Introduction

In this article we investigate empirically the joint effects of the democratic attributes of countries' formal political institutions and the political influence of industry on electricity preferences and deployment rates. Electricity generation and consumption account for around two thirds of greenhouse gas emissions worldwide, putting the power sector at the centre of efforts to mitigate global climate change (IEA 2017). It is, therefore, widely agreed that significant emissions cuts need to be undertaken in the electricity sector to keep global warming below the much-feared 1.5 degree limit[1] in accordance with the global mitigation target set by the 2015 Paris Agreement.

An important part of this effort involves transitioning from fossil fuels to low-carbon energy sources such as renewables; a move which, according to leading energy forecasts, has the potential to provide 39 percent of the necessary reduction in energy-related carbon emissions by 2050 (IRENA 2019).[2] Yet despite its urgency, the path of global energy transition has been staggered and uneven; while some, such as EU member states, have embraced change and pledged to achieve a carbon neutral economy (EC 2018), the majority have been protective of the core position occupied by fossil fuels in the power sector, leading to concern that the international community will fail to meet its shared mitigation target.

Countries' divergent energy preferences have been attributed to several factors such as, for example, the political influence of interest groups (Marques et al. 2010; Cadoret and Padovano 2016), repercussions of the energy transition on employment and the national economy (Bogdanov 2019; IEA 2017; Teske et al. 2018; Brown et al. 2018), linkages to international issue-areas (Bobrow and Kudrle 1979), the quest for energy security (Gan et al. 2007; Chien and Hu 2008) and the unequal positions that countries occupy in the world economy (Parks and Roberts 2006; Betsill et al. 2006). Yet all of these explanations originate from the assumption that political actors design energy policy with one fundamental goal in mind - to remain in power by deploying the most politically expedient energy sources.

While numerous studies have found evidence that political factors influence electricity deployment (e.g. Henisz and Zelner 2006; Marques et al. 2010; Cadoret and Padovano 2016; Bogdanov 2019; Teske et al. 2018; Bobrow and Kudrle 1979; Gan et al. 2007; Chein and Hu 2008; Parks and Roberts 2010), most quantitative work focuses on cross-sectional differences between countries (e.g. Bayer and Urperlainen 2016; Menz and Vachon 2006; Carley 2009; Yi and Feiock 2014), which creates the possibility that observed correlations might be due to other (unmodelled) factors that vary between-countries or (supranational) regions rather than political drivers.[3] In contrast, we employ a three-level hierarchical model consisting of country-years nested in countries, which are further nested in supranational regions, to isolate the effects of fluctuations in the levels of democracy and industrial

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[1] According to the leading scientific authorities on climate change, a 1.5 degree rise in average world temperature is the critical point after which global warming would result in 'irreversible loss of the most fragile ecosystems, and crisis after crisis for the most vulnerable people and societies' (IPCC 2018:Foreword).

[2] The remaining emissions reductions need to be derived from electrification of heat and transport, improvements in energy efficiency and deployment of negative emissions technologies (IRENA 2019).

[3] Unmodelled factors might include, for example, national culture, risk perceptions, technological know-how, public knowledge of environmental issues and media coverage of climate change.

strength within the same country and region, thereby eliminating the possibility for country and regional confounding.

We make two novel contributions to the literature. Our substantive contribution is theoretical. We examine how two elements of the domestic political setting influence political actors' energy preferences and ensuing deployment rates: the democratic attributes of the formal political institutions, which shape the political incentives (and disincentives) attached to different energy sources; and the role of industrial consumers of energy as a key interest group that possesses the power to utilise the allegedly increased opportunity for civil society to influence policymakers in democracies, thereby increasing the sensitivity of energy deployment to the democratic process. Second, we subject two of the leading political explanations of electricity deployment – regime type and interest group pressure – to stricter quantitative tests by investigating whether they continue to wield explanatory power when the possibility for country and regional confounding is eliminated.

We test our hypotheses on the worldwide electricity sector using country-year energy deployment data spanning 136 countries from 1990 to 2018. Specifically, we investigate the joint effects of the democratic attributes of a country's formal political institutions and political influence of industrial energy consumers on the annual deployment rate of solar, wind, hydro, geothermal, gas, coal, oil and nuclear energy for electricity generation, ceteris paribus.

