm's size and age. We use the firm's total assets for size and the number of years a firm is present in TR Worldscope as the firm age.	
LeftWing $_{j,t}$	Indicator if country *j*'s chief executive belongs to a left-wing political party in year *t*.	Beck, Clarke, Groff, Keefer, and Walsh, 2001
CivilLaw $_{j,t}$	Legal system of origin of country *j* in year *t*	Djankov, Hart, McLiesh, and Shleifer, 2008
Investment		IMF
Unemployment $_{j,t}$	Unemployment rate in country *j* in year *t*	IMF
FinCrisis $_{i,t}$	Indicator denoting firm *i* is headquartered in a country experiencing a financial crisis in year *t*	Laeven and Valencia (2013)

Table 2: Summary Statistics

This table provides summary statistics for firms within our sample. Panel A tabulates the distributions of firms (SOEs and non-SOEs) by industry. Panel B provides summary statistics for the dispersion of countries represented in the sample. Panel C provides summary statistics for the firm-year characteristics while Panels D provides a comparison of means for the subsample of firms that are non-sovereign owned and sovereign owned enterprises.

Panel A: Firms by Industry

	Non-SOE		SOE	
	N	%	N	%
Agriculture, Forestry, & Fishing	61	1.60%	11	0.81%
Mining and Construction	365	9.59%	128	9.39%
Manufacturing	1477	38.79%	624	45.78%
Transportation & Public Utilities	363	9.53%	184	13.50%
Retail Trade	402	10.56%	129	9.46%
Services	1127	29.60%	282	20.69%
Public Administration and Non-Classified	13	0.34%	5	0.37%
	3808	100.00%	1363	100.00%

Panel B: Country Composition of Firm-Year observations

	Frequency			Frequency	
AT - Austria	556	1.63%	HU - Hungry	216	0.63%
BE – Belgium	847	2.48%	IE – Ireland	543	1.59%
BG – Bulgaria	466	1.36%	LT – Lithuania	87	0.25%
CY – Cyprus	308	0.90%	LU – Luxemburg	234	0.68%
CZ – Czech Republic	143	0.42%	LV – Latvia	112	0.33%
DE – Germany	5,503	16.09%	MT – Malta	50	0.15%
DK – Denmark	953	2.79%	NL – Netherlands	1,051	3.07%
EE – Estonia	66	0.19%	PL – Poland	1,708	5.00%
ES – Spain	948	2.77%	PT = Portugal	449	1.31%
FI – Finland	1,132	3.31%	RO - Romania	407	1.19%
FR – France	4,819	14.09%	SE – Sweden	2,214	6.48%
GB – United Kingdom	9,972	29.16%	SI – Slovenia	142	0.42%
GR - Greece	1,212	3.54%	SK - Slovakia	54	0.16%

Panel C: Full Sample

Variable	N	mean	sd	p25	p50	p75
R&D/TA $_{i,t}$	34,192	0.019	0.054	0	0	0.003
R&D ($k)	34,192	6,079	17,868	0	0	445
Count $_{i,t}$	34,192	5.43	61.5	0	0	0
Count$_t$ /R&D$_t$ ($m)	32,783	0.192	3.31	0	0	0
CitePerCount $_{i,t}$	34,192	0.067	0.734	0	0	0
CitePerCount$_t$/R&D$_{t\ I}$ ($b)	33,815	60.1	6770	0	0	0
SOE $_{i,t}$	34,192	0.098	0.298	0	0	0
GovStake $_{i,t}$	34,192	0.671	5.095	0	0	0
GovControl $_{i,t}$	34,192	0.004	0.062	0	0	0
FinCrisis $_{i,t}$	34,192	0.220	0.413	0	0	0
ROA $_{i,t}$ (%)	34,192	0.337	19.9	-0.26	4.48	8.65
PPE/TA $_{i,t}$	34,192	0.268	0.236	0.067	0.206	0.410
Debt/TA $_{i,t}$	34,192	0.207	0.192	0.035	0.172	0.324
CAPEX/TA $_{i,t}$	34,192	0.055	0.062	0.015	0.035	0.070
Assets $_{i,t}$ ($m)	34,192	2,308	10,790	28	108	557
HP index	34,192	-2.14	0.679	-2.61	-2.29	-1.82
Constrained $_{i,t}$	34,192	0.493	0.500	0	0	1

Panel D: Non-Sovereign Owned Enterprises and SOE differences

	Non-SOE		SOE			
Variable	N	Mean	N	Mean	Difference	t
R&D/TA $_{i,t}$	30,834	0.018	3,358	0.0229	-0.00456***	-28.88
R&D ($k)	30,834	5260	3,358	13600	-8320***	-27.88
Count $_{i,t}$	30,834	5.02	3,358	9.25	-4.24***	-26.88
Count$_t$ /R&D$_t$ ($m)	29,545	0.194	3,238	0.169	0.0257	-25.88
CitePerCount $_{i,t}$	30,834	0.068	3,358	0.060	0.00783	-24.88
CitePerCount$_t$/R&D$_{t\ I}$ ($b)	30,473	66.0	3,342	6.35	59.6	-23.88
GovStake $_{i,t}$	30,834	0	3,358	6.83	-6.83***	-21.88
GovControl $_{i,t}$	30,834	0	3,358	0.040	-0.0399***	-20.88
FinCrisis $_{i,t}$	30,834	0.190	3,358	0.484	-0.294***	-19.88
ROA $_{i,t}$ (%)	30,834	-0.008	3,358	3.51	-3.51***	-18.88
PPE/TA $_{i,t}$	30,834	0.266	3,358	0.286	-0.0192***	-17.88
Debt/TA $_{i,t}$	30,834	0.206	3,358	0.212	-0.00588*	-16.88
CAPEX/TA $_{i,t}$	30,834	0.055	3,358	0.054	0.000882	-15.88
Assets $_{i,t}$ ($m)	30,834	1,860	3,358	6,440	-0.00458***	-14.88
HP index	30,834	-2.11	3,358	-2.40	0.288***	-13.88
Constrained $_{i,t}$	30,834	0.516	3,358	0.279	0.237***	-12.88

Table 3: R&D expenditures and Sovereign Ownership

This table presents the OLS regression results from Equation (2) where scaled R&D expenditures in year *t+1* are regressed on contemporaneous government ownership, time varying firm level characteristics, country-year fixed effects, and industry-year fixed effects. *SOE* is an indicator that firm *i* has a domestic sovereign owner in year *t* while *GovStake* is a continuous variable denoting the percent ownership of the domestic sovereign. *GovControl* is an indicator that firm *i* has a domestic sovereign owner with at least a 50% ownership stake. Definitions for the firm characteristics can be found in the Variable Appendix. Firm level characteristics are winsorized at the 1% and 99%. Standard errors are clustered by firm. The numbers in parenthesis are t-statistics. ***, **, and * represent 1%, 5%, and 10% statistical significance levels respectively.

