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The political economy of energy innovation

Shouro Dasgupta, Enrica De Cian, and Elena Verdolini*

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Abstract: This paper empirically investigates the effects of environmental policy, institutions, political orientation, and lobbying on energy innovation and finds that they significantly affect the incentives to innovate and create cleaner energy efficient technologies. We conclude that political economy factors may act as barriers even in the presence of stringent environmental policy, implying that, to move towards a greener economy, countries should combine environmental policy with a general strengthening of institutional quality, consider the influence of government's political orientation on environmental policies, and the implications of the size of energy intensive sectors in the economy.

Keywords: energy innovation, environmental policy, patents, political economy
JEL classification: C23, D02, O30, Q58

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* All authors entro Euro-Mediterraneo sui Cambiamenti Climatici (CMCC), Lecce, Italy and Fondazione Eni Enrico Mattei (FEEM), Venice, Italy; corresponding author: enrica.decian@feem.it.

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Information and requests: publications@wider.unu.edu

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Katajanokanlaituri 6 B, 00160 Helsinki, Finland

1 Introduction

Technological change directed towards more efficient and eco-friendly technologies is a priority for both developed and developing countries. Insights on past trends and determinants of energy innovation, including political economy factors and non-financial drivers, are important to set the basis for cost-effective climate and energy policies in the coming years. Issues such as the role of institutions, as enabling or inhibiting factors, and of lobbying as a barrier to clean energy transitions, are important factors that have been only marginally examined by the existing literature. A thorough investigation of these questions often proves difficult due to the fact that defining energy innovation is challenging: innovation per se encompasses several important phases, from idea development to full commercialization. Furthermore, clearly defining which innovations improve the use of energy in an economy is very challenging, while comprehensive statistics on energy-related innovation are also not readily available. The Organisation for Economic Cooperation and Development (OECD) countries provide information on public energy Research and Development (R&D) budget and industrial R&D investments. Conversely, neither private investment data nor public R&D data for non-OECD countries are collected in a systematic manner (Verdolini et al. 2016). The broader geographic and temporal coverage of patent statistics, which can be classified in several energy- and climate-related technology fields, spurred a wealth of contributions on the topic, most of which focus on the inducement effect of environmental policy (Carraro et al. 2010; Popp et al. 2010).

The contribution of this paper is twofold. First, we provide an overview of the different proxies for energy-related innovation, which we define as innovation aimed at improving energy efficiency and/or at reducing carbon intensity of energy, such as renewables and more efficient power-generating technologies. We compile information on two of the commonly used indicators of innovation, namely energy industrial R&D, which measure innovation inputs, and energy patents, which measure innovation outputs.[1] We describe their dynamics using a panel dataset of 20 countries over the years 1995–2010. When focussing on industrial R&D, we provide both a lower and an upper bound estimate of investments. Second, we use the collected data to examine the influence of political economy factors on energy-related innovations using econometric analysis. This methodology allows us to assess the impact of one of these factors conditional on all other aspects considered.

Political economy factors can be broadly defined as those concerning the interactions and tensions between de jure and de facto power, including the distribution of resources, the rules for the exercise of power and the enforcement of contracts, the procedures and institutions for settling conflicts over these rules, or the physical and organizational infrastructure supporting economic activities, transactions, and collective actions.[2] In this paper, we focus on four aspects: the types and stringency of government support to energy innovation (e.g. the various policy instruments implemented to this end such as environmental and R&D policies); the quality of governance (e.g. government effectiveness); the political orientation of the government; and the distribution of resources across interest groups.

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[1] Arguably, R&D investments and patents represent only part of the full innovation process, as they somewhat disregard the issue of technology diffusion. Specifically, patent data is an imperfect indicator of technology diffusion, but nonetheless widely used in the literature to proxy for the other, earlier stages of innovation (see for instance Hall and Rosenberg 2010).

[2] Stavins (2004) refers to political economy as the process through which political decisions are made.

The role of these factors in relation to energy innovation dynamics, the energy transition, and sustainable development has been acknowledged by several contributions both in the policy and in the economics realms (Anadón 2012; Friedrichs and Inderwildi 2013; Hughes and Lipscy 2013; IPCC 2014; IEA 2015a). More than other sectors, energy can be dominated by large incumbent companies and utilities, which often seek to influence policy. Their investments, especially in new technologies are shaped by the incentives and regulations set by policy makers (Lockwood 2013a). Moreover, the actual impact of regulations and government policies is affected by the broader institutional settings (Stavins 2004). Good governance is particularly important as many of the government interventions are economic policies (Lockwood 2013a) and bureaucrats are the actors ultimately implementing these policies (Lockwood 2013b).

However, the empirical literature on energy innovation has not explored the inducement effect of the abovementioned factors jointly. In the specific domain of energy and the environment, the role of public policies as drivers of innovation has received more attention than institutions and political economy factors. The existing literature shows that both market-based and non-market-based instruments along with innovation policies supporting cleaner technologies, affect the rate and direction of technological change (Carraro et al. 2010; Popp et al. 2010).[3] The multiple sources of market failures that characterize the energy sector and the recent debate regarding the actions governments should undertake to curb rising greenhouse gas emissions partly explains the focus of the current literature on the role of environmental, energy, and innovation policies. In the energy-environmental realm, state intervention is motivated by the presence of environmental externalities (a gap between private and social returns to pollution control), as well as of innovation externalities (a gap between private and social returns to innovation). Moreover, in comparison to other sectors, energy R&D often entails large-scale projects, which need public support (Anadón 2012). Conversely, the role of governance quality, political orientation of the government, and distribution of resources across interest groups have received only marginal attention in the contributions focussing on the determinants of energy technology innovation.

We contribute to the literature by addressing this gap, namely by jointly assessing the influence of environmental and R&D policies, governance quality, political orientation, and distribution of resources to energy intensive industries on energy innovation. Our results suggest that all institutional and political economy factors affect the incentives to devote resources to energy R&D and to create newer clean and energy efficient technologies. Political economy factors can influence R&D and innovation even in the presence of stringent environmental policies. This implies that in order to induce changes towards a greener economy countries should combine environmental policy with a general strengthening of institutional quality, and consider the influence of government's political orientation on environmental policy and of the size of energy intensive sectors, which can affect both the lobbying structure and the demand for energy innovations.

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[3] The contributions directly assessing the relationship between environmental policies and investments in energy innovation are part of a vast literature on the inducement effect of energy and environmental policy. The many issues, which have been addressed include the complementarity between environmental and technology policies (see Newell 2010 for a review); between public and private R&D (David et al. 2000; Popp 2006; Nemet and Kammen 2007; Gallagher et al. 2011; Popp and Newell 2012); between energy and total R&D (Nemet and Kammen 2007; Popp and Newell 2012); and between clean and dirty technologies (Popp and Newell 2012). These studies focus on specific countries, mostly the United States. Cross-country analyses of the aforementioned issues are mostly confined to qualitative descriptions (Wiesenthal et al. 2012; Buchner et al. 2011) because, as explained in Section 2, distinguishing between private and public R&D and collecting comparable statistics can be problematic.

The rest of the paper is organized as follows. Section 2 presents a discussion of our measures of energy innovation and describes energy innovation trends in our sample. Section 3 provides a framework to set up the main hypotheses explored in the empirical analysis and presents descriptive statistics. Section 4 discusses the results, while Section 5 concludes highlighting policy implications and future research needs.

2 Measuring energy innovation trends

Studying innovation systems and dynamics using an empirical approach is challenging, as innovation comprises both tangible and intangible outputs (e.g. new technologies, machines, products, patents but also ideas, process innovation, managerial, and organizational innovation). Following a large empirical innovation economics literature, we study the more tangible and measurable aspects of the innovation process. While these constitute only a part of the innovation output relevant for the energy system and sector, they nonetheless provide important insights that can complement those from qualitative and bottom-up case studies, focussing on more intangible and less measureable aspects such as organizational innovation.

We focus on R&D expenditures and patent counts. The former informs on the inputs of the innovation process, while the latter is a proxy of innovation outputs. Both indicators suffer from some specific shortcomings; R&D investments provide insights on innovation effort but not on innovation quality. Conversely, while patent statistics can be weighted using information on several indicators to control for quality such as citations or the type of route chosen to protect the innovation, they nonetheless provide a partial measure as not all innovations are patented (Griliches 1990). Furthermore, patents may increase due to changes in patent law or strategic reasons to signal in which companies to invest in, regardless of innovative activity (Mazzucato 2013).

In the case of energy innovation, matters are further complicated by the fact that it is unclear how clean innovation or even energy innovation are defined (Gallagher et al. 2011). A number of studies focus specifically on the energy supply sector (Salies 2010; Sterlacchini, 2012; Costa-Campi et al. 2014) but energy-saving R&D and innovation are pervasive. Energy is an input for nearly all sectors in the economy and the way in which energy is produced, transformed, and distributed depends on innovative activities well beyond the energy supply sector itself. All R&D expenditures are inputs into complex processes that ultimately lead to innovations that may or may not be clean. Upstill and Hall (2006) state that the R&D expenditure by the mineral industry underestimates the actual total innovative effort of that sector as a significant fraction of the R&D value is embodied in the capital goods and materials acquired and used by the extractive industry but not performed within the sector. Some of these input sectors (e.g. machinery and equipment) are very R&D-intensive and not accounting for the R&D embedded in other sectors is likely to result in severe underestimation.

In order to proxy for industrial R&D investments in energy, we rely on the Analytical Business Enterprise Research and Development (ANBERD) database (OECD 2016), which provides information on the R&D expenditures at the sectoral level for 30 countries for the years 1990–2013[4] (for more details on the content of ANBERD see Appendix A1). We define energy R&D investments in two ways. First, we focus on R&D spending in the 'Electricity, water and gas distribution industry', which represents the downstream sector for energy production (power

[4] Our analysis focuses on the 20 countries between 1995 and 2010 for which both policy and institutional data are available.

R&D). Second, we define energy investments as a combination of R&D expenditures from 'Electricity, water and gas distribution industry' and 'Mining', which capture the combined R&D effort in the upstream and downstream energy supply sector (energy R&D).

These measures arguably represent a lower bound estimate of energy-related innovation (Upstill and Hall 2006), as they only include the R&D directly performed by the energy supply sectors. Indeed, non-energy sectors indirectly contribute to energy-related innovation. For instance, improvements in the manufacturing of chemicals and chemical products, and in computer and electronics, contribute to the development of energy system technologies, such as solar power or smart grids. These are 'embedded' in the capital that is supplied to the energy supply sector. The sum of the direct and 'embedded' R&D can be considered an estimate of the upper bound of industrial energy-related R&D in a given country.

To provide an estimate of energy-related R&D expenditures, which include research performed in the other economic sectors that are embedded in the capital purchased by the electricity and the mining sectors, we use input–output data from the World Input–Output Database (WIOD) (Timmer et al. 2015).[5] Specifically, we calculate a weight, $S_{m,i,e,j}$, representing the average share of production that the manufacturing sector *m* of country *i* performed in the energy sector *e* (i.e. electricity and mining) of country *j* (including the case *i=j*) between the years 1995 and 2009:

$$S_{m,i,e,j} = \frac{EX_{m,i,e,j}}{\sum_j EX_{m,i,j}} \tag{1}$$

where $EX_{m,i,e,j}$ is the value of trade between the manufacturing sector of country *i* (*m, i*) to the energy sector in country *j* (*e, j*) and $\sum_j EX_{m,i,j}$ is the sum of all exports from the manufacturing sector of country *i* to all other sectors (including energy) and countries (including *i=j*).