Our findings indicate that, even when country and regional clustering are accounted for, democracy does indeed have a significant effect on the deployment of half of the energy sources analysed (namely: solar, wind, hydro, and nuclear). However, we also find that the democracy effect varies substantially across countries, suggesting that international generalisations about the influence of democracy on energy preferences are misleading. Furthermore, we find strong evidence that industrial strength significantly increases the sensitivity of energy policy to democracy; as industrial representation rises, the positive marginal effect of democratization (or an increase in the level of democracy in a country's formal political institutions) becomes more pronounced because stronger interest groups are better able to take advantage of the opportunity for non-governmental interests to influence energy policy. Conversely, when industrial representation is low, the positive marginal effect of an increase in democratic institution falls as weaker interest groups exert less pressure on energy preferences through democratic platforms.

This paper consists of five sections. The first part draws on three bodies of literature on the political motives behind energy deployment, political regimes and energy preferences and interest group politics to set out the theoretical approach of our analysis. The second part describes our modelling approach and operationalisation strategy. The third section discusses the results of our empirical analyses and is followed by section four, which evaluates the robustness of our findings when we use different proxies to measure democracy. We conclude by reflecting on the theoretical contributions and policy relevance of our findings.

Theoretical framework

This section draws on three bodies of literature to formulate the theoretical foundation of our hypotheses. The first literature focuses on the political motivation behind policymakers' deployment decisions as well as the factors that underlie expectations about political returns from energy sources. The second part draws on the scholarship on political regimes and energy preferences to identify causal pathways through which democratic political institutions can promote or hinder the deployment of different energy sources, focusing particularly on the distinction between renewables and fossil fuels. The third part discusses the literature on interest group politics to provide a framework for studying the role of an important political actor – industrial energy consumers – in moderating the effect of democracy over energy deployment.

Political motivation behind energy deployment

Electricity deployment is fundamentally a political affair. First and foremost, governments decide which energy infrastructure to finance based on the expected positive return in terms of political support (Henisz and Zelner 2006; Yi and Feiock 2014; Brown and Mubarak 2009), whether this be exercised by the number of votes cast in support of elected governments or quiet acquiesce to appointed rulers. Since the generation, transmission and distribution of electricity require large sunk costs and economies of scale (Bergara et al. 1997), most energy projects start out as government initiatives, making deployment decisions directly traceable back to political actors (Brown and Mobarak 2009).

Which factors determine the political returns associated with different energy sources? Although the precise costs and benefits of deployment decisions faced by political actors are difficult to measure, the scholarship identifies several sources. Perhaps the most obvious is the effect of energy preferences on the national economy (Bogdanov 2019; Teske et al. 2018; Pursiheimo et al. 2018; Brown et al. 2018). Energy is a key input into almost all economic activities, therefore, any change in energy preferences has significant repercussions on operating costs throughout the economy. Deployment decisions have also been shown to affect employment, although there is no consensus on which energies are likely to create more jobs (Ortega et al. 2015; Bohringer and der Werf 2013; Frondel et al. 2010; Yi and Feiock 2014). Whatever the outcome, deployment-driven interference in the economy generates winners and losers, creating strong attitudes towards energy policy, thereby significantly shaping political actors' expectations of political returns. A third political (dis)incentive to deployment is the effect of energy infrastructure on proximate areas. Power plants are land intensive and, depending on the energy source, affect the close environment (e.g. environmental health, aesthetics and noise levels), shaping local attitudes towards deployment (Yi and Feiock 2014). Some scholars explore the role of political ideology in shaping attitudes towards different energy sources. Accordingly, exponents of leftist political ideologies are supposedly more supportive of renewables compared to adherents of rightist ideologies, who are allegedly more supportive of fossil fuels (Chang and Berdiev 2011; Biresselioglu and Karaibrahimoglu 2012). Presumably, then, policymakers' affiliations to political parties determine which deployment decisions are likely to be politically viable among target voters who prescribe to their party's ideology. Other lines of enquiry explore the linkages between deployment decisions and related issue-areas such as energy security (Gan et al. 2007; Chien and Hu 2008) and national competitiveness in the world markets (Fisher 2006).