	(1)	(2)	(3)	(4)	(5)
Variables	R&D/TA $_{i,t+1}$	R&D/TA $_{i,t+1}$	R&D/TA $_{i,t+1}$	R&D/TA $_{i,t+1}$	R&D/TA $_{i,t+1}$
SOE $_{i,t}$	0.001*	0.001**	0.001**	0.002**	0.001**
	(-1.90)	(-2.12)	(-1.99)	(-2.28)	(-2.10)
GovStake $_{i,t}$		-0.000**		-0.000**	
		(-2.36)		(-2.48)	
GovControl $_{i,t}$			-0.002**		-0.002**
			(-2.36)		(-2.49)
SOE $_{i,t}$ x Constrained $_{i,t}$				0.002*	0.002
				(-1.68)	(-1.58)
GovStake $_{i,t}$ x Constrained $_{i,t}$				-0.000**	
				(-2.12)	
GovControl $_{i,t}$ x Constrained $_{i,t}$					-0.008***
					(-3.29)
SOE $_{i,t}$ x FinCrisis $_{i,t}$				-0.002*	-0.002*
				(-1.86)	(-1.70)
GovStake $_{i,t}$ x FinCrisis $_{i,t}$				0.00	
				(-0.88)	
GovControl $_{i,t}$ x FinCrisis $_{i,t}$					0.002**
					(-2.02)
Constrained $_{i,t}$	-0.001*	-0.001*	-0.001*	-0.001**	-0.001**
	(-1.88)	(-1.87)	(-1.87)	(-2.14)	(-2.16)
FinCrisis $_{i,t}$	-0.009	-0.009	-0.009	-0.008	-0.008
	(-0.77)	(-0.75)	(-0.76)	(-0.72)	(-0.73)
ROA $_{i,t}$	-0.000***	-0.000***	-0.000***	-0.000***	-0.000***
	(-3.29)	(-3.30)	(-3.30)	(-3.30)	(-3.30)
PPE/TA $_{i,t}$	-0.005***	-0.004***	-0.004***	-0.005***	-0.005***
	(-7.93)	(-7.84)	(-7.87)	(-7.93)	(-7.96)
Debt/TA $_{i,t}$	-0.007***	-0.007***	-0.007***	-0.007***	-0.007***
	(-6.49)	(-6.50)	(-6.50)	(-6.47)	(-6.46)
CAPEX/TA $_{i,t}$	-0.005**	-0.005**	-0.005**	-0.005**	-0.005**
	(-2.18)	(-2.20)	(-2.19)	(-2.16)	(-2.15)
Assets $_{i,t}$	-0.000	-0.000	-0.000	-0.000	-0.000
	(-0.39)	(-0.24)	(-0.32)	(-0.07)	(-0.13)
R&D/TA $_{I,t}$	0.858***	0.858***	0.858***	0.858***	0.858***
	(-96.41)	(-96.38)	(-96.4)	(-96.2)	(-96.22)
Constant	0.004	0.004	0.004	0.004	0.004

	(-1.57)	(-1.56)	(-1.56)	(-1.59)	(-1.60)
Observations	34,192	34,192	34,192	34,192	34,192
SE	Firm	Firm	Firm	Firm	Firm
clusters	5,153	5,153	5,153	5,153	5,153
Country x Year FE	Yes	Yes	Yes	Yes	Yes
Industry x Year FE	Yes	Yes	Yes	Yes	Yes
Adjusted R-squared	0.760	0.760	0.760	0.760	0.760

Table 4: R&D expenditures and Sovereign Ownership (Firm FE)

This table presents the OLS regression results from Equation (2) where scaled R&D expenditures in year *t+1* are regressed on contemporaneous government ownership, time varying firm level characteristics, year fixed effects, and firm fixed effects. *SOE* is an indicator that firm *i* has a domestic sovereign owner in year *t* while *GovStake* is a continuous variable denoting the percent ownership of the domestic sovereign. *GovControl* is an indicator that firm *i* has a domestic sovereign owner with at least a 50% ownership stake. Definitions for the firm characteristics can be found in the Variable Appendix. Firm level characteristics are winsorized at the 1% and 99%. Standard errors are clustered by firm. The numbers in parenthesis are t-statistics. ***, **, and * represent 1%, 5%, and 10% statistical significance levels respectively.

	(1)	(2)	(3)	(4)	(5)
Variables	R&D/TA $_{i,t+1}$	R&D/TA $_{i,t+1}$	R&D/TA $_{i,t+1}$	R&D/TA $_{i,t+1}$	R&D/TA $_{i,t+1}$
SOE $_{i,t}$	0.000	-0.000	0.000	0.002*	0.001*
	(0.06)	(-0.10)	(0.05)	(1.84)	(1.86)
GovStake $_{i,t}$		0.000		-0.000	
		(1.27)		(-1.45)	
GovControl $_{i,t}$			0.000		-0.001*
			(0.09)		(-1.68)
SOE $_{i,t}$ x Constrained $_{i,t}$				0.000	0.000
				(0.06)	(0.28)
GovStake $_{i,t}$ x Constrained $_{i,t}$				0.000	
				(1.36)	
GovControl $_{i,t}$ x Constrained $_{i,t}$					-0.001
					(-0.50)
SOE $_{i,t}$ x FinCrisis $_{i,t}$				-0.003**	-0.003**
				(-2.39)	(-2.40)
GovStake $_{i,t}$ x FinCrisis $_{i,t}$				0.000	
				(1.32)	
GovControl $_{i,t}$ x FinCrisis $_{i,t}$					0.002**
					(2.26)
Constrained $_{i,t}$	-0.002**	-0.002**	-0.002**	-0.002**	-0.002**
	(-2.55)	(-2.55)	(-2.55)	(-2.57)	(-2.58)
FinCrisis $_{i,t}$	-0.001	-0.001	-0.001	-0.000	-0.000
	(-1.39)	(-1.40)	(-1.39)	(-0.60)	(-0.59)
ROA $_{i,t}$	-0.000	-0.000	-0.000	-0.000	-0.000
	(-0.86)	(-0.86)	(-0.86)	(-0.86)	(-0.86)
PPE/TA $_{i,t}$	0.002	0.002	0.002	0.002	0.002
	(1.47)	(1.47)	(1.47)	(1.42)	(1.41)
Debt/TA $_{i,t}$	-0.009***	-0.009***	-0.009***	-0.009***	-0.009***
	(-3.72)	(-3.72)	(-3.72)	(-3.71)	(-3.71)
CAPEX/TA $_{i,t}$	-0.006*	-0.006*	-0.006*	-0.006*	-0.006*
	(-1.71)	(-1.71)	(-1.71)	(-1.69)	(-1.68)
Assets $_{i,t}$	-0.000**	-0.000**	-0.000**	-0.000**	-0.000**
	(-2.21)	(-2.22)	(-2.21)	(-2.18)	(-2.17)
R&D/TA $_{I,t}$	0.412***	0.412***	0.412***	0.412***	0.412***
	(20.97)	(20.97)	(20.97)	(20.96)	(20.97)
Constant	0.011***	0.011***	0.011***	0.011***	0.011***