We then use $S_{m,i,e,j}$ to apply weights to the annual R&D expenditures in the manufacturing sector (*m*) of country *i*. $(S_{m,i,e,j} * R\&D_{m,i,t})$ thus represents the share of R&D expenditures in the manufacturing sector (*m, i*) from which sector (*e, j*) benefits through trade of goods and capital.[6] The sum of direct and embedded R&D expenditures provides an upper-bound estimate of industrial energy-related innovation effort, *R&D_UP*:

$$R\&D\_UP_{e,j,t} = R\&D_{e,j,t} + \sum_{m,i}\left(S_{m,i,e,j} * R\&D_{m,i,t}\right) \tag{2}$$

[5] The World Input–Output Database (WIOD) provides time-series of world input–output tables for 40 countries worldwide, covering the period from 1995 to 2011. Data is available from www.wiod.org.

[6] Using $(S_{m,i,e,j} * RD_{m,i})$ as proxy of the R&D carried out in sector manufacturing sector (m,i) and embedded on the trade with sector (e, j) is equivalent to assuming that R&D intensity of sector (m, i) is constant across products and years. While this is a restrictive assumption, which in our framework cannot be tested, we still believe our proxy is informative insofar as it provides some understanding of embedded R&D investments.

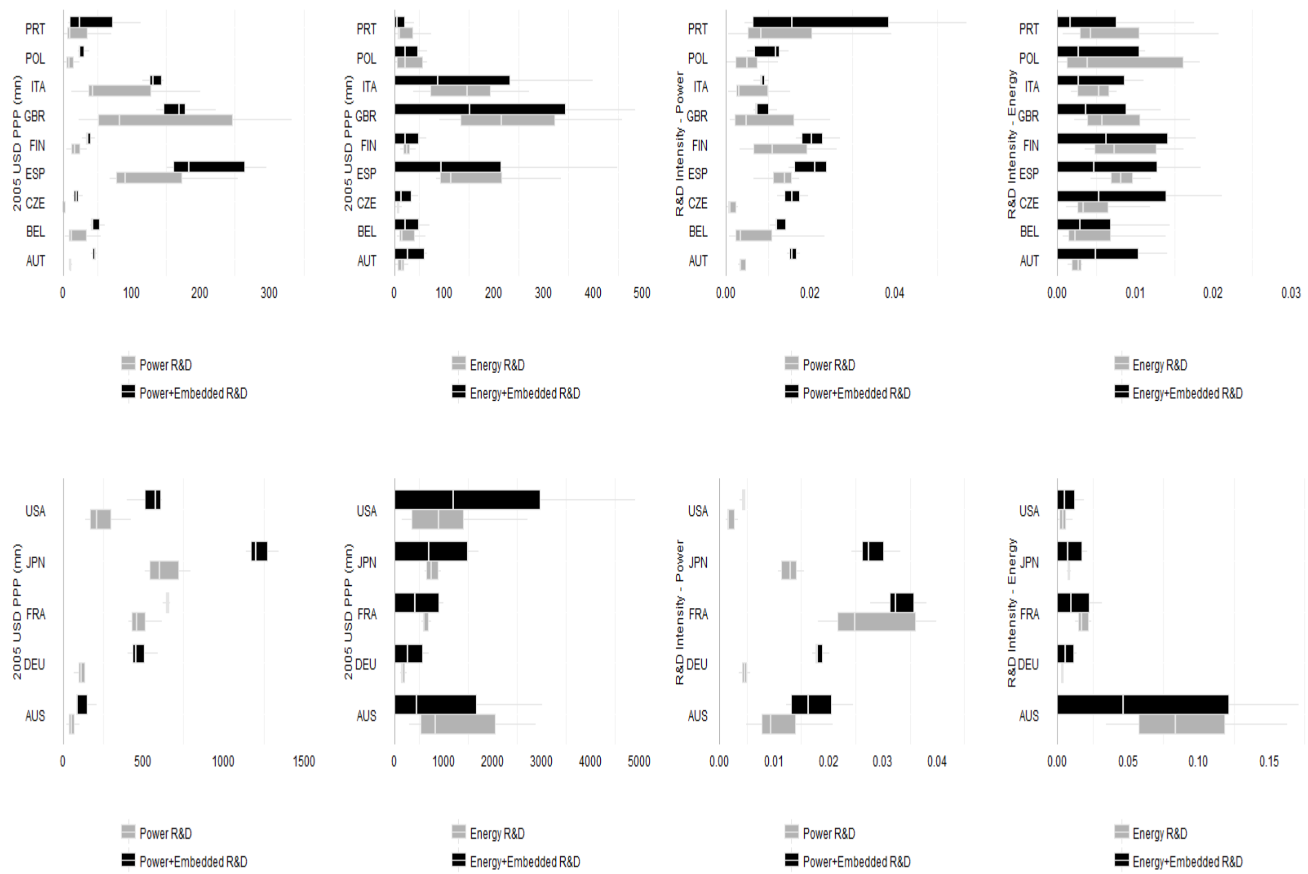
However, note that an estimate of $R\&D\_UP_{e,j,t}$ can be produced only for a subset of countries and years due to data issues, and specifically the fact that the terms $\sum_{m,i}(S_{m,i,e,j} * R\&D_{m,i,t})$ should be comparable across years, i.e. they should include the same countries throughout the sample period. If this were not the case, then higher estimates of $R\&D\_UP_{e,j,t}$ in a given year may simply be given by the availability of a specific country's $R\&D_{m,i,t}$. Given that the ANBERD database is characterized by many missing observations and gives rise to an unbalanced panel, this is a concern we had to address. As a result, comparison of $R\&D_{e,j,t}$ and $R\&D\_UP_{e,j,t}$ can be carried out only in a subset in our sample.[7]

Figure 1 shows both the lower (grey boxes) and the upper bound (black boxes) of energy $R\&D_{e,j}$ for the two definitions of power and energy R&D for the years 1995–2010. The comparison of these two variables is important to understand to what extent the estimates of energy-related R&D change when considering direct investment by the power sector or the R&D investments from manufacturing embedded in the capital goods acquired by the energy sector. Indeed, the correlation between the lower and upper bound estimate of R&D is rather high, 0.95 in the power sector and 0.71 in the energy sector. The energy-related R&D embedded in the manufacturing inputs in the energy sector, measured as the ratio between upper and lower R&D, varies between 1.04 (mining in Australia) and as high as 50 in Poland, and it is generally larger in the power sector. R&D intensity, defined as energy R&D expenditure over the total value added to the economy, is also larger when considering the embedded R&D. Although the definition of energy R&D significantly affects the magnitude of R&D, the ranking of top innovators do not vary substantially. Accounting for the embedded R&D introduces more heterogeneity across countries, for example, Germany and Spain have similar R&D expenditure levels in the power sector in case of lower bound, but when accounting for the embedded R&D, Germany spends almost twice as much as Spain does.

While providing insights on the extent of energy innovation efforts, the ANBERD statistics have some shortcomings. For instance, they report R&D expenditure by sector of performance expenditure, regardless of whether funds were provided by the private or by the public sector. This means that industrial R&D reported by ANBERD statistics might include a fraction of R&D expenditure funded by the government and therefore reported in the government budget outlays as well. For this reason, we refer to the R&D reported in the ANBERD statistics as industrial rather than private R&D.

[7] The balanced database is available for 14 countries between 1995 and 2010.

Figure 1: Direct and indirect estimate of energy R&D and of energy R&D intensity: 1995–2010



Note: Boxes measure energy R&D between 2002 and 2009 (sum of direct and embedded R&D in the manufacturing goods used in the energy sector).

Source: Author’s illustration based on ANBERD data (OECD 2016).

Another widely used proxy for innovation is patent counts, which is an indicator of the output of the industrial R&D process (Griliches 1990).[8] The temporal and country coverage of patent data is often broader than that of R&D statistics and makes it an attractive empirical proxy. In the specific case of energy-related innovation, a further advantage of using patent data is the possibility of assigning patents to specific energy technology classes in the energy sector, which also include renewables (Johnstone et al. 2010) and efficient fossil-based technologies for electricity generation (Lanzi et al. 2011). We collect patent statistics from the OECD Patent Statistics Database (OECD 2015) and count applications through the Patent Cooperation Treaty (PCT) by the inventor country and priority date. By filing one international patent application under the PCT, applicants can simultaneously seek protection for an invention in 148 countries throughout the world. PCT applications are more expensive than national applications and usually, cover innovation of higher values than those protected by national patent offices (OECD 2009).[9] The technologies included in our patent counts are the following:[10]

(1) Power Patents: related to energy generation and include both energy generations from renewable and non-fossil sources and technologies improving the efficiency of fossil fuels, such as Integrated Gasification Combined Cycle and improved burners. Both renewable and fossil-efficient technologies have significant mitigation potential (IEA 2014).
(2) Green Patents: includes power patents as well as the patents in the technology domains of general environmental management, technologies specific to climate change mitigation, energy efficiency in buildings and lighting, technologies with potential or indirect contribution to emissions mitigation, emissions abatement and fuel efficiency in transportation

Figure 2 shows the count of power and environmental patents for the countries in our sample, where we define environmental patents as the sum of power and green patents. Top innovator countries are the United States, Japan, and Germany, though patent intensity, defined as the count of patents over the total value added of the economy is larger in smaller countries, such as Finland and Austria, especially when considering power and green patents together.