Building on this literature, we assume that political actors design energy policy to maximise political support by financing electricity infrastructures that balance the (often conflicting) interests of their constituents in energy and other areas. We do not observe political actor's motivations or causal pathways directly; but rather, study the effects of two observable sources of political returns attached to deployment decisions - the level of democracy in countries' formal political institutions and the strength of industrial energy consumers – on energy deployment rates.

Political regimes and energy preferences

Following Kant's (1983) well-known thesis,[4] the International Relations literature has become replete with claims that democracy can solve some of the world's most pressing problems such as, for example, war (Schultz 1999; Maoz and Russett 1993), global poverty (Ross 2006) and trade protectionism (Mansfield et al. 2002; Milner and Kubota 2005; McGillivray and Smith 2008). The environmental strand of this scholarship argues that, for various reasons[5], democracies outperform autocracies in the provision of environmental quality (Barrett and Graddy 2000; Burnell 2012,2014; Farzin and Bond 2006; Battig and Bernauer 2009; Bohmelt et al. 2015). Several scholars have extended this argument to the energy sector by arguing that democratic superiority in environmental matters predisposes open political regimes to be more supportive for greener, low-carbon energy sources such as renewables relative to closed regimes (e.g. Marques et al. 2010; Yi and Feiock 2014; Cadoret and Padovano 2016; Bayer and Urpelainen 2016; Brown and Mobarak 2009). Yet the reluctance of some of the world's strongest democracies to undermine the central role of fossil fuels in the electricity sector as well as the unprecedented scale of renewable energy deployed by some closed political regimes suggests that the democracy-energy transition thesis does not always hold.[6] Indeed, a growing body of contradictory empirical findings (e.g. Yi and Feiock 2014; Stepping and Banhlzer 2017; Held and Hervey 2007; Winslow 2005) suggests that democracy also has the potential to obstruct energy transition.

This section draws on these arguments to map out how the democratic attributes of political regimes can both promote and obstruct the deployment of a wide range of energies, with particular emphasis on the ramifications for energy transition. To frame our discussion, we refer to two broad distinctions between energy sources. First, we draw on the distinction between fossil fuels and renewables in the literature to align prioritisations of the environment vis-à-vis other interests (such as energy) with different energy sources. Broadly, we expect that 'environmental prioritisers' are likely to prefer renewable energies such as solar, wind, hydro and geothermal while 'other interest prioritises' are expected to deploy more fossil fuel-based sources such as coal, oil and gas.[7] We also refer to the distinction between conventional centralised (coal, nuclear and gas) and renewable de-

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[4] The democratic peace thesis draws on the observation that democracies do not war with each other and asserts that world peace can be achieved if all countries become democracies.

[5] Burnell (2012) provides an excellent overview of the various reasons why democracies should be better at mitigating climate change than authoritarian states.

[6] The US is a prime example of the former while China is an example of the latter.

[7] We recognise that the fossil fuel-renewable distinction cannot capture all nuances in energy sources. For example, nuclear energy is low-carbon, but has other detrimental effects on the environment so does not fit perfectly with either category. Nonetheless, we feel the distinction is useful theoretically to help map out the pathways through which political regimes shape energy preferences.

centralised sources (wind and solar), which are *generally* deployed on large and small scales respectively.[8]

We theorise the effect of political regimes on energy deployment by focusing on five core distinctions between democracies and autocratic regimes, namely; accountability, the prevalence of corruption, opportunity for civil society activism, protection of individual freedoms and time horizons. First, an extensive literature claims that democracies excel at providing widely distributed public goods because of the strong incentive that political actors face to secure political support in the next round of elections (e.g. Olson 1993; Brown 1999; Bueno de Mesquita et al. 2003; Brown and Mobarak 2009). Conversely, autocratic rulers only need to satisfy a narrow 'winning coalition' (such as military or economic elites), making it more rational to provide goods to exclusive groups (Wurster 2013). Indeed, several studies have found that democracies outperform autocracies in the provision of environmental public goods (e.g. Barrett and Grady 2000; Battig and Bernauer 2009; Bhattarai and Hammig 2001). Since environmental quality is highly dependent on outputs from the energy sector, the strong political incentives for environmental goods in democracies should presumably create an additional pressure to transition to sustainable energy practices (Burnell 2012,2014; Szulecki 2017). Therefore, when faced with equal demand for environmental goods, elected political actors should be more willing to deploy renewable energy and wean off fossil fuels than appointed officials in more closed political regimes (Bayer and Urpelainen 2016).[9]