	(10.43)	(10.43)	(10.43)	(10.54)	(10.54)
Observations	34,192	34,192	34,192	34,192	34,192
SE	Firm	Firm	Firm	Firm	Firm
clusters	5,153	5,153	5,153	5,153	5,153
Year FE	Yes	Yes	Yes	Yes	Yes
Firm FE	Yes	Yes	Yes	Yes	Yes
Adjusted R-squared	0.809	0.809	0.809	0.809	0.809

Table 5: R&D expenditures and Sovereign Ownership (Instrument Variables)

This table presents the two stage least squared (2SLS) regression results from Equation (2) where government ownership variables are instrumented by LeftWing, CivilLaw, Investment, and Unemployment in the first stage. Columns (1)-(5) present the second stage results. *SOE* is an indicator that firm *i* has a domestic sovereign owner in year *t* while *GovStake* is a continuous variable denoting the percent ownership of the domestic sovereign. *GovControl* is an indicator that firm *i* has a domestic sovereign owner with at least a 50% ownership stake. Definitions for the firm characteristics can be found in the Variable Appendix. Firm level characteristics are winsorized at the 1% and 99%. Standard errors are clustered by firm. The numbers in parenthesis are t-statistics. ***, **, and * represent 1%, 5%, and 10% statistical significance levels respectively.

Variables	(1) R&D/TA $_{i,t+1}$	(2) R&D/TA $_{i,t+1}$	(3) R&D/TA $_{i,t+1}$	(4) R&D/TA $_{i,t+1}$	(5) R&D/TA $_{i,t+1}$
SOE $_{i,t}$	0.003	0.009***	0.007*	0.018***	0.010**
	(1.18)	(2.76)	(1.84)	(3.26)	(2.21)
GovStake $_{i,t}$		-0.001**		-0.002***	
		(-2.06)		(-3.04)	
GovControl $_{i,t}$			-0.239**		-0.120**
			(-2.51)		(-2.06)
SOE $_{i,t}$ x Constrained $_{i,t}$				0.005	-0.001
				(0.49)	(-0.18)
GovStake $_{i,t}$ x Constrained $_{i,t}$				-0.003	
				(-1.31)	
GovControl $_{i,t}$ x Constrained $_{i,t}$					-0.674
					(-1.15)
SOE $_{i,t}$ x FinCrisis $_{i,t}$				-0.014**	-0.004
				(-2.29)	(-0.64)
GovStake $_{i,t}$ x FinCrisis $_{i,t}$				0.002**	
				(2.38)	
GovControl $_{i,t}$ x FinCrisis $_{i,t}$					0.186*
					(1.69)
Constrained $_{i,t}$	-0.000	-0.001	-0.001*	-0.000	0.000
	(-1.29)	(-1.56)	(-1.74)	(-0.12)	(0.08)
FinCrisis $_{i,t}$	0.001*	0.000	-0.000	0.001	0.001
	(1.67)	(0.48)	(-0.47)	(0.99)	(0.60)
ROA $_{i,t}$	-0.000***	-0.000***	-0.000***	-0.000***	-0.000***
	(-3.12)	(-3.30)	(-3.54)	(-3.32)	(-3.33)
PPE/TA $_{i,t}$	-0.004***	-0.003**	0.000	-0.002**	-0.004***
	(-9.69)	(-2.56)	(0.06)	(-2.45)	(-2.82)
Debt/TA $_{i,t}$	-0.007***	-0.008***	-0.009***	-0.008***	-0.008***
	(-6.75)	(-6.85)	(-6.25)	(-7.11)	(-6.60)
CAPEX/TA $_{i,t}$	-0.005**	-0.007***	-0.009***	-0.004	0.001
	(-2.43)	(-2.89)	(-2.88)	(-1.15)	(0.17)
Assets $_{i,t}$	-0.000	0.000	0.000	0.000	0.000
	(-1.04)	(1.13)	(1.59)	(1.60)	(0.54)
R&D/TA $_{i,t}$	.	0.857***	0.857***	0.855***	0.855***
	(102.39)	(101.55)	(100.55)	(97.34)	(93.62)

Constant	0.004***	0.004***	0.003***	0.003***	0.003***
	(6.53)	(5.73)	(4.21)	(4.39)	(4.63)
Observations	33,726	33,726	33,726	33,726	33,726
SE	Robust	Robust	Robust	Robust	Robust
Country x Year FE	No	No	No	No	No
Industry x Year FE	Yes	Yes	Yes	Yes	Yes

Table 6: Patent Efficiency and Sovereign Ownership

This table presents the OLS regression results where future patent counts scaled by contemporaneous R&D are regressed on contemporaneous government ownership, time varying firm level characteristics, country-year fixed effects, and industry-year fixed effects. *SOE* is an indicator that firm *i* has a domestic sovereign owner in year *t* while *GovStake* is a continuous variable denoting the percent ownership of the domestic sovereign. *GovControl* is an indicator that firm I has a domestic sovereign owner with at least a 50% ownership stake. Definitions for the firm characteristics can be found in the Variable Appendix. Firm level characteristics are winsorized at the 1% and 99%. Standard errors are clustered by firm. The numbers in parenthesis are t-statistics. ***, **, and * represent 1%, 5%, and 10% statistical significance levels respectively.

Variables	(1) $Count_{t+2}/RD_t$	(2) $Count_{t+2}/RD_t$	(3) $Count_{t+2}/RD_t$	(4) $Count_{t+2}/RD_t$	(5) $Count_{t+2}/RD_t$
$SOE_{i,t}$	-0.110**	-0.102**	-0.110**	-0.083	-0.096
	(-2.16)	(-2.08)	(-2.18)	(-1.33)	(-1.42)
$GovStake_{i,t}$		-0.001		-0.001	
		(-0.47)		(-0.43)	
$GovControl_{i,t}$			-0.014		0.002
			(-0.11)		(0.02)
$SOE_{i,t}$ x $Constrained_{i,t}$				0.080	0.078
				(1.26)	(1.20)
$GovStake_{i,t}$ x $Constrained_{i,t}$				-0.002	
				(-0.71)	
$GovControl_{i,t}$ x $Constrained_{i,t}$					-0.249
					(-1.34)
$SOE_{i,t}$ x $FinCrisis_{i,t}$				-0.108	-0.102
				(-1.30)	(-1.32)
$GovStake_{i,t}$ x $FinCrisis_{i,t}$				-0.001	
				(-0.24)	
$GovControl_{i,t}$ x $FinCrisis_{i,t}$					-0.052
					(-0.33)
$Constrained_{i,t}$	-0.099*	-0.099*	-0.099*	-0.103*	-0.103*
	(-1.87)	(-1.87)	(-1.87)	(-1.86)	(-1.86)
$FinCrisis_{i,t}$	0.216***	0.218***	0.215***	0.258***	0.251***
	(2.96)	(2.98)	(2.96)	(3.13)	(2.95)
$ROA_{i,t}$	-0.001	-0.001	-0.001	-0.001	-0.001
	(-1.00)	(-1.00)	(-1.00)	(-0.98)	(-0.98)
$PPE/TA_{i,t}$	-0.161	-0.160	-0.161	-0.161	-0.162
	(-1.49)	(-1.47)	(-1.48)	(-1.48)	(-1.50)
$Debt/TA_{i,t}$	-0.382***	-0.383***	-0.382***	-0.381***	-0.380***
	(-3.45)	(-3.45)	(-3.45)	(-3.45)	(-3.44)
$CAPEX/TA_{i,t}$	0.588***	0.586***	0.587***	0.589***	0.591***
	(3.68)	(3.68)	(3.68)	(3.69)	(3.70)
$Assets_{i,t}$	0.000**	0.000**	0.000**	0.000**	0.000**
	(2.52)	(2.51)	(2.52)	(2.51)	(2.51)
Constant	-0.061	-0.061	-0.061	-0.058	-0.058
	(-0.39)	(-0.39)	(-0.39)	(-0.37)	(-0.37)