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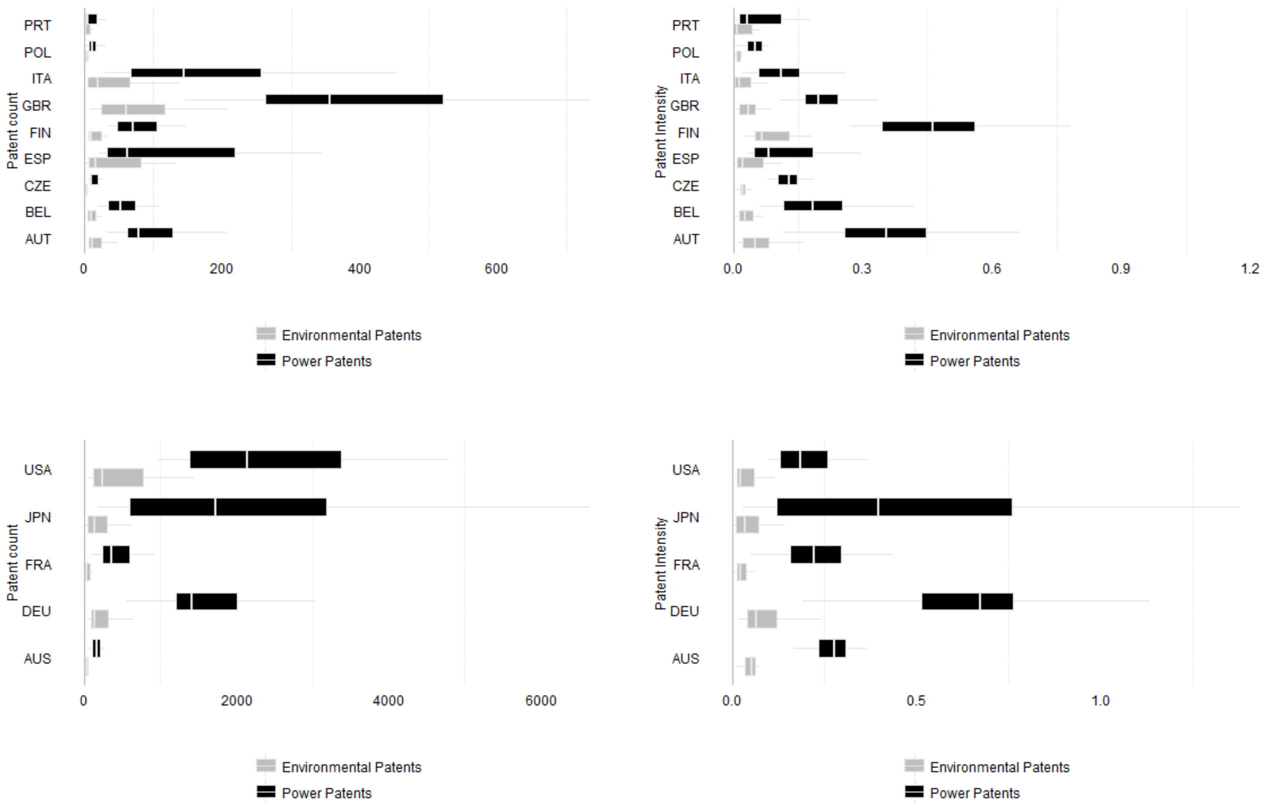
8 Indeed patents are positively correlated with power R&D (correlation coefficient for power patents is 0.41 and 0.62 for environmental patents) and with energy R&D (power patents 0.50 and environmental patents 0.44).

9 The Patent Cooperation Treaty (PCT) is one of several possible routes to apply for a patent. Other routes are the national route and a patent application to a regional office covering several markets, such as the European Patent Office. We select PCT applications because by choosing these routes, applicants pay a higher fee but keep open the possibility to protect the innovation in more than one designated country (for more details, see OECD 2009).

10 Please refer to Haščič and Migotto (2015) and ENV-TECH (2015) for more details about the technologies included.

Figure 2: Counts of power and environmental patents and patent intensity of total value added: 1995–2010



Note: power patents are indicated in black, environmental patents in grey.

Source: Author's illustration based on OECD patent data (OECD 2015).

3 Empirical model and research framework

Combining the data sources on our variables of interest described in sub-Section 3.2, we build an unbalanced panel of 20 countries for the years 1995 to 2010 (see Tables A1–A4 in the Appendix A2). We use an econometric approach to evaluate hypotheses regarding the role of four key political economy factors in the context of energy innovation. The literature has used alternative methods to examine the role of political economy in the context of energy technology choices and in the context of innovation, such socio-technical transition studies (see Johnstone and Stirling (2015) for an example of such approach and Turnheim et al. (2015) for a review of the approach). Socio-technical transition studies can analyse multiple dimensions of change, including economic, political, and socio-cultural aspects at different levels and temporalities. Econometric analysis, specifically panel regression analysis, can complement this approach and isolate the influence of environmental policy, institutional quality, political orientation, and resource distribution conditional on each of the other factors, controlling for country-invariant and time-invariant characteristics. The next section introduces the empirical models hypotheses.

3.1 Empirical model

We use our data to estimate the following general reduced form equation:

$$y_{it} = \alpha_i + \gamma_t + \boldsymbol{\pi}_{it}\beta_1 + \beta_2\varphi_{it} + \beta_3\rho_{it} + \beta_4\theta_{it} + \boldsymbol{Z}_{it}\omega + \varepsilon_{it} \quad (3)$$

where the subscripts *i* and *t* indicate respectively the country and the year and:

- y_{it} is a variable measuring the energy innovation intensity of the economy. Specifically, we define y_{it} as the share of one of our innovation proxies discussed in Section 2 (i.e. industrial energy R&D, power R&D, power patents, or environmental patents) over total value added.[11] We scale all innovation proxies relative to the total value added to account for the heterogeneity in the countries included in our sample. This is in line with the general literature on this topic (see, for instance, Popp 2002). Note that R&D investments are measured in millions of dollars, while patents are measured in fractional counts (OECD 2009). Within our sample, power R&D intensity varies between 0.00007 and 0.08, with an average of 0.01, whereas power patent intensity varies between 0 and 0.46, with an average of 0.05 (see also Table 1 reporting the descriptive statistics).
- $\boldsymbol{\pi}_{it}$ is a vector of policy stringency measures, discussed in detail in the next subsection and includes both Market-Based (MB) and Non-Market-Based (NMB) instruments directly targeting the environmental externality, such as taxes or standards, as well as government R&D investments in energy innovation targeting the knowledge externality.
- φ_{it} is a proxy for institutional quality, measured either by government effectiveness or by an aggregate indicator of governance quality discussed in the next section.
- ρ_{it} is a proxy of the political orientation of the government.
- θ_{it} is a proxy of the distribution of resources to the energy sector relative to the rest of the economy, which in our framework inform on two different aspects, market-size effect and the power of the energy lobby within each country.
- $\mathbf{Z}_{it}$ is a vector of other relevant control variables influencing innovation investments, including an index for industrial energy prices and trade openness. Higher energy prices are expected to increase innovation incentives, net of any political economy consideration (Popp 2002), whereas trade openness can have an ambiguous effect.
- a_i and γ_t are country and year fixed effects, while ε_{it} is a random error term. Country fixed effects control for time-invariant factors, including persistent institutional factors, such as the democratic/autocratic characteristics and system of government of countries. While these factors may influence incentives to invest in energy-related innovation, they do not vary significantly over time. The time fixed effects control for inter-temporal trends that are uniform across countries, such as the economic cycle.

The expectations about the roles of the variables of interest, $\boldsymbol{\pi}_{it}$, φ_{it}, ρ_{it}, θ_{it}, is detailed in the research hypotheses presented in sub-Section 3.2. The regressions are estimated using fixed effect linear models as both R&D and patent data[12] are continuous variables. Due to the different nature of R&D

[11] While in Section 2, we provided estimates of $R\&D\_UP_{e,j,t}$ (upper bound estimate of industrial energy R&D), given the limited coverage of this variable we do not include it in the main specifications in our empirical analysis but for robustness checks in Section 3.

[12] The patents from the OECD database are computed using fractional counting and hence are continuous in nature.

investments and patents, we use a different lag structure in the specifications. Specifically, we assume that R&D investments react faster to environmental policies than patents. This is due to the fact that patents measure the output of the innovation process. Applying for patent requires first to put the R&D investment to work and then develop and test new ideas. For this reason, the R&D specifications consider a one-year time lag, while the patent equation considers a two-year time lag.[13]

3.2 Research hypotheses

We use the model presented above to test a set of hypotheses inspired by the existing literature. The four hypotheses of interest are discussed below.

Hypothesis 1 (H1): *Environmental policy stringency* (π_{it}) *results in dynamic efficiency gains. Stringent regulations provide long-term incentives for innovation in energy-saving and pollution-reducing technologies.*

Overcoming environmental issues requires addressing two market failures. Since pollution is not priced appropriately, private firms tend to over-pollute with respect to the social optimum. The environmental externality can be directly targeted by using two different policy instruments: market-based policies, such as a tax on pollution, feed-in tariffs, or trading schemes, and non-market based policies, such as standards or incentives for R&D investments in cleaner energy. Both instruments have been widely used in the countries in our sample.

As argued in the introduction, in the specific domain of energy and the environment, the role of government and public policies as drivers of innovation has recently attracted much attention (Carraro et al. 2010; Newell 2010; Popp et al. 2010). Key questions in this respect relate to the effectiveness of such policy approaches and on their costs and implications for the economy. The available literature provides evidence on both market-based and non-market-based instruments, together with innovation policies, supporting cleaner technologies, and affecting the rate and direction of technological change (Jaffe et al. 1995; Popp 2002; Johnstone et al. 2010) but a priori their effectiveness may be different. Theoretical studies argue that non-market-based instruments generally provide less innovation incentives than market-based instruments, as innovators are not pushed to exceed the standards set by the regulators. However, the ranking of different policy instruments is ambiguous and depends on a number of other factors (Fischer et al. 2003; Newell 2010). The implementation of market-based instruments is generally more difficult than that of the non-market based instruments, as taxes are generally opposed more strongly than R&D incentives or standards are. The empirical literature on the matter has only recently provided some limited evidence to support the hypothesis that market-based instruments may be more effective (see, for instance, Johnstone et al. 2010).

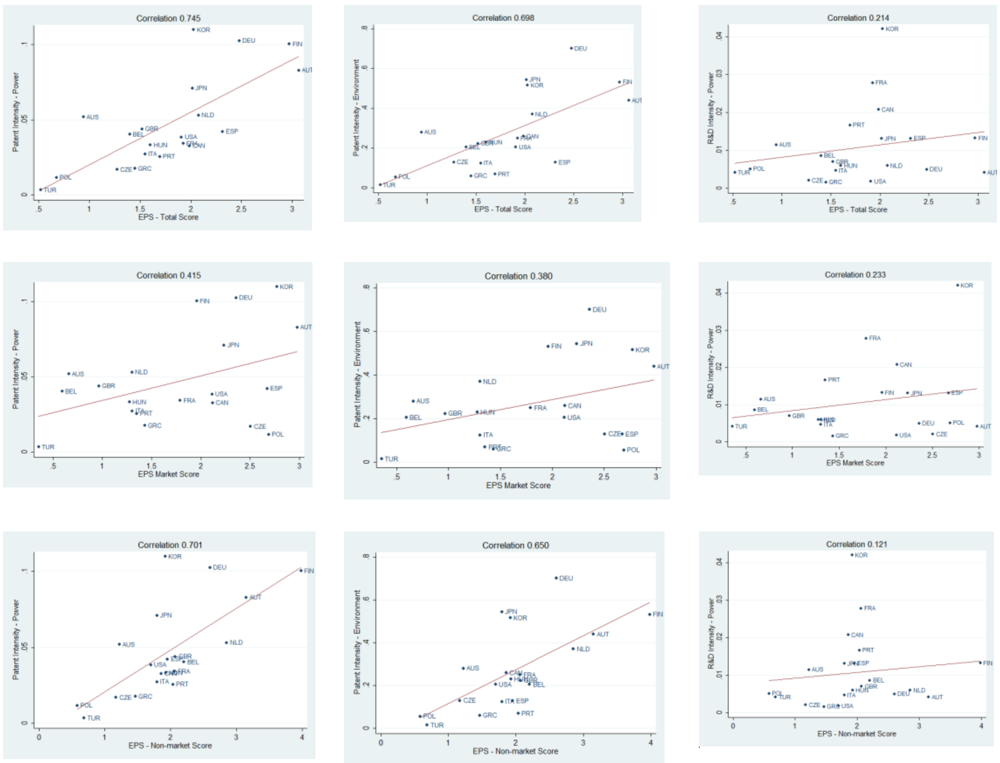
Previous empirical studies on the inducement effect of environmental and energy policy on innovation have employed different measures of environmental stringency, policy instruments, and innovation indicators (Brunel and Levinson 2013). In this paper, we rely on the recent environmental policy stringency (EPS) database of the OECD (Botta and Koźluk 2014), which provides detailed cross-country information on several instruments and on the International Energy Agency (IEA) Energy

[13] Note that, incidentally, allowing for a one (two) year lag structure in the R&D (patent) equation also partly addresses concerns regarding the endogeneity of the explanatory variables. Regarding country-level variables such as good governance, the political orientation of the government and the lobbying power of the energy sector, endogeneity corners are weak to non-existent, since environmental innovation represents only a fraction of the innovative capacity of the countries in our sample during the time period explored. Hence, it is unlikely to be a major driver of country-level variables. Conversely, there may be concerns regarding the endogeneity of the EPS policy indicators, as the availability of cleaner and more efficient energy technologies may be influencing the ability of countries to propose, pass, and adopt environmental policies (Carrion-Flores and Innes 2010). Allowing for a time lag reduces concerns in this respect. In the case of the patent regression, results with one-period lag are available upon request.