Second, owing to its comprehensive system of checks and balances and emphasis on transparent policymaking, democracy is widely regarded as an effective antidote to political corruption (Daimond et al. 1990).[10] Corruption is associated with poor government quality and impairs the responsiveness of political actors to citizens' demands, reducing the efficiency of policy implementation (Cadoret and Padovano 2016). This matters for energy deployment because inefficient governments struggle to implement the fiscal measures (e.g. renewable subsidies and carbon taxes) needed to finance deployment decisions, particularly those that channel resources away from traditional fossil fuel actors to renewable interests (Fredriksson and Svensson 2003; Hughes and Urperlainen 2015) and attract the necessary investment for R&D in low-carbon options (Cheung et al. 2019). Laird and Stefer (2009), for example, show empirically that greater institutional capacity in Germany relative to the US was critical in facilitating its early success in renewable deployment. Furthermore, the nature and scale of change required for the energy transition requires institutional stability over a long period of time - a quality that is not usually forthcoming in authoritarian political contexts (Olson 2000; Gandhi 2008). Compounding this, autocracies also have much greater difficulties transitioning to new political leadership without experiencing 'succession crisis' (Niskanen 2003). In democracies, on the other hand, clear election rules and institutional continuity between successive governments provide politicians with the socio-political stability and policymaking space needed to resculpt the energy sector in line with energy transition (Wurster 2013; Ward 2008).

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[8] We acknowledge below that fossil fuels are sometimes deployed in decentralised structures and renewables centralised structures.

[9] To be clear, the argument is not that democracies have higher demand for environmental goods, but rather, that democratic politicians are more sensitive to these demands than autocratic counterparts.

[10] Indeed, the V-dem index lists (inverse) corruption as a proxy for the level of democracy.

Third, by promoting freedom of expression and providing increased opportunity for civil scoeity to influence policymaking, democracies create more channels for stakeholders to shape deployment decisions. While this means that environmental activists and low-carbon industries can exert more pressure over energy policy, actors with conflicting interests such as fossil fuel lobbies also gain access to similar channels. Furthermore, local populations, which are most directly affected by energy generation, can also mobilise to influence (usually stalling) deployment decisions. Therefore, by allowing the universe of actors to voice their perspectives, democratic pluralism raises the risk of inaction, constraining deployment all around (Weinberg 1990). In contrast, autocratic rulers forego the complex and time consuming process of balancing different interests, allowing them to reach and implement deployment decisions more efficiently than their democratic counterparts (Feiock et al. 2003). Indeed, various scholars (e.g. Beeson 2009; Wurster 2011) have proposed that 'autocratic steering' may be the necessary and logical solution to overcome the opposition of 'manifold stakeholders who see ecological measures [such as the transition to renewable energy] as detrimental to their short-term economic interests' (Fliegauf and Sanga 2010:2).

While the complexity of balancing multiple interests gives us reason to expect that energy deployment is more difficult in democracies in general, the precise effect of democratic pluralism on the deployment of different energy sources depends on the relative strength of various political actors in each national context. Thus, for example, countries with stronger fossil fuel industries might face higher political pressure to resist the energy transition and safeguard coal, oil and gas energy whereas democratic pluralism in countries that host stronger low-carbon industries should facilitate relatively easier deployment of wind, solar, geothermal and hydro energy. Furthermore, competing interests are more likely to slow-down deployment decisions when political power is distributed evenly between different interest groups (Olsen 1971).