Observations	27,855	27,855	27,855	27,855	27,855
SE	Firm	Firm	Firm	Firm	Firm
clusters	4,778	4,778	4,778	4,778	4,778
Country x Year FE	Yes	Yes	Yes	Yes	Yes
Industry x Year FE	Yes	Yes	Yes	Yes	Yes
Adjusted R-squared	0.00688	0.00685	0.00685	0.00672	0.00672

Table 7: Patent Efficiency and Sovereign Ownership

This table presents the OLS regression results where future patent counts scaled by contemporaneous R&D are regressed on contemporaneous government ownership, time varying firm level characteristics, and fixed effects. In columns (1)-(3) we include country-year fixed effects, and industry-year fixed effects while in columns (4)-(6) we include year and firm fixed effects. *SOE* is an indicator that firm *i* has a domestic sovereign owner in year *t* while *GovStake* is a continuous variable denoting the percent ownership of the domestic sovereign. *GovControl* is an indicator that firm I has a domestic sovereign owner with at least a 50% ownership stake. Definitions for the firm characteristics can be found in the Variable Appendix. Firm level characteristics are winsorized at the 1% and 99%. Standard errors are clustered by firm. The numbers in parenthesis are t-statistics. ***, **, and * represent 1%, 5%, and 10% statistical significance levels respectively.

Variables	(1) $Count_{t+2}/RD_t$	(2) $Count_{t+2}/RD_t$	(3) $Count_{t+2}/RD_t$	(4) $Count_{t+2}/RD_t$	(5) $Count_{t+2}/RD_t$	(6) $Count_{t+2}/RD_t$
$SOE_{i,t}$	-0.110**	-0.102**	-0.110**	-0.098*	-0.116*	-0.104*
	(-2.16)	(-2.08)	(-2.18)	(-1.74)	(-1.88)	(-1.82)
$GovStake_{i,t}$		-0.001			0.003*	
		(-0.47)			(1.76)	
$GovControl_{i,t}$			-0.014			0.162**
			(-0.11)			(2.44)
$Constrained_{i,t}$	-0.099*	-0.099*	-0.099*	-0.059	-0.059	-0.059
	(-1.87)	(-1.87)	(-1.87)	(-1.51)	(-1.51)	(-1.52)
$FinCrisis_{i,t}$	0.216***	0.218***	0.215***	0.042	0.040	0.041
	(2.96)	(2.98)	(2.96)	(0.47)	(0.45)	(0.46)
$ROA_{i,t}$	-0.001	-0.001	-0.001	0.001	0.001	0.001
	(-1.00)	(-1.00)	(-1.00)	(1.10)	(1.10)	(1.10)
$PPE/TA_{i,t}$	-0.161	-0.160	-0.161	-0.015	-0.016	-0.015
	(-1.49)	(-1.47)	(-1.48)	(-0.08)	(-0.08)	(-0.08)
$Debt/TA_{i,t}$	-0.382***	-0.383***	-0.382***	-0.406	-0.406	-0.406
	(-3.45)	(-3.45)	(-3.45)	(-1.23)	(-1.23)	(-1.23)
$CAPEX/TA_{i,t}$	0.588***	0.586***	0.587***	0.197	0.197	0.195
	(3.68)	(3.68)	(3.68)	(0.90)	(0.90)	(0.89)
$Assets_{i,t}$	0.000**	0.000**	0.000**	-0.000*	-0.000*	-0.000*
	(2.52)	(2.51)	(2.52)	(-1.91)	(-1.91)	(-1.91)
Constant	-0.061	-0.061	-0.061	0.469***	0.469***	0.470***
	(-0.39)	(-0.39)	(-0.39)	(3.08)	(3.08)	(3.08)
Observations	27,855	27,855	27,855	27,855	27,855	27,855
SE	Firm	Firm	Firm	Firm	Firm	Firm
clusters	4,778	4,778	4,778	4,778	4,778	4,778
Country x Year FE	Yes	Yes	Yes	No	No	No
Industry x Year FE	Yes	Yes	Yes	No	No	No
Year FE	No	No	No	Yes	Yes	Yes
Firm FE	No	No	No	Yes	Yes	Yes
Adjusted R-squared	0.00688	0.00685	0.00685	0.0597	0.0597	0.0597

Table 8: Patent Output and Sovereign Ownership

This table presents the OLS regression results where future patent counts are regressed on contemporaneous government ownership, time varying firm level characteristics, year fixed effects, and firm fixed effects. *SOE* is an indicator that firm *i* has a domestic sovereign owner in year *t* while *GovStake* is a continuous variable denoting the percent ownership of the domestic sovereign. *GovControl* is an indicator that firm I has a domestic sovereign owner with at least a 50% ownership stake. Definitions for the firm characteristics can be found in the Variable Appendix. Firm level characteristics are winsorized at the 1% and 99%. Standard errors are clustered by firm. The numbers in parenthesis are t-statistics. ***, **, and * represent 1%, 5%, and 10% statistical significance levels respectively.