Technologies R&D database (IEA 2015b). The EPS aggregate policy indicator (EPS–Total score) is constructed using information on both MB policies and NMB policies.[14] For each policy instrument, countries are scored on a scale from 0 to 6 depending on the stringency of the policy they implement. Such scores are then weighted and aggregated to construct the aggregate policy indicator.[15]

Figure 3 shows the correlation between the mean values of patent and R&D intensity, and the three EPS policy indicators (Total score, MB, and NMB) for the period 1995–2010. The correlation is positive and stronger for patents. This is likely due to the fact that, whereas power and environmental patents are defined as cleaner technologies (e.g. inventions that reduce or eliminate the use of fossil-based energy resources), power R&D is defined as the R&D expenditure of the electricity sector without any characterization in terms of its environmental impact.

Figure 3: Environmental policy and innovation intensity over total value added



Note: Mean values over the period 1995–2010.

Source: Author's illustration based on OECD R&D data (OECD 2016).

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14 MB includes feed-in tariffs (FITs—solar and wind), taxes (on CO2, SOx, NOx, and diesel), certificates (White, Green, and CO2), and the presence of deposit and refund schemes (DRS). NMB includes standards, such as emission limits for SOx, NOx, and SO2 and on the sulphur content of diesel, as well as public R&D investment in energy technologies.

15 We refer the interested reader to Botta and Koźluk (2014) for details about the indicators' construction.

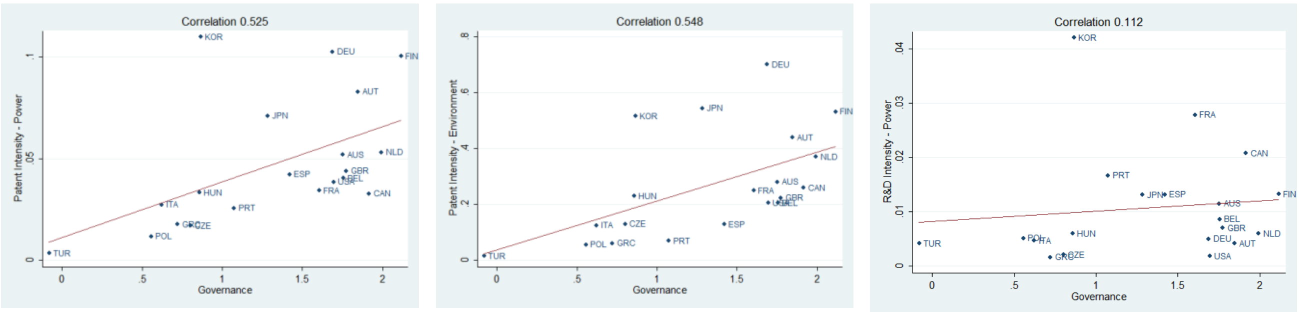
Hypothesis 2 (H2): *Institutional quality, measured as good governance, increases the incentives to invest in energy-related innovation.*

The role of governance quality has been widely examined in the context of investments by the literature on Foreign Direct Investment (FDI) drivers and to a lesser extent, by the general literature on innovation.[16] The dominant view is that good governance[17] aids FDI (Ayal and Karras 1996; Globerman and Shapiro 2003; Biglaiser and DeRouen 2006; Gani 2007; Staats and Biglaiser 2012). However, poor governance can also lead to more foreign investments if combined with high levels of corruption (Bellos and Subasat 2012). The literature on general innovation states that better institutions are likely to promote general innovation and investments (Habiyaremye and Raymond 2013; Tebaldi and Elmslie 2013; Silve and Plekhanov 2015). The contributions focussing on the relationship between institutions and the environment suggest that good governance is generally associated with a greater adoption of environmental policies and with better environmental outcomes (Castiglione et al. 2012, 2014).

We test whether government effectiveness and more broadly good governance as measured by the World Governance Indicators (WGI) (Kaufman et al. 2010)[18] affect energy-related innovation. WGI institutional quality indicators are measured on a normalized scale from -2.5 to +2.5, where the highest value indicates better governance. We focus on government effectiveness, which is an indicator of bureaucratic quality and speed. Low levels of government effectiveness can be associated with excessive regulations, lengthy processes, and lower transparency in the form of flow of information.[19]

The correlation between patent and R&D intensity and governance effectiveness are portrayed in Figure 4. The correlation is positive, suggesting that good governance is generally associated with more innovation in the energy sector, especially when measured in terms of innovation output.

Figure 4: Governance and innovation intensity over total value added



Note: Mean values over the period 1995–2010.

Source: Author's illustration based on WGI data (Kaufman et al. (2010) and OECD R&D (OECD 2016).

16 The general literature on the determinants of innovation in the manufacturing sector is broad (Becheikh et al. 2006; Hall and Rosenberg 2010) and focusses on several key internal factors, such as size, firm age, skills, and qualified personnel.

17 Governance consists of the traditions and institutions by which authority in a country is exercised. This includes the process by which governments are selected, monitored, and replaced; the capacity of the government to formulate and implement sound policies effectively; and the respect of citizens and the state for the institutions that govern economic and social interactions among them (Kaufmann et al. 2000). Good governance is defined as a government that entails an independent judiciary and legislation, fair and transparent laws with impartial enforcement, reliable public financial information, and high public trust (Subasat and Bellos 2011).

18 For more detailed information on the WGI, please see: http://info.worldbank.org/governance/wgi/index.aspx#home.

19 As a robustness test, we also consider an aggregate governance indicator defined as the simple average between the four WGI indicators: government effectiveness, regulatory quality, rule of law, and perception of corruption in the public sector. The indicator, government effectiveness, shows a higher correlation compared to the aggregate WGI indicator.

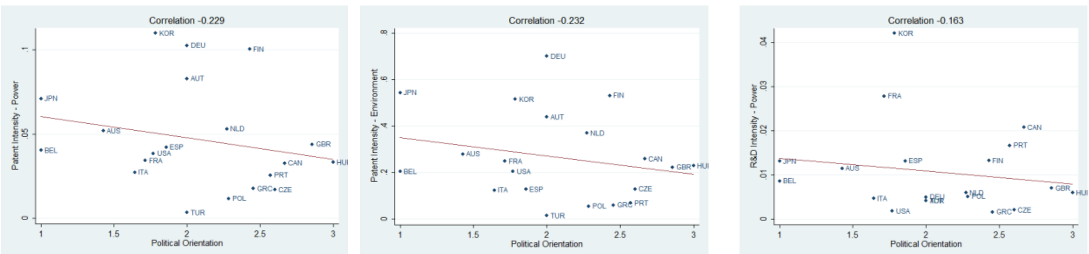
Hypothesis 3 (H3): *The political orientation of the government influences investments in energy R&D and patents. On the one hand, left-leaning governments are more likely to implement regulations that attract innovation and investment in energy-related R&D. On the other hand, right-wing-oriented governments are more likely to take a laissez faire approach. Therefore, the impact of political orientation can be ambiguous.*

The role of government political orientation has been examined in the context of environmental policy adoption (Fankhauser et al. 2014; Folke 2014) and to some extent, in the context of private investment and FDI. In the former, the consensus seems to be that right-wing governments generally oppose laws to support climate regulations (McCright and Dunlap 2011; Painter and Ashe 2012), while left-wing governments are more likely to pass them (Neumayer 2003). Fankhauser et al. (2014) conclude that left-leaning governments are also more likely to enact laws on energy supply and low-carbon R&D. On the contrary, right-leaning governments are more inclined to allow the market forces to stimulate investment efforts (Esping-Andersen 1990; Boix 1998). The FDI literature, however, provides somewhat contrasting insights. Shleifer (1998) states that right-wing governments consider the private sector to be more conducive in terms of innovation and therefore tend not to intervene in the market. Hawkins et al. (1976) and Jensen (2006) mention that left-leaning governments are more likely to expropriate foreign assets, which discourages FDI. Pinto (2008), Jensen et al. (2012), and Pinto (2013) argue that FDI inflows are likely to be greater in labour-intensive sectors, thus left-wing governments receive greater FDI in the manufacturing sector. The argument is that FDI inflows decrease return to capital while they increase the return to labour. Thus as left-wing governments favour labour interests, they are more likely to promote FDI inflows in sectors where FDI can complement labour.

We use political orientation of governments from the Database of Political Institutions 2012 (DPI) (Beck et al. 2001 as proxies for political institutions, specifically, the political orientation of the executive party with respect to economic policy. This is a categorical variable that takes three values: right (1), centre (2), and left (3) orientations.

Figure 5 shows the correlation between patent, R&D intensity, and political orientation. The negative correlation, particularly in the case of patent intensity, suggest that right- and centre-oriented countries are associated with higher innovation activity relative to the total value added of the economy, reflecting the second part of Hypothesis 3. However, correlation might be confounded by the interaction between political orientation and other factors, which will be controlled for in the regression analysis discussed in the next section. Furthermore, note that the graph in Figure 5 presents the average correlation over the sample period with one observation per country, while the analysis we present after exploits within country variation over time.

Figure 5: Political orientation and innovation intensity over total value added



Note: Mean values over the period 1995–2010.

Source: Author's illustration based on DPI data (Beck et al. 2001) and OECD R&D (OECD 2016).

Hypothesis 4 (H4): *A higher share of energy intensive sectors will (a) give rise to a market-size effect (i.e. higher demand for energy), (b) lead to more lobbying power of the energy intensive sectors towards the government, and (c) increase the coordination costs of such lobbying activities. Therefore, the impact of resource distribution on energy-related innovation is not clear a priori.*

The distribution of resources across interest groups may give rise to several dynamics. First, if an economy relies more on energy intensive sectors, the market for new energy inventions will be larger. As a result, the value associated with any innovation relative to energy goods will be higher, as it is more profitable to develop technologies that have a larger market (see, for instance, the discussion of market-size effects in the directed technical change literature, Acemoglu 2002). This would suggest that larger energy intensive sectors will likely result in more energy-related innovation. Second, energy intensive incumbent industries with access to significant resources tend to engage in lobbying for government support and seek to influence policy decisions. For instance, Fredrickson and Svensson (2003) argue that strong industry lobbies may engage in corruption to reduce environmental policy stringency while Fredriksson et al. (2004) remark that incumbent industries utilize their lobbying power to oppose structural transformation. Third, larger sectors may imply more firms/actors, and this would result in higher coordination costs of such lobbying activities (Olson 1965; Fredriksson et al. 2004).