Variables	(1) $LnCount_{t+2}$	(2) $LnCount_{t+2}$	(3) $LnCount_{t+2}$	(4) $LnCount_{t+2}$	(5) $LnCount_{t+2}$
$SOE_{i,t}$	-0.097***	-0.098***	-0.102***	-0.104***	-0.105***
	(-4.81)	(-4.88)	(-5.03)	(-3.72)	(-3.72)
$GovStake_{i,t}$		0.000		0.001	
		(0.17)		(0.48)	
$GovControl_{i,t}$			0.141*		0.137
			(1.72)		(1.47)
$SOE_{i,t}$ x $Constrained_{i,t}$				0.068*	0.072**
				(1.92)	(2.08)
$GovStake_{i,t}$ x $Constrained_{i,t}$				-0.001	
				(-0.50)	
$GovControl_{i,t}$ x $Constrained_{i,t}$					-0.095
					(-0.97)
$SOE_{i,t}$ x $FinCrisis_{i,t}$				-0.029	-0.045*
				(-1.09)	(-1.84)
$GovStake_{i,t}$ x $FinCrisis_{i,t}$				-0.004	
				(-1.47)	
$GovControl_{i,t}$ x $FinCrisis_{i,t}$					0.091
					(1.37)
$Constrained_{i,t}$	-0.011	-0.011	-0.011	-0.015	-0.015
	(-0.86)	(-0.86)	(-0.87)	(-1.17)	(-1.20)
$FinCrisis_{i,t}$	-0.003	-0.003	-0.004	0.003	0.002
	(-0.28)	(-0.30)	(-0.38)	(0.31)	(0.20)
$ROA_{i,t}$	0.000**	0.000**	0.000**	0.000*	0.000*
	(1.97)	(1.97)	(1.97)	(1.91)	(1.91)
$PPE/TA_{i,t}$	0.024	0.024	0.024	0.021	0.022
	(0.64)	(0.64)	(0.64)	(0.57)	(0.58)
$Debt/TA_{i,t}$	-0.037	-0.037	-0.037	-0.036	-0.036
	(-1.40)	(-1.40)	(-1.41)	(-1.36)	(-1.35)
$CAPEX/TA_{i,t}$	0.067	0.067	0.065	0.068	0.065
	(1.29)	(1.29)	(1.26)	(1.32)	(1.27)
$Assets_{i,t}$	-0.000	-0.000	-0.000	-0.000	-0.000
	(-1.40)	(-1.40)	(-1.41)	(-1.32)	(-1.33)
$R\&D/TA_{i,t}$	-0.330**	-0.330**	-0.329**	-0.332**	-0.333**
	(-2.10)	(-2.10)	(-2.09)	(-2.11)	(-2.12)
Constant	0.360***	0.360***	0.360***	0.362***	0.362***

	(19.29)	(19.29)	(19.30)	(19.23)	(19.22)
Observations	29,062	29,062	29,062	29,062	29,062
SE	Firm	Firm	Firm	Firm	Firm
clusters	4,825	4,825	4,825	4,825	4,825
Year FE	Yes	Yes	Yes	Yes	Yes
Firm FE	Yes	Yes	Yes	Yes	Yes
Adjusted R-squared	0.853	0.852	0.853	0.853	0.853

Table 9: Patent Efficiency (Citations per Patent) and Sovereign Ownership

This table presents the OLS regression results where future citation per patent quality measures scaled by contemporaneous R&D are regressed on contemporaneous government ownership, time varying firm level characteristics, country-year fixed effects, and industry-year fixed effects. *SOE* is an indicator that firm *i* has a domestic sovereign owner in year *t* while *GovStake* is a continuous variable denoting the percent ownership of the domestic sovereign. *GovControl* is an indicator that firm I has a domestic sovereign owner with at least a 50% ownership stake. Definitions for the firm characteristics can be found in the Variable Appendix. Firm level characteristics are winsorized at the 1% and 99%. Standard errors are clustered by firm. The numbers in parenthesis are t-statistics. ***, **, and * represent 1%, 5%, and 10% statistical significance levels respectively.

Variables	(1) CpC_{t+2}/ R&D $_{i,t}$	(2) CpC_{t+2}/ R&D $_{i,t}$	(3) CpC_{t+2}/ R&D $_{i,t}$	(4) CpC_{t+2}/ R&D $_{i,t}$	(5) CpC_{t+2}/ R&D $_{i,t}$
SOE $_{i,t}$	-37.094	-41.779	-38.687	-71.495	-63.673
	(-0.83)	(-0.83)	(-0.83)	(-0.89)	(-0.90)
GovStake $_{i,t}$		0.531		1.057	
		(0.74)		(0.86)	
GovControl $_{i,t}$			29.578		58.484
			(0.69)		(0.89)
SOE $_{i,t}$ x Constrained $_{i,t}$				43.108	38.408
				(1.31)	(1.26)
GovStake $_{i,t}$ x Constrained $_{i,t}$				-1.148	
				(-0.79)	
GovControl $_{i,t}$ x Constrained $_{i,t}$					-139.850
					(-1.14)
SOE $_{i,t}$ x FinCrisis $_{i,t}$				45.165	39.667
				(0.68)	(0.67)
GovStake $_{i,t}$ x FinCrisis $_{i,t}$				-0.548	
				(-0.54)	
GovControl $_{i,t}$ x FinCrisis $_{i,t}$					-25.432
					(-0.52)
Constrained $_{i,t}$	-52.070	-52.118	-52.100	-54.667	-54.537
	(-0.91)	(-0.91)	(-0.91)	(-0.93)	(-0.93)
FinCrisis $_{i,t}$	37.944	36.331	38.850	28.699	31.482
	(0.95)	(0.96)	(0.95)	(1.11)	(1.16)
ROA $_{i,t}$	0.052	0.054	0.053	0.042	0.041
	(0.51)	(0.54)	(0.53)	(0.39)	(0.38)
PPE/TA $_{i,t}$	-66.485	-67.254	-66.981	-67.846	-67.486
	(-1.06)	(-1.05)	(-1.06)	(-1.06)	(-1.06)
Debt/TA $_{i,t}$	-99.290	-98.883	-99.013	-98.691	-98.901
	(-0.91)	(-0.91)	(-0.91)	(-0.90)	(-0.90)
CAPEX/TA $_{i,t}$	-42.214	-41.439	-41.823	-40.615	-40.799
	(-0.31)	(-0.30)	(-0.30)	(-0.30)	(-0.30)
Assets $_{i,t}$	-0.000	-0.000	-0.000	-0.000	-0.000
	(-1.22)	(-1.22)	(-1.22)	(-1.20)	(-1.20)
Constant	93.986	94.160	94.096	96.267	96.093

	(0.98)	(0.98)	(0.98)	(0.99)	(0.99)
Observations	28,510	28,510	28,510	28,510	28,510
SE	Firm	Firm	Firm	Firm	Firm
clusters	4,779	4,779	4,779	4,779	4,779
Year FE	Yes	Yes	Yes	Yes	Yes
Firm FE	Yes	Yes	Yes	Yes	Yes
Adjusted R-squared	-0.00589	-0.00593	-0.00593	-0.00607	-0.00607

Table 10: Market reaction to Patent News and Sovereign Ownership

This table presents summary statistics from event studies around patent publication dates. We examine the market adjusted returns for each firm before and after the public release of patent application information following the method introduced by Kogan et al. (2017). We divide the firm events by *SOE*, the indicator that firm *i* has a domestic sovereign owner in year *t*, and present the results for non-sovereign owned enterprises in Panel A and sovereign owned enterprises in Panel B. We formally test the difference in means for each event window in Panel C assuming unequal variance among the two populations. The numbers in parenthesis are t-statistics. ***, **, and * represent 1%, 5%, and 10% statistical significance levels respectively.