Which one of the three effects described above prevails remains an empirical question. In the energy sector, market dominance by established firms can arguably be stronger and more likely than in other sectors. Given the strategic role of energy as an input to economic growth, the presence of large and, until very recently, highly regulated utilities is more likely to lead to a dominance of existing technologies, a barrier to energy innovation and in general, a holding back of the development of more radical technologies (OECD 2009; D'Este et al. 2012; Blanchard et al. 2013; Costa-Campi et al. 2014). Incumbent energy utilities will likely oppose any structural transformation destabilizing their resources and power (Costa-Campi et al. 2014), while strong industry lobbies might engage in corruption to reduce environmental policy stringency (Fredriksson, et al. 2004). Moreover, fuel-rich countries might have weaker incentives to invest in energy R&D compared to import-dependent countries (Friedrichs and Inderwildi 2013). In this respect, Anadón (2012) shows that lobbying has a major influence in the energy sector appropriation of the public R&D budget in the US.

In line with previous literature (Fredriksson et al. 2004; Costa-Campi et al. 2014), we use the value added share of energy-intensive industries (Coke, Refined Petroleum and Nuclear Fuel, Chemicals and Chemical Products, Rubber and Plastics, Water and Air Transport, Electricity, Basic Metals and Fabricated Metal Mining)[20] in the economy computed using industrial value added data from the WIOD database (Timmer et al. 2015) as an indicator of market-size, lobbying power, and coordination costs. Figure 6 depicts the correlation plots between patent, R&D intensity, and the value added share of energy intensive industries. The negative correlation indicates that countries with a larger energy sector tend to perform less innovation. The correlation is stronger for patent data as patents explicitly refer to cleaner technologies that reduce the use of energy resources.

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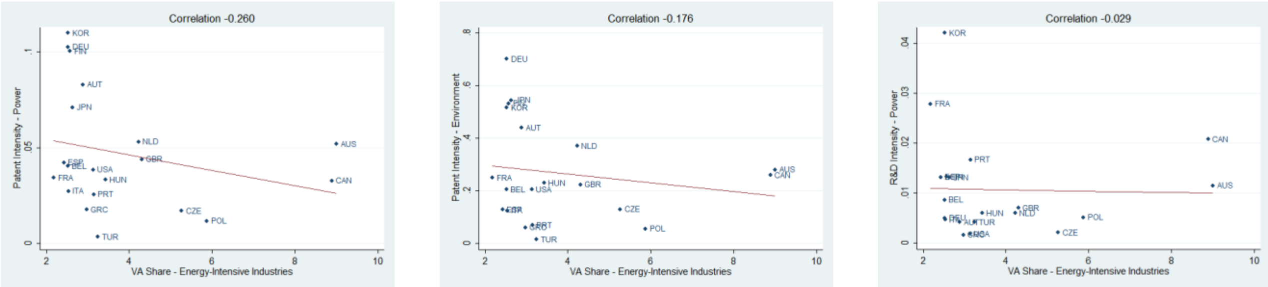
[20] Energy-intensive sectors have been defined as the sectors with energy intensity above the 75th percentile. As a robustness test, two other proxy variables have been considered; the value added share of carbon-intensive industries (other non-metallic mineral, inland, water, and air transport, electricity, mining), and value added share of the electricity or energy (electricity +mining) sector. Carbon-intensive sectors have been defined as the sectors with carbon intensity above the 75th percentile.

Figure 6: Lobbying and innovation intensity over total value added



Note: Mean values over the period 1995–2010.

Source: Author's illustration based on WIOD data (Timmer et al. 2015) and OECD R&D (OECD 2016).

Table 1 summarizes data sources and descriptive statistics for the variables used in the empirical analysis. Tables A2–A5 in the Appendix report the mean value and the coefficient of variation of all variables for all countries included in our sample. Table 2 summarizes the main proxy variables that are used to measure the key drivers behind the four hypotheses just described.

Table 1: Descriptive statistics of variables used in the empirical analysis and data sources

Variable	Mean	Std. Dev.	Min	Max	Source
Log of Patent Intensity—Power	0.046	0.053	0.00	0.38	OECD, 2015
Log of Patent Intensity—Environment	0.227	0.174	0.00	0.97	OECD, 2015
Log of R&D Intensity—Power	-5.088	1.254	-9.38	-2.55	OECD, 2016
Patent Intensity—Power	0.048	0.060	0.00	0.46	OECD, 2015
Patent Intensity—Environment	0.276	0.257	0.00	1.65	OECD, 2015
R&D Intensity—Power	0.011	0.012	0.00	0.08	OECD, 2016
R&D Intensity—Energy	0.027	0.046	0.00	0.326	OECD, 2016
EPS Score	1.792	1.000	0.00	4.16	Botta and Koźuk (2014)
EPS Market Score	1.794	0.938	0.25	4	Botta and Koźluk (2014)
EPS Non-market Score	1.979	1.174	0.00	5.38	Botta and Koźluk (2014)
Government Effectiveness	1.347	0.566	-0.28	2.26	WB WGI (Kaufman et al. 2010)[21]
Corruption Control	1.268	0.738	-0.71	2.59	WB WGI (Kaufman et al. 2010)
Average WGI	1.278	0.528	-0.16	2.14	WB WGI (Kaufman et al. 2010)
Political Orientation	2.055	0.952	1.00	3	DPI (Beck et al. 2001)
Energy-Intensive Industries - VA Share	3.800	2.103	1.59	13.81	WIOD (Timmer et al. 2015)
Carbon-Intensive Industries - VA Share	7.209	2.458	4.10	16.36	WIOD (Timmer et al. 2015)
Electricity—VA Share	0.024	0.006	0.01	0.04	WIOD (Timmer et al. 2015)
Energy Price Index	4.514	0.164	4.09	4.87	IEA, 2016[22]
Trade Openness (% of GDP)	70.084	33.078	18.76	159.89	WDI, 2016[23]

Source: Authors' estimations based on Beck et al. (2001), Kaufman et al. (2010), OECD (2012, 2015, 2016), Botta and Koźuk (2014), Timmer et al. (2015), and EIA (2016).

[21] For additional information associated with government effectiveness, please see the World Bank database: http://data.worldbank.org/.

[22] For additional information on the Energy Price Index, please see IEA: http://www.iea.org/statistics/topics/pricesandtaxes/.

[23] The World Bank's data for WGI can be found at: http://info.worldbank.org/governance/wgi/index.aspx#home.

Table 2: Political economy factors: Hypothesis and proxy variables

Hypothesis	Proxy Variables
H1: Environmental policy	EPS—Market, EPS—Non market, EPS—Total
H2: Governance	Governance effectiveness, Governance Average WGI indicator, Governance x EPS—Total
H3: Left-wing political orientation	Political orientation
H4: Lobbying	Value added share of energy-intensive industries Value added share of carbon-intensive industries Value added share of electricity

Source: Authors' conceptualization.

4 Results

The empirical results of our analysis using the two main indicators of innovation are provided in Tables 3 and 4. Table 3 focusses on power and energy R&D intensity while Table 4 presents the results relative to power and environmental patent intensity.

4.1 Role of environmental policy stringency

Our results generally confirm previous findings on the inducement effect of environmental policies with respect to energy-related innovation activities. We find that the effect is weaker in the case of energy-related R&D and stronger in the case of energy-related patents.

Focussing on the R&D specification (Table 3), the coefficient for EPS variables is positive only if we consider investments in the power sector alone (hence, electricity) and MB policy instruments. Furthermore, the coefficient is only significant at the 15 per cent level. Non-market based policies instead do not have any significant effect on R&D, in line with Ulph and Katsoulacos (1998) and Fischer et al. (2003) who suggest that stricter regulations fail to have any significant effect on R&D.

Conversely, stronger results emerge when patent intensity (Table 4) is used as the indicator for innovation. Both market and non-market-based environmental policy stringency are positive and significant for both types of patents. The effect of market-based instruments is stronger in most specifications and the inducement effect is larger when the broader definition based on environmental patents is considered. Our results suggest that one unit increase in the market based score (corresponding approximately to an interquartile (IQR) change)[24] increases power patents intensity by between 1.3 and 1.4 per cent and environmental patent intensity by between 3 and 3.2 per cent. In the case of non-market-based policies, a similar change[25] increases power patents intensity by between 1.2 and 1.5 per cent, and environmental patents intensity by 2.3 per cent. It should be noted that the

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[24] In the case of EPS market score, moving from the 25th quartile (1.1) to the 75th quartile (2.3) is equivalent to a one-unit increase in the EPS and is equivalent to moving from the policy stringency of Belgium to that of Finland in 2010.

[25] In the case of EPS non-market score, the IQR is larger than one. Moving from the 25th quartile (1.1) to the 75th quartile (2.6) is equivalent to the increase in policy stringency observed in Portugal between 1995 and 2010.

median improvement in policy stringency between 1995 and 2010 across the 20 countries has been approximately 1 unit for EPS market-based score and 2 units on a scale of 0 to 6 for EPS non-market-based score.[26]

These findings are in line with Johnstone et al. (2010) who show that increasing number of international climate policies have resulted in an increase in renewable energy patents. These results are also in line with findings from some of the previous literature including Lanjouw and Mody (1996) and Popp (2002), namely that the number of environmental patents tends to increase as the cost of pollution abatement rises. Finally, the apparently stronger results in the case of the patent specification than in the R&D specification are in line with the evidence presented by Rubashkina et al. (2015), who focusses on overall patenting within different sectors of the economy. A reason for the stronger evidence of induced innovation when using patents as opposed to R&D in the present work might be due to the different ways patents and R&D are defined. Patents explicitly refer to clean and energy-saving innovations while the definition of energy R&D does not specify the purpose of the expenditure. Overall, with respect to Hypothesis 1, our regression results suggest that more stringent environmental policies provide dynamic efficiency gains and incentives for innovation in energy-saving and pollution-reducing technologies.

4.2 Role of good governance

Good governance appears to be an important driver of innovation. Depending on the governance proxy used, a one-unit increase in government effectiveness is associated with between 62 per cent and 96.4 per cent increase in power R&D intensity (Table 3) and between 6.5 per cent and 31.3 per cent increase in patent intensity (Table 4).[27] This suggests that stronger economic institutions promote innovation and are in line with the existing literature, which provides evidence that strong economic institutions promote generic innovation (Ayal and Karras 1996; Habiyaremye and Raymond 2013; Tebaldi and Elmslie 2013; Silve and Plekhanov 2015).

The marginal effect of governance might appear substantial given the coefficient interpretation provided above. However, a one-unit increase in the governance proxy is a rather significant change. It is comparable to moving from the governance quality of a country such as Portugal (1.02) or Slovenia (1.03) to that of countries such as Sweden or Finland (2.01 and 2.25) in 2010. Historically, the biggest improvements in governance quality have been achieved by South Korea and Estonia, where the governance WGI score increased by 0.6 and 0.5 between 1995 and 2010, respectively.