Panel A – Non-SOE firms

Days	N	Mean Cumulative Abnormal Return	Median Cumulative Abnormal Return	Patell Z	p-value
(-1,+1)	63,120	0.10%	0.00%	7.389	<.0001
(0,0)	63,115	0.03%	0.00%	4.239	<.0001
(0,+1)	63,117	0.04%	-0.02%	3.915	<.0001
(-5,+5)	63,145	0.36%	0.18%	13.375	<.0001
(-10,+10)	63,179	0.64%	0.41%	17.268	<.0001

Panel B – SOE firms

Days	N	Mean Cumulative Abnormal Return	Median Cumulative Abnormal Return	Patell Z	p-value
(-1,+1)	21,160	0.09%	0.04%	5.361	<.0001
(0,0)	21,160	0.04%	0.00%	4.447	<.0001
(0,+1)	21,160	0.07%	0.01%	5.118	<.0001
(-5,+5)	21,160	0.35%	0.29%	10.838	<.0001
(-10,+10)	21,162	0.67%	0.63%	15.057	<.0001

Panel C – Difference in Means

Days	Non-SOE	SOE	t	Prob t
(-1,+1)	0.10%	0.09%	0.417	0.676
(0,0)	0.03%	0.04%	-1.04	0.300
(0,+1)	0.04%	0.07%	-1.25	0.211
(-5,+5)	0.36%	0.35%	0.194	0.846
(-10,+10)	0.64%	0.67%	-0.394	0.694

Table 11: Sustainable Patent Output and Sovereign Ownership

This table presents the OLS regression results where future sustainable patent counts are regressed on contemporaneous government ownership, time varying firm level characteristics, year fixed effects, and firm fixed effects. *SOE* is an indicator that firm *i* has a domestic sovereign owner in year *t* while *GovStake* is a continuous variable denoting the percent ownership of the domestic sovereign. *GovControl* is an indicator that firm I has a domestic sovereign owner with at least a 50% ownership stake. Definitions for the firm characteristics can be found in the Variable Appendix. Firm level characteristics are winsorized at the 1% and 99%. Standard errors are clustered by firm. The numbers in parenthesis are t-statistics. ***, **, and * represent 1%, 5%, and 10% statistical significance levels respectively.

Variables	(1) $LnSusCt_{t+2}$	(2) $LnSusCt_{t+2}$	(3) $LnSusCt_{t+2}$	(4) $LnSusCt_{t+2}$	(5) $LnSusCt_{t+2}$
$SOE_{i,t}$	-0.000	-0.001	-0.000	-0.001	-0.000
	(-0.42)	(-0.90)	(-0.43)	(-0.56)	(-0.08)
$GovStake_{i,t}$		0.000		0.000	
		(1.17)		(1.07)	
$GovControl_{i,t}$			0.000		0.000
			(0.59)		(0.09)
$SOE_{i,t}$ x $Constrained_{i,t}$				0.001	0.001
				(1.30)	(0.95)
$GovStake_{i,t}$ x $Constrained_{i,t}$				-0.000	
				(-1.20)	
$GovControl_{i,t}$ x $Constrained_{i,t}$					-0.000
					(-0.50)
$SOE_{i,t}$ x $FinCrisis_{i,t}$				-0.001	-0.001*
				(-1.60)	(-1.71)
$GovStake_{i,t}$ x $FinCrisis_{i,t}$				0.000	
				(0.05)	
$GovControl_{i,t}$ x $FinCrisis_{i,t}$					0.001**
					(2.18)
$Constrained_{i,t}$	-0.000	-0.000	-0.000	-0.000*	-0.000*
	(-1.47)	(-1.48)	(-1.47)	(-1.90)	(-1.79)
$FinCrisis_{i,t}$	-0.001	-0.001	-0.001	-0.000	-0.000
	(-0.99)	(-1.05)	(-0.99)	(-0.91)	(-0.77)
$ROA_{i,t}$	0.000	0.000	0.000	0.000	0.000
	(0.11)	(0.12)	(0.11)	(0.10)	(0.11)
$PPE/TA_{i,t}$	-0.000	-0.000	-0.000	-0.000	-0.000
	(-0.23)	(-0.24)	(-0.23)	(-0.28)	(-0.28)
$Debt/TA_{i,t}$	-0.000	-0.000	-0.000	-0.000	-0.000
	(-0.53)	(-0.53)	(-0.53)	(-0.49)	(-0.48)
$CAPEX/TA_{i,t}$	0.000	0.000	0.000	0.000	0.000
	(0.03)	(0.03)	(0.03)	(0.05)	(0.04)
$Assets_{i,t}$	-0.000	-0.000	-0.000	-0.000	-0.000
	(-1.05)	(-1.07)	(-1.05)	(-1.00)	(-0.99)
$R\&D/TA_{i,t}$	-0.000	-0.000	-0.000	-0.000	-0.000
	(-0.02)	(-0.01)	(-0.02)	(-0.03)	(-0.03)

Constant	0.001	0.001	0.001	0.001	0.001
	(1.33)	(1.33)	(1.33)	(1.37)	(1.36)
Observations	28,825	28,825	28,825	28,825	28,825
SE	Firm	Firm	Firm	Firm	Firm
clusters	4,788	4,788	4,788	4,788	4,788
Year FE	Yes	Yes	Yes	Yes	Yes
Firm FE	Yes	Yes	Yes	Yes	Yes
Adjusted R-squared	0.0526	0.0526	0.0526	0.0526	0.0525

Appendix

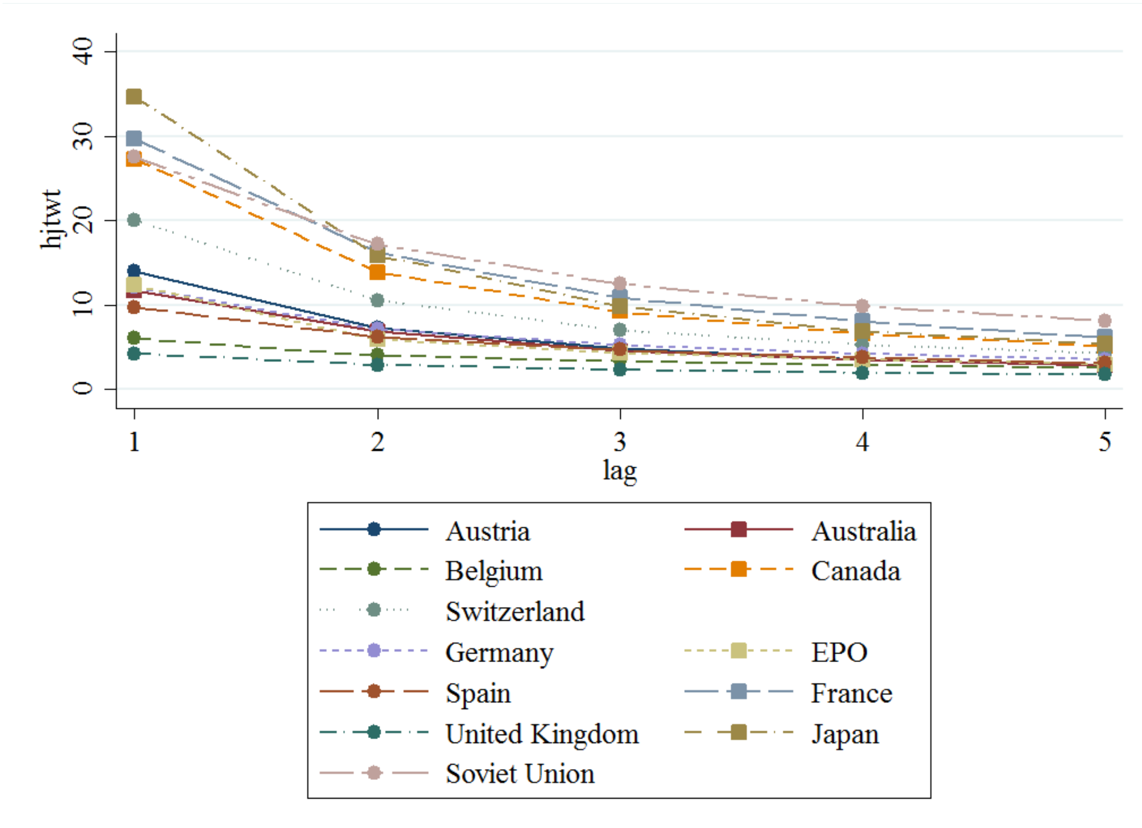

Figure A1: Patent Office Specific Citation Adjustment Factors

We graph the first five lags of patent citation adjustment factors for various patent offices using data from 1976-1985 to generate average citation lag adjustment factors by Patent Office-Industry section-lag. The graph above shows various adjustment factors for the IPC section A: Human Necessities at various patent offices.

Table A1: Aggregate Citation Adjustment

This table presents average citation adjustment factors for patents granted from the European Patent Convention (EPC) member offices. Following the spirit of Hall et al. (2000) we report the adjustment factor for 29 lags across the 8 Industrial Patent Classification (IPC) codes reported by the EPO.

		IPC Section							
		A	B	C	D	E	F	G	H
Lag	0	60.465	43.668	32.393	33.313	50.019	31.989	30.936	31.754
	1	26.131	18.954	14.237	14.642	21.693	14.771	13.823	14.119
	2	16.226	11.776	9.008	9.320	13.529	9.564	8.745	8.971
	3	11.796	8.593	6.724	7.039	9.878	7.211	6.480	6.659
	4	9.289	6.807	5.433	5.710	7.851	5.877	5.202	5.363
	5	7.675	5.658	4.598	4.863	6.503	5.007	4.387	4.524
	6	6.539	4.851	4.015	4.238	5.571	4.389	3.812	3.942
	7	5.673	4.258	3.580	3.761	4.885	3.920	3.391	3.509
	8	5.005	3.796	3.239	3.392	4.336	3.552	3.066	3.176
	9	4.465	3.428	2.964	3.087	3.905	3.259	2.803	2.907
	10	4.014	3.125	2.729	2.829	3.558	3.009	2.583	2.682
	11	3.639	2.871	2.531	2.609	3.265	2.798	2.400	2.492
	12	3.320	2.651	2.362	2.418	3.012	2.616	2.244	2.330
	13	3.051	2.464	2.219	2.261	2.792	2.459	2.111	2.189
	14	2.817	2.303	2.094	2.125	2.600	2.317	1.996	2.065
	15	2.613	2.161	1.982	2.000	2.434	2.191	1.893	1.953
	16	2.430	2.032	1.882	1.886	2.282	2.076	1.800	1.850
	17	2.260	1.913	1.786	1.782	2.142	1.969	1.711	1.755
	18	2.096	1.800	1.695	1.681	2.003	1.863	1.627	1.664
	19	1.941	1.691	1.606	1.585	1.869	1.760	1.545	1.576
	20	1.800	1.589	1.523	1.500	1.746	1.660	1.467	1.494
	21	1.670	1.496	1.444	1.421	1.632	1.563	1.395	1.417
	22	1.550	1.410	1.371	1.346	1.525	1.473	1.327	1.346
	23	1.441	1.331	1.302	1.277	1.426	1.386	1.264	1.280
	24	1.342	1.259	1.237	1.216	1.334	1.305	1.207	1.220
	25	1.252	1.193	1.178	1.160	1.249	1.229	1.154	1.164
	26	1.173	1.133	1.123	1.109	1.174	1.160	1.107	1.114
	27	1.104	1.081	1.075	1.066	1.107	1.098	1.065	1.070
	28	1.047	1.037	1.034	1.030	1.048	1.045	1.030	1.032
	29	1	1	1	1	1	1	1	1

Table A2: Citation lag adjustment by patent office for IPC section A: Human Necessities

This table presents citation adjustment factors for individual patent offices adhering to the European Patent Convention (EPC) for one Industrial Patent Code class (A). Following the spirit of Hall et al. (2000) we report the adjustment factor for 29 lags.