In specification (5) of Table 2 and (5) and (10) of Table 3, we test whether the governance affects the marginal effect of policy stringency by including the interaction term between the aggregate environmental policy stringency indicator and governance effectiveness. When considering power patents (Specification 5, Table 3), we do find evidence that governance augments the inducement effect of environmental policy.

Overall, with respect to Hypothesis 2, our regression results suggest that improvements in governance and government effectiveness provide incentives for energy-related innovation.

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[26] During 1995–2010, modest increases of 1 have been achieved in Italy, Australia, Portugal, while more ambitious increases of 3–4 units have been achieved in South Korea, The Netherlands, while Germany has achieved increase of about 2 units.

[27] Recall the different units of measurement of R&D and patent intensity, see Table 1.

4.3 Role of political orientation

Political orientation seems to be a more important factor for the input rather than the output of innovation, as the variable has a statistically significant effect only in the case of power and energy R&D intensity. A change in the political orientation of the government from right towards a left-leaning position, which corresponds to an IQR change in our sample, is associated with an increase in industrial R&D of 11 per cent (power) and 22 per cent (energy), respectively. To put these effects in perspective, countries such as Portugal in our sample moved from a right-leaning orientation in 1995 to a left-leaning government in 2010, while countries such as Canada, The Netherlands, and Sweden underwent the opposite change.

Overall, with respect to Hypothesis 3, left-leaning governments are more likely to implement regulations that attract energy R&D investments, but this does not translate into higher patent intensity.

4.4 Role of resource distribution, market-size effect, and lobbying

The size of the energy sector, measured as the value added share of energy intensive industries, has a positive impact on R&D intensity, suggesting that either due to the larger size of the potential market for energy innovations, industries will allocate more resources towards R&D, or a larger energy sector will be able to lobby for more resources to be allocated to energy R&D. A 1 per cent increase in the value added share of energy intensive industries, approximately corresponding to an IQR change, increases power R&D intensity by between 0.54 and 0.83 per cent. It should be noted that a 1 per cent increase is a rather modest increase in this case. Between 1995 and 2010, changes in the share of energy intensive industries in our sample varied between (-) 62 per cent to (+) 28 per cent in France and Australia, respectively.

The smaller marginal effect on energy R&D intensity[28], might reflect a different relevance of political economy factors within the energy sector itself. As explained by Hughes and Lipscy (2013), power markets tend to be more concentrated within domestic markets whereas many oil and gas companies are vertically integrated and international in scope. Therefore, the political economy factors that matter for electricity are likely to differ from those relevant for the oil and gas industry, which are included in our definition of energy R&D. Factors such as lobbying are therefore more relevant for the more inward-oriented sectors, such as power. Since the size of the energy sector is a proxy of the lobbying power of energy-intensive industries, it has the opposite effect on patent intensity, indicating that a larger energy sector reduces the incentive to carry out energy-saving and clean innovation.

Overall, with respect to Hypothesis 4*,* the larger the size of the potential markets for energy innovation, the larger the inducement effect for industries to invest in energy R&D. At the same time, larger energy sector has power to lobby for more resources to be allocated to energy R&D. These effects seem to prevail over coordination costs, however, market-size effects or lobbying from the energy sector do not result in a larger number of cleaner patents. This could mean that R&D investments are either used less effectively, or that they are used to improve other aspects of the technologies, which are more intangible and which are not codified in patents.

4.5 Role of other factors

We briefly comment here on the coefficients associated with our additional control variables, namely the energy price index and trade openness. The energy price index has a negative and statistically

[28] Including the mining sector (oil and gas extraction).

significant effect on both power and energy R&D intensities. A possible explanation in this respect is that higher energy prices increase energy expenditure, both in the private and public sectors, reducing resources available for other uses, including R&D. Energy prices provide a positive incentive for patents, but the coefficients are not statistically significant. Although the evidence is only imprecisely estimated, it suggests that even though fewer resources are allocated as input to innovation, the innovation process is more efficient at delivering new inventions.

Trade openness has a negative and significant effect on energy R&D intensity, suggesting that countries with developed trade relationships have fewer incentives to allocate resources to power and mining R&D and that technology adoption and imitation displace domestic innovation. Note that the effect is only significant when the definition of energy R&D include the mining sector, which is more outward-oriented than power, making the energy aggregate sensitive to changes in trade exposure.

4.6 Robustness tests

Appendix 3 reports additional regression that test the robustness of our results to the proxy variables used to measure lobbying and to the definition of power R&D. Tables A5, A6, and A7 test the role of value added share of carbon intensive industries and of electricity value added as alternative proxy variables for lobbying. These variables are generally less significant than the proxy selected for the main specification but, when significant, they have the expected signs. The use of a different proxy for lobbying does not affect the empirical evidence supporting Hypotheses 1–3.

As discussed in Section 2, power R&D is arguably a lower bound of the power-related innovation and energy-related R&D is performed by the manufacturing sector. Appendix Table A8 reports a number of selected specifications that use power R&D and power R&D embedded in manufacturing sectors to define the dependent variable R&D intensity. Given the different sample size, results are not comparable to the ones discussed in Table 3 and estimates are less precise. The specifications considered confirm the evidence regarding Hypothesis 3 and Hypothesis 4 on the role of political orientation and that of lobbying. The relationship behind Hypothesis 2 has also the expected sign. Regarding Hypothesis 1, we find that an increase in policy stringency either does not affect or reduce power R&D if it includes the energy-related R&D performed by the manufacturing sector.

Table 3: Regression results using R&D intensity over value added as innovation proxy: One-year lag for all independent variables

		1	2	3	4	5	6	7	8	9
	Dependent Variable	Log of R&D Intensity—Power					Log of R&D Intensity—Energy			
	EPS Market Score	0.198+	0.189+	0.165			-0.006	-0.018		
H1		(0.125)	(0.121)	(0.122)			(0.111)	(0.111)		
	EPS Non-market Score	-0.089	-0.014	0.018			-0.058	-0.043		
		(0.108)	(0.107)	(0.108)			(0.098)	(0.098)		
	EPS Total Score				0.135	0.164			-0.079	0.006
					(0.110)	(0.162)			(0.101)	(0.148)
	Govt. Effectiveness	0.964***	0.769**		0.619**	0.666*	0.399		0.409	0.549+
H2		(0.323)	(0.317)		(0.312)	(0.367)	(0.294)		(0.288)	(0.338)
	WGI			0.754				0.418		
				(0.538)				(0.498)		
	Govt. Effectiveness*EPS Interaction					-0.033				-0.098
						(0.135)				(0.123)
H3	Political orientation	0.222***	0.211***	0.202***	0.200***	0.199***	0.112*	0.107*	0.111*	0.106*
		(0.065)	(0.063)	(0.064)	(0.063)	(0.063)	(0.058)	(0.058)	(0.057)	(0.058)
	VA Share Energy-intensive industries	0.710**	0.827**	0.814**	0.815**	0.822**	0.537+	0.525+	0.542+	0.553+
H4		(0.356)	(0.356)	(0.363)	(0.356)	(0.358)	(0.342)	(0.348)	(0.341)	(0.341)
	Energy price index		-3.053***	-3.203***	-3.193***	-3.202***	-8.309***	-8.629***	-8.286***	-8.388***
			(0.756)	(0.760)	(0.753)	(0.756)	(3.034)	(3.029)	(3.012)	(3.017)
	Trade openness		0.005	0.005	0.004	0.004	-0.027***	-0.027***	-0.027***	-0.027***
			(0.008)	(0.008)	(0.008)	(0.008)	(0.007)	(0.007)	(0.007)	(0.007)
	Observations	256	256	256	256	256	256	256	256	256
	R-squared	0.200	0.257	0.244	0.254	0.254	0.235	0.231	0.236	0.239
	Number of countries	20	20	20	20	20	20	20	20	20

Note: Standard errors in parentheses; *** p<0.01, ** p<0.05, * p<0.1, + p<0.15.

Source: Authors' estimations.

Table 4: Regression results using patent intensity over value added as innovation proxy: Two-year lag for all independent variables

		1	2	3	4	5	6	7	8	9	10
	Dependent Variable	Log of Patent intensity—Power					Log of Patent intensity—Environment				
H1	EPS Market Score	0.013***	0.014***	0.013***			0.031***	0.032***	0.029**		
		(0.005)	(0.003)	(0.007)			(0.012)	(0.007)	(0.016)		
	EPS Non-market Score	0.012***	0.013***	0.015***			0.018+	0.018+	0.023**		
		(0.004)	(0.005)	(0.001)			(0.011)	(0.110)	(0.046)		
	EPS Total Score				0.017***	0.004			-0.007	0.030**	0.020
					(0.000)	(0.587)				(0.011)	(0.277)
H2	Govt. Effectiveness	0.069***	0.070***		0.065***	0.045***	0.211***	0.212***		0.199***	0.183***
		(0.013)	(0.000)		(0.000)	(0.003)	(0.033)	(0.000)		(0.000)	(0.000)
	WGI			0.095***					0.313***		
				(0.000)					(0.000)		
	Govt. Effectiveness*EPS Interaction					0.015**					0.012
						(0.010)					(0.416)
H3	Political Orientation	-0.002	-0.002	-0.002	-0.002	-0.002	-0.006	-0.007	-0.007	-0.008	-0.007
		(0.003)	(0.395)	(0.379)	(0.330)	(0.514)	(0.006)	(0.286)	(0.314)	(0.212)	(0.256)
H4	VA Share Energy-intensive industries	-0.003	-0.009	-0.009	-0.012	-0.012	-0.048	-0.061*	-0.058+	-0.068*	-0.069*
		(0.014)	(0.546)	(0.557)	(0.419)	(0.380)	(0.035)	(0.089)	(0.114)	(0.061)	(0.059)
	Energy price index		0.025	0.016	0.024	0.027		0.058	0.032	0.053	0.056
			(0.338)	(0.544)	(0.367)	(0.309)		(0.390)	(0.640)	(0.431)	(0.413)
	Trade Openness		-0.000	-0.000+	-0.000	-0.000		-0.001	-0.001+	-0.001	-0.001
			(0.170)	(0.130)	(0.175)	(0.277)		(0.180)	(0.127)	(0.189)	(0.224)
	Observations	256	256	256	256	256	256	256	256	256	256
	R-squared	0.662	0.666	0.651	0.657	0.663	0.634	0.638	0.623	0.630	0.630
	Number of countries	20	20	20	20	20	20	20	20	20	20

Note: Standard errors in parentheses; *** p<0.01, ** p<0.05, * p<0.1, + p<0.15.

Source: Authors' estimations.

5 Conclusion

This paper contributes to the literature by collecting and harmonizing data on energy innovation and environmental policy across countries and over time, and by empirically investigating the impact of political economy and institutional factors on the incentives to innovate in the energy sector. We propose four empirical proxies that can measure energy-related innovation, namely power R&D, energy R&D (consisting of the investment of the power and mining sector), power patents (related to renewable and energy efficient technologies for power production), and environmental patents (including energy patents as well as patents generally aimed at environmental protection). For the R&D proxies, we calculate both a lower-bound and an upper-bound estimate in order to account for the fact that energy-related R&D may not be carried out directly by the power or the energy sector but may be embedded in the machines, which these sectors acquire from the manufacturing sector. We focus on the empirical analysis of the role of four political economy factors, namely environmental policy, good governance, political orientation, and the distribution of resources to energy intensive industries that can induce effects of both market-size and lobbying.

The insights emerging from our empirical analysis show that all the factors affect the incentives to devote resources to energy R&D and to create new clean and energy efficient technologies. Specifically, market-based incentives, and to some extent also non-market based incentives, results in dynamic efficiency gains. Countries with better governance are characterized by higher levels of energy-related R&D, while left-wing governments are more likely to devote R&D resources to the energy sector but this does not translate into higher power-related patent intensity. A larger distribution of resources toward energy intensive sectors can induce market-size effects and have more power to lobby for more resources to be allocated to energy R&D but this does not translate into higher patent intensity.

Overall, our results show that political economy factors can act as barriers even in the presence of stringent environmental policy. This implies that in order to favour changes towards a greener economy, countries should combine environmental policy with a general strengthening of institutional quality, consider the influence of government's political orientation on environmental policy, as well as the size of energy intensive sectors in the economy, which affect both the lobbying structure and the demand for energy innovations. Hence, our contribution calls for increased attention to the determinants of energy-related innovation, to go beyond the focus on environmental policy instruments that has dominated the environmental economics literature in recent years.

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Appendix

A1. Innovation data

Industrial R&D investments

Data on industrial investment in energy innovation are from the OECD (2016) ANBERD database (ANBERD). ANBERD provides information on the R&D expenditures performed by the 60 manufacturing and service sectors, agriculture, mining, and electricity.[29] To proxy private energy R&D spending, we use the ANBERD database statistics for the 'Electricity, water and gas distribution industry'[30] and the 'Mining' sectors, which we argue represent together the best available proxy for the energy sector. Since different versions of the ANBERD database have been released with different coverage, we combine information from Revision 3[31] and Revision 4[32] of the database.

There are three main challenges in using the ANBERD data. First, the statistics are presented by sector of performance expenditures regardless of whether funding was sourced from private or public spending. This means that part of the R&D that is reported in ANBERD might have actually been reported in the government budget outlay. The ANBERD data is classified using a territorial principle, namely expenditures are assigned to the country where the money is spent, but the parent company of the enterprise doing the R&D could actually be located elsewhere (Azagra Caro and Grablowitz 2008). Differences in the type of classification principle used when attributing R&D expenditure or budget to sectors and objectives affect the cross-country comparability between different R&D datasets and can be a source of differences across different datasets.

Second, R&D expenditure can be classified by Main activity or Product Field. Main activity R&D only considers the R&D carried out by the main activity of a given enterprise, whereas product field considers also the R&D performed in secondary activities. Product field data provide a more complete measure of R&D activity but are available only for a limited number of countries. We therefore consider Main Activity R&D whenever possible, and use Product Field R&D only for those countries not reporting Main Activity R&D (Belgium, France, Great Britain, Russia).

Third, the sectors 'Electricity, water and gas distribution industry' and 'Mining' clearly do not satisfactorily capture R&D expenditure related to energy. On one hand, water distribution cannot be considered as part of the energy sector and mining includes information not only on fossil fuels but also on a number of other minerals. However, given the pervasive lack of R&D statistics, this is the best approximation possible to the best of our knowledge. On the other hand, and perhaps more importantly, much of the R&D related to energy is not carried out within the energy sector itself, rather it is embedded in machinery that the energy sector acquires from manufacturing. For this reason, we propose here an 'upper bound estimate' of energy-

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[29] The Frascati Manual (OECD 2002) defines the business enterprise sector as 'All firms, organizations and institutions whose primary activity is the market production of goods or services (other than higher education) for sale to the general public at an economically significant price'. The information is collected though performer-based surveys at the enterprise level. Each enterprise is then allocated to the industrial class of its principal activity (Azagra Caro and Grablowitz 2008).

[30] The electricity, gas, and water sector includes all activities related to the production, transmission, and distribution of electricity; manufacture of gas; distribution of gaseous fuels; and steam and hot water supply.

[31] ANBERD database revision 3 is available here: https://stats.oecd.org/Index.aspx?DataSetCode=ANBERD2011_REV3. REV3 goes until 2008.

[32] Current ANBERD database revision 4 is available here: https://stats.oecd.org/Index.aspx?DataSetCode=ANBERD_REV4 . REV4 goes until 2011 (OECD 2016).

related R&D, which is based on the estimation of the R&D spending embedded in the machinery used by the energy sector.

A2. Additional descriptive statistics

Table A1: Mean dependent variables

Country	Log of Patent Intensity - Power	Log of Patent Intensity - Environment	Log of R&D Intensity - Power	Patent Intensity - Power	Patent Intensity - Environment	R&D Intensity - Power
AUS	0.05	0.25	-4.53	0.05	0.28	0.01
AUT	0.08	0.36	-5.52	0.08	0.44	0.00
BEL	0.04	0.18	-5.20	0.04	0.20	0.01
CAN	0.03	0.23	-3.91	0.03	0.26	0.02
CZE	0.02	0.12	-7.05	0.02	0.13	0.00
DEU	0.10	0.52	-5.33	0.10	0.70	0.00
ESP	0.04	0.12	-4.38	0.04	0.13	0.01
FIN	0.09	0.42	-4.54	0.10	0.53	0.01
FRA	0.03	0.22	-3.62	0.03	0.25	0.03
GBR	0.04	0.20	-5.38	0.04	0.22	0.01
GRC	0.02	0.06	-7.02	0.02	0.06	0.00
HUN	0.03	0.20	-5.39	0.03	0.23	0.01
ITA	0.03	0.12	-5.72	0.03	0.12	0.00
JPN	0.07	0.40	-4.34	0.07	0.55	0.01
KOR	0.10	0.37	-3.20	0.11	0.52	0.04
NLD	0.05	0.31	-5.15	0.05	0.37	0.01
POL	0.01	0.05	-5.99	0.01	0.06	0.01
PRT	0.03	0.07	-4.76	0.03	0.07	0.02
TUR	0.00	0.02	-5.52	0.00	0.02	0.00
USA	0.04	0.19	-6.35	0.04	0.21	0.00

Source: Authors' estimations.

Table A2: Coefficient of variation dependent variables

Country	Log of Patent Intensity - Power	Log of Patent Intensity - Environment	Log of R&D Intensity - Power	Patent Intensity - Power	Patent Intensity - Environment	R&D Intensity - Power
AUS	0.29	0.17	-0.08	0.30	0.19	0.38
AUT	0.60	0.35	-0.05	0.63	0.43	0.35
BEL	0.68	0.39	-0.20	0.70	0.43	0.93
CAN	0.66	0.20	-0.07	0.67	0.22	0.25
CZE	0.60	0.26	-0.19	0.60	0.28	1.66
DEU	0.70	0.24	-0.05	0.74	0.31	0.29
ESP	0.87	0.63	-0.08	0.89	0.67	0.32
FIN	0.74	0.32	-0.16	0.79	0.43	0.65
FRA	0.76	0.36	-0.08	0.77	0.41	0.28
GBR	0.69	0.30	-0.18	0.71	0.33	0.92
GRC	0.84	0.57	-0.16	0.84	0.59	1.21
HUN	0.76	0.38	-0.14	0.77	0.43	0.88
ITA	0.90	0.52	-0.15	0.91	0.55	0.94
JPN	1.07	0.63	-0.03	1.12	0.74	0.11
KOR	1.35	0.77	-0.08	1.43	0.98	0.29
NLD	0.44	0.18	-0.05	0.45	0.21	0.27
POL	0.58	0.48	-0.28	0.58	0.50	0.79
PRT	0.98	0.89	-0.27	0.99	0.91	1.09
TUR	0.97	0.66	-0.06	0.97	0.66	0.35
USA	0.90	0.36	-0.05	0.92	0.40	0.40

Source: Authors' estimations.

Table A3: Mean independent variables

Country	EPS Score	EPS Market Score	EPS Non-market Score	Government Effectiveness	Average WGI	Political Orientation	Energy-Intensive Industries - VA Share	Carbon-Intensive Industries - VA Share	Electricity - VA Share	Energy Price Index	Trade Openness (per cent of GDP)
AUS	0.94	0.66	1.22	1.75	1.76	1.43	2.18	2.47	-3.69	4.59	40.58
AUT	3.07	2.98	3.15	1.85	1.81	2.00	1.06	1.81	-3.71	4.60	92.19
BEL	1.40	0.59	2.21	1.76	1.42	1.00	0.92	1.68	-3.74	4.47	138.92
CAN	1.99	2.12	1.85	1.92	1.81	2.67	2.17	2.50	-3.66	4.40	73.68
CZE	1.28	2.50	1.17	0.80	0.74	2.60	1.66	2.30	-3.26	4.50	103.32
DEU	2.48	2.36	2.60	1.69	1.67	2.00	0.92	1.53	-3.79	4.50	66.08
ESP	2.31	2.67	1.96	1.42	1.27	1.86	0.88	1.70	-3.85	4.51	54.39
FIN	2.97	1.96	3.98	2.12	2.06	2.43	0.94	1.91	-3.80	4.50	73.59
FRA	1.93	1.79	2.06	1.60	1.37	1.71	0.72	1.58	-3.97	4.53	52.36
GBR	1.52	0.97	2.07	1.78	1.80	2.86	1.45	1.97	-3.92	4.53	54.49
GRC	1.45	1.43	1.47	0.72	0.73	2.45	1.09	2.02	-3.70	4.49	50.36
HUN	1.60	1.28	1.93	0.86	0.84	3.00	1.22	1.90	-3.46	4.51	131.87
ITA	1.55	1.30	1.79	0.62	0.64	1.64	0.93	1.86	-3.86	4.52	49.11
JPN	2.02	2.24	1.79	1.29	1.17	1.00	0.96	1.82	-3.72	4.58	24.90
KOR	2.03	2.77	1.92	0.87	0.70	1.79	0.92	1.84	-3.81	4.54	73.91
NLD	2.08	1.30	2.85	1.99	1.94	2.27	1.43	2.02	-4.13	4.53	121.97
POL	0.68	2.69	0.58	0.56	0.57	2.29	1.77	2.24	-3.36	4.48	68.11
PRT	1.69	1.35	2.04	1.07	1.12	2.57	1.14	1.69	-3.61	4.55	64.85
TUR	0.52	0.35	0.69	-0.08	-0.07	2.00	1.18	2.57	-3.82	4.54	46.33
USA	1.91	2.11	1.70	1.69	1.60	1.77	1.13	1.62	-4.04	4.40	24.69

Source: Authors' estimations.