		Patent Office												
		AU	AT	BE	CA	CH	DE	DD	ES	FR	GB	JP	SU	US
Lag	0	23.379	53.763	20.646	112.82	77.187	38.131	61.373	210.85	24.295	142.69	8.693	198.44	62.686
	1	11.659	13.998	6.052	27.323	20.038	12.152	17.255	46.903	9.748	29.698	4.266	34.694	27.526
	2	6.897	7.316	4.035	13.893	10.556	7.161	9.255	29.066	6.207	16.232	2.935	15.890	17.196
	3	4.684	4.819	3.347	9.248	6.987	5.255	6.041	21.117	4.733	10.906	2.338	9.872	12.510
	4	3.586	3.587	2.871	6.613	5.272	4.230	4.875	17.972	3.761	8.057	1.974	6.897	9.863
	5	2.917	2.913	2.570	5.160	4.269	3.545	3.924	14.846	3.142	6.183	1.745	5.384	8.157
	6	2.407	2.499	2.324	4.198	3.561	3.063	3.350	8.999	2.716	4.905	1.590	4.351	6.957
	7	2.093	2.190	2.151	3.598	3.066	2.714	2.891	6.360	2.532	3.940	1.479	3.652	6.035
	8	1.858	1.946	2.023	3.161	2.699	2.454	2.562	5.237	2.326	3.416	1.405	3.143	5.318
	9	1.637	1.758	1.909	2.737	2.424	2.226	2.364	3.779	2.084	2.941	1.351	2.729	4.738
	10	1.527	1.644	1.807	2.430	2.220	2.062	2.186	3.093	1.958	2.623	1.313	2.403	4.250
	11	1.445	1.542	1.722	2.185	2.049	1.916	2.015	2.708	1.846	2.388	1.282	2.155	3.843
	12	1.386	1.459	1.651	2.005	1.877	1.794	1.869	2.370	1.749	2.206	1.262	1.969	3.497
	13	1.315	1.395	1.579	1.827	1.734	1.691	1.758	2.139	1.676	2.062	1.248	1.810	3.204
	14	1.275	1.339	1.516	1.702	1.632	1.598	1.661	1.946	1.608	1.935	1.236	1.680	2.950
	15	1.235	1.291	1.451	1.592	1.540	1.521	1.563	1.809	1.561	1.838	1.226	1.573	2.728
	16	1.203	1.261	1.402	1.496	1.467	1.453	1.503	1.693	1.490	1.719	1.217	1.481	2.529
	17	1.174	1.228	1.356	1.423	1.400	1.395	1.440	1.589	1.456	1.608	1.208	1.407	2.344
	18	1.153	1.199	1.316	1.357	1.341	1.340	1.397	1.510	1.431	1.516	1.197	1.341	2.167
	19	1.141	1.174	1.269	1.304	1.294	1.291	1.342	1.417	1.375	1.444	1.187	1.290	1.999
	20	1.129	1.149	1.234	1.261	1.236	1.243	1.304	1.344	1.324	1.391	1.176	1.250	1.848
	21	1.110	1.130	1.197	1.219	1.199	1.209	1.263	1.290	1.276	1.324	1.162	1.212	1.708
	22	1.096	1.113	1.168	1.182	1.167	1.179	1.224	1.243	1.247	1.276	1.146	1.180	1.580
	23	1.084	1.099	1.133	1.152	1.135	1.150	1.191	1.209	1.207	1.238	1.130	1.155	1.465
	24	1.069	1.085	1.107	1.119	1.106	1.124	1.155	1.162	1.163	1.205	1.111	1.129	1.359

25	1.054	1.066	1.081	1.090	1.080	1.097	1.110	1.121	1.128	1.168	1.091	1.106	1.265
26	1.041	1.048	1.055	1.066	1.063	1.071	1.081	1.091	1.085	1.136	1.070	1.076	1.180
27	1.028	1.026	1.033	1.045	1.037	1.046	1.053	1.058	1.048	1.100	1.047	1.047	1.108
28	1.015	1.015	1.012	1.020	1.018	1.021	1.024	1.024	1.016	1.052	1.023	1.024	1.049
29	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000

Table A3: CPC sustainable patent tagging scheme

This table lists the Cooperative Patent Classification (CPC) sub-groups created by the EPO to tag sustainable technologies. Each sub-group was devised in coordination with field experts using the United Nations Framework Convention on Climate Change and Intergovernmental Panel on Climate Change. For more information see https://www.epo.org/news-issues/issues/classification/classification.html

Sub-group	Description	Comment
Y02B	Climate change mitigation technologies related to buildings, including housing and appliances or related end-user applications	Integration of renewables in buildings, lighting, HVAC (heating, ventilation and air conditioning), home appliances, elevators and scalators, constructional or architectural elements, ICT, power management
Y02C	Capture, storage, sequestration or disposal of greenhouse gases (GHG).	CO2 capture and storage, also of other relevant GHG
Y02E	Climate change mitigation technologies in energy generation, transmission and distribution	Renewable energy, efficient combustion, nuclear energy, biofuels, efficient transmission and distribution, energy storage, hydrogen technology
Y02P	Climate change mitigation technologies in the production or processing of goods	Metal processing, chemical/petrochemical industry, minerals processing (e.g. cement, lime, glass), agroalimentary industries,
Y02T	Climate change mitigation technologies related to transportation	e-mobility, hybrid cars, efficient internal combustion engines, efficient technologies in railways and air/waterways transport
Y04S	Smart grid technologies	Power networks operation, end-user applications management, smart metering, electric and hybrid vehicles interoperability, trading and marketing aspects

Table A4: Patent Offices of Publication

Patent Office	Abbreviation
Albania	AL
Austria	AT
Bosnia and Herzegovina	BA
Belgium	BE
Bulgaria	BG
Croatia	HR
Cyprus	CY
Czech Republic	CZ
Denmark	DK
Estonia	EE
European Patent Office	EP
Finland	FI
France	FR
Germany	DE
Georgia	GE
Greece	GR
Hungary	HU
Iceland	IS
Ireland	IE
Italy	IT
Latvia	LV
Liechtenstein	LI
Lithuania	LT
Luxembourg	LU
Malta	MT
Monaco	MC
Montenegro	ME
Netherlands	NL
Norway	NO
Poland	PL
Portugal	PT
Romania	RO
San Marino	SM
Serbia	RS
Slovakia	SK
Slovenia	SI
Spain	ES
Sweden	SE
Switzerland	CH
United Kingdom	GB

Table A5: R&D/TA (IV First Stage) from Table 5

R&D expenditures

Variables	(1) $SOE_{i,t}$	(2) $GovStake_{i,t}$	(3) $GovControl_{i,t}$
$CivilLaw_{j,t}$	0.059***	0.483***	0.002*
	(14.19)	(5.10)	(1.67)
$Investment_{j,t}$	-0.013***	-0.023	0.000
	(-21.44)	(-1.60)	(0.27)
$Unemployment_{j,t}$	0.001*	0.022	0.000
	(1.68)	(1.34)	(1.27)
$LeftWing_{j,t}$	-0.034***	-0.398***	-0.002
	(-9.00)	(-4.82)	(-1.56)
$Constrained_{i,t}$	-0.071***	-0.438***	-0.002***
	(-22.70)	(-9.34)	(-4.64)
$FinCrisis_{i,t}$	-0.116***	-0.694***	-0.006**
	(-12.87)	(-4.10)	(-2.48)
$ROA_{i,t}$	0.000***	-0.002***	-0.000***
	(7.35)	(-2.94)	(-4.88)
$PPE/TA_{i,t}$	0.009	1.761***	0.020***
	(1.24)	(8.87)	(7.56)
$Debt/TA_{i,t}$	-0.041***	-1.070***	-0.011***
	(-5.34)	(-7.12)	(-5.92)
$CAPEX/TA_{i,t}$	0.019	-1.266*	-0.015*
	(0.81)	(-1.95)	(-1.94)
$Assets_{i,t}$	0.000***	0.000***	0.000***
	(12.08)	(5.29)	(3.37)
$R\&D/TA_{I,t}$	0.300***	0.601**	-0.002
	(10.06)	(2.43)	(-0.82)
Constant	0.306***	0.252	-0.005
	(18.56)	(0.80)	(-1.52)
Observations	33,726	33,726	33,726
SE	Robust	Robust	Robust
Country x Year FE	No	No	No
Industry x Year FE	Yes	Yes	Yes