Table A4: Coefficient of variation - independent variables

Country	EPS Score	EPS Market Score	EPS Non-market Score	Government Effectiveness	Average WGI	Political Orientation	Energy-Intensive Industries - VA Share	Carbon-Intensive Industries - VA Share	Electricity - VA Share	Energy Price Index	Trade Openness (per cent of GDP)
AUS	0.39	0.38	0.41	0.06	0.05	0.60	0.10	0.06	-0.01	0.02	0.05
AUT	0.16	0.11	0.29	0.06	0.04	0.53	0.04	0.05	-0.01	0.03	0.09
BEL	0.45	0.56	0.44	0.10	0.04	0.00	0.14	0.06	-0.03	0.04	0.08
CAN	0.35	0.14	0.61	0.04	0.02	0.29	0.09	0.05	-0.03	0.04	0.08
CZE	1.17	0.31	1.15	0.23	0.17	0.32	0.03	0.03	-0.02	0.02	0.17
DEU	0.33	0.39	0.31	0.11	0.03	0.52	0.15	0.05	-0.04	0.04	0.16
ESP	0.35	0.35	0.37	0.28	0.13	0.55	0.10	0.03	-0.03	0.03	0.06
FIN	0.24	0.13	0.31	0.06	0.03	0.21	0.15	0.03	-0.04	0.03	0.09
FRA	0.36	0.31	0.43	0.07	0.05	0.58	0.46	0.10	-0.08	0.04	0.06
GBR	0.47	0.76	0.37	0.08	0.07	0.19	0.07	0.03	-0.04	0.04	0.05
GRC	0.22	0.22	0.24	0.11	0.07	0.38	0.04	0.09	-0.02	0.02	0.12
HUN	0.46	0.52	0.45	0.14	0.09	0.00	0.11	0.06	-0.04	0.05	0.16
ITA	0.31	0.29	0.39	0.37	0.21	0.45	0.05	0.02	-0.01	0.04	0.08
JPN	0.13	0.06	0.28	0.15	0.14	0.00	0.15	0.03	-0.04	0.02	0.22
KOR	0.83	0.31	0.95	0.34	0.23	0.24	0.17	0.04	-0.05	0.05	0.17
NLD	0.35	0.92	0.13	0.06	0.04	0.44	0.09	0.02	-0.03	0.02	0.05
POL	1.99	0.20	1.99	0.19	0.17	0.44	0.03	0.02	-0.03	0.05	0.16
PRT	0.33	0.34	0.35	0.09	0.10	0.33	0.06	0.03	-0.02	0.03	0.05
TUR	0.18	0.09	0.30	-1.89	-0.90	0.55	0.06	0.03	-0.03	0.02	0.13
USA	0.30	0.10	0.57	0.07	0.05	0.57	0.11	0.04	-0.01	0.05	0.10

Source: Authors' estimations.

A3. Additional regression results

Table A5: Regression results using R&D intensity over value added as innovation proxy: Robustness test for lobbying (one-year lag for all independent variables)

		1	2	3	4	5	6	7	8
	Dependent Variable	Log of R&D Intensity - Power							
H1	EPS Market Score	0.205+	0.180	0.198+	0.174	0.175	0.150		
		(0.126)	(0.125)	(0.123)	(0.122)	(0.123)	(0.122)		
	EPS Non-market Score	-0.083	-0.095	-0.008	-0.013	0.026	0.019		
		(0.109)	(0.109)	(0.108)	(0.108)	(0.108)	(0.109)		
	EPS Total Score							0.143	0.125
								(0.112)	(0.111)
H2	Govt. Effectiveness	0.886***	0.932***	0.687**	0.766**			0.535*	0.629*
		(0.321)	(0.329)	(0.317)	(0.323)			(0.312)	(0.319)
	WGI					0.596	0.728		
						(0.534)	(0.554)		
H3	Political Orientation	0.225***	0.216***	0.215***	0.205***	0.205***	0.195***	0.203***	0.195***
		(0.066)	(0.065)	(0.064)	(0.063)	(0.065)	(0.064)	(0.063)	(0.063)
H4	Carbon Intensive Industries - VA Share	0.797		0.914+		0.940+		0.873+	
		(0.564)		(0.567)		(0.572)		(0.562)	
	Electricity - VA Share		0.372		0.527		0.492		0.527
			(0.390)		(0.381)		(0.391)		(0.379)
	Energy price index			-2.971***	-2.970***	-3.128***	-3.119***	-3.110***	-3.103***
				(0.759)	(0.762)	(0.762)	(0.765)	(0.757)	(0.758)
	Trade Openness			0.003	0.001	0.004	0.001	0.003	0.000
				(0.008)	(0.007)	(0.008)	(0.008)	(0.008)	(0.008)
	Observations	256	256	256	256	256	256	256	256
	R-squared	0.193	0.189	0.247	0.245	0.236	0.232	0.244	0.242
	Number of countries	20	20	20	20	20	20	20	20

Notes: Standard errors in parentheses; *** p<0.01, ** p<0.05, * p<0.1, + p<0.15.

Source: Authors' estimations.

Table A6: Regression results using patent intensity over value added as innovation proxy: Robustness test for lobbying (two-year lag for all independent variables)

		1	2	3	4	5	6	7	8
	Dependent Variable	Log of Patents Intensity - Power							
H1	EPS Market Score	0.014***	0.014***	0.014***	0.014***	0.013***	0.013***		
		(0.004)	(0.003)	(0.003)	(0.002)	(0.007)	(0.006)		
	EPS Non-market Score	0.013***	0.012***	0.013***	0.013***	0.015***	0.015***		
		(0.005)	(0.005)	(0.005)	(0.005)	(0.001)	(0.001)		
	EPS Total Score							0.017***	0.017***
								(0.000)	(0.000)
H2	Govt. Effectiveness	0.070***	0.072***	0.071***	0.072***			0.066***	0.067***
		(0.000)	(0.000)	(0.000)	(0.000)			(0.000)	(0.000)
	WGI					0.098***	0.100***		
						(0.000)	(0.000)		
H3	Political Orientation	-0.002	-0.002	-0.002	-0.002	-0.002	-0.002	-0.002	-0.002
		(0.482)	(0.502)	(0.420)	(0.466)	(0.412)	(0.449)	(0.334)	(0.393)
H4	Carbon Intensive Industries - VA Share	0.003		-0.005		-0.003		-0.014	
		(0.893)		(0.824)		(0.888)		(0.553)	
	Electricity - VA Share		0.009		0.007		0.007		0.004
			(0.523)		(0.614)		(0.666)		(0.810)
	Energy price index			0.024	0.022	0.015	0.013	0.023	0.021
				(0.364)	(0.417)	(0.586)	(0.643)	(0.386)	(0.445)
	Trade Openness			-0.000	-0.000	-0.000	-0.000	-0.000	-0.000
				(0.202)	(0.217)	(0.160)	(0.162)	(0.193)	(0.241)
	Observations	256	256	256	256	256	256	256	256
	R-squared	0.662	0.663	0.665	0.666	0.651	0.651	0.656	0.656
	Number of countries	20	20	20	20	20	20	20	20

Notes: Standard errors in parentheses; *** p<0.01, ** p<0.05, * p<0.1, + p<0.15.

Source: Authors' estimations.

Table A7: Regression results using patent intensity over value added as innovation proxy: Robustness test for lobbying (two-year lag for all independent variables)

		1	2	3	4	5	6	7	8
	Dependent Variable	Log of Patents Intensity - Environment							
H1	EPS Market Score	0.030**	0.033***	0.031**	0.034***	0.028**	0.031**		
		(0.012)	(0.006)	(0.010)	(0.005)	(0.021)	(0.011)		
	EPS Non-market Score	0.017+	0.018+	0.017+	0.019+	0.022*	0.023**		
		(0.132)	(0.106)	(0.129)	(0.103)	(0.055)	(0.043)		
	EPS Total Score							0.029**	0.031***
								(0.017)	(0.009)
H2	Govt. Effectiveness	0.216***	0.221***	0.218***	0.223***			0.206***	0.209***
		(0.000)	(0.000)	(0.000)	(0.000)			(0.000)	(0.000)
	WGI					0.324***	0.335***		
						(0.000)	(0.000)		
H3	Political Orientation	-0.006	-0.005	-0.007	-0.005	-0.007	-0.005	-0.008	-0.007
		(0.328)	(0.434)	(0.280)	(0.410)	(0.317)	(0.449)	(0.198)	(0.313)
H4	Carbon Intensive Industries - VA Share	-0.061		-0.081		-0.074		-0.100*	
		(0.282)		(0.167)		(0.220)		(0.088)	
	Electricity - VA Share		0.015		0.011		0.013		0.003
			(0.697)		(0.771)		(0.742)		(0.932)
	Energy price index			0.054	0.041	0.027	0.014	0.051	0.036
				(0.422)	(0.549)	(0.690)	(0.837)	(0.455)	(0.597)
	Trade Openness			-0.001	-0.001	-0.001+	-0.001	-0.001	-0.001
				(0.205)	(0.355)	(0.147)	(0.244)	(0.201)	(0.392)
	Observations	256	256	256	256	256	256	256	256
	R-squared	0.633	0.631	0.636	0.633	0.621	0.619	0.629	0.624
	Number of countries	20	20	20	20	20	20	20	20

Notes: Standard errors in parentheses; *** p<0.01, ** p<0.05, * p<0.1, + p<0.15.

Source: Authors' estimations.

Table A8: Regression results using R&D intensity over value added as innovation proxy: Robustness test for the definition of power R&D intensity using upper bound (one-year lag for all independent variables)

		1	2	3	4	5	6	7	8	9
	Dependent Variable	Log of R&D Intensity - Power + Embedded								
H1	EPS Market Score	-0.121	-0.124	-0.139	-0.155	-0.149	-0.175+			
		(0.110)	(0.108)	(0.113)	(0.107)	(0.105)	(0.111)			
	EPS Non-market Score	-0.103+	-0.078	-0.109+	-0.105+	-0.078	-0.111+			
		(0.069)	(0.069)	(0.070)	(0.070)	(0.069)	(0.071)			
	EPS Total Score							-0.114	-0.099	-0.122+
								(0.082)	(0.080)	(0.083)
H2	Govt. Effectiveness	0.244	0.117	0.306				0.308	0.185	0.373+
		(0.241)	(0.238)	(0.248)				(0.232)	(0.228)	(0.242)
	WGI				-0.031	-0.167	-0.021			
					(0.407)	(0.390)	(0.424)			
H3	Political Orientation	0.153***	0.168***	0.155***	0.138***	0.156***	0.136***	0.154***	0.170***	0.156***
		(0.049)	(0.048)	(0.050)	(0.049)	(0.048)	(0.050)	(0.049)	(0.049)	(0.050)
H4	Energy Intensive Industries - VA Share	0.952**			0.924**			0.936**		
		(0.377)			(0.387)			(0.376)		
	Carbon Intensive Industries - VA Share		1.757***			1.778***			1.759***	
			(0.577)			(0.573)			(0.570)	
	Electricity - VA Share			0.809**			0.708*			0.746*
				(0.397)			(0.412)			(0.392)
	Energy price index	0.815	0.700	0.767	0.775	0.617	0.752	0.723	0.611	0.682
		(0.804)	(0.794)	(0.820)	(0.819)	(0.805)	(0.836)	(0.803)	(0.791)	(0.823)
	Trade Openness	0.001	0.005	-0.002	0.003	0.006	0.000	-0.000	0.004	-0.003
		(0.008)	(0.009)	(0.008)	(0.008)	(0.008)	(0.008)	(0.009)	(0.009)	(0.009)
	Observations	110	110	110	110	110	110	110	110	110
	R-squared	0.276	0.299	0.257	0.267	0.299	0.244	0.262	0.288	0.240
	Number of countries	14	14	14	14	14	14	14	14	14

Notes: Standard errors in parentheses; *** p<0.01, ** p<0.05, * p<0.1, + p<0.15.

Source: Authors' estimations.