Fourth, owing to their core emphasis on individual freedoms, democracies are generally reluctant to intervene in markets and interfere with individual lifestyle decisions (Battig and Bernauer 2009). Autocracies, on the other hand, are presumably more comfortable imposing top-down policies and regulating individual behaviour (Beeson 2010; Hobson 2012). We argue that this distinction makes different political regimes more accommodating to different structures of energy source. Specifically, there is an important distinction between the deployment of conventional large-scale sources such as coal, gas and nuclear and renewables such as solar and wind, which can be deployed in different areas on a smaller scale (Szulecki 2015). Given their apparent political capacity to implement centralised projects, it is reasonable to expect that autocratic regimes will be better at deploying the conventional large-scale energy sources. In contrast, while struggling with the prospect of imposing top-down projects, open political contexts provide an ideal environment for decentralised, small-scale energy sources to flourish (Burke and Stephens 2018). Indeed, the fundamental tenet of the nascent energy democracy scholarship is that sustainable energy practices are more effective and widely deployed when driven by decentralised grass-roots actors such as communities and individual households (Szulecki 2017).

Fifth, the conflicting time horizons faced by political actors in democracies and autocracies create different incentives for energy deployment. Since the chief priority of elected policymakers is to garner enough political support for the next election round, democratic rulers hold relatively shorter time horizons than appointed political actors (Bluhdorn 2011; Wurster 2013).[11] Shorter time horizons have been shown to cause officials to adopt myopic policies which improve immediate conditions while generating negative long-term consequences (Lipscy 2018). These distinct time horizons can affect energy deployment in two ways; on the one hand, since one of the fundamental incentives for transitioning to renewables is the promise of environmental quality in the future, shorter time horizons can reduce the political motives for elected policymakers to deploy renewables, particularly because they do not expect to remain in office by the time the environmental benefits materialise. In contrast, autocratic rulers generally have longer time horizons and can be expected to support renewable energy from a long-term planning perspective (Yi and Feiock 2013; Beeson 2012).

Yet decentralised, small-scale projects such as installing solar panels on a building roof require less time to deploy than traditional fossil fuels, which involve building large-scale plants. Furthermore, with the appropriate infrastructure and market conditions in place (which usually are in democracies), local producers of energy can also become electricity suppliers, providing additional immediate benefits (Inderberg et al. 2018).[12] Therefore, from a time-incentive perspective, small-scale renewable deployment projects can be more appealing for democratic political actors with shorter time horizons than traditional large-scale options. Conversely, autocratic rulers who do not face similar time constraints can be more open to fossil fuel deployment.[13]

Table one summarises the five attributes and the associated pathways through which democracy is theorised to affect energy deployment, focusing particularly on renewable energy sources that are compatible with energy transition.

Attribute	Democratic pathway	Autocratic pathway
Accountability	The desire to secure political support for re-election makes policymakers eager to deliver public environmental goods by, for example, deploying more renewables. On the other hand, elected policymakers might be compelled to deploy high-carbon energies that employ large segments of the population.	Autocratic rulers are only accountable to narrow interests and are, therefore, relatively immune to political demands for environmental public goods, removing an important incentive for renewable deployment.
Prevalence of corruption	Democratic checks and balances inhibit corruption, increasing the ability of governments to implement deployment decisions in general and create conditions conducive to energy transition.	The lack of democratic checks and balances makes autocracies more prone to corruption and instability, making it difficult for governments to invest in and deploy renewable energy.

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[11] Based on data covering the last 150 years, the average time in office for a democratic leader is around five years and twelve years for an autocratic leader (Goemans et al. 2009).

[12] Small scale end-users who generate power for their own use and export back into the electricity system are referred to as ‘prosumers’ in the literature.

[13] It is recognised that the promise of more immediate benefits could also make decentralised deployment more appealing in closed political contexts.

Opportunity for freedom of expression and civil society activism	The increased opportunity for different interests to influence policymaking makes it difficult to reach decisions on energy deployment, particularly when conflicting interests are balanced in terms of political influence.	Autocratic rulers bypass the need to balance competing interests and can therefore ‘steer’ deployment decisions more efficiently.
Protection of individual freedoms	Democracies are reticent to intervene in individual lifestyle decisions, making it difficult to implement traditional large-scale fossil fuel projects. This open environment is conducive to decentralised small-scale deployment projects such as solar and wind energy.	Autocracies are more comfortable imposing centralised, top-down projects, assisting the deployment of large-scale fossil fuel energy. Conversely, the closed political environment inhibits the emergence of decentralised wind and solar deployment.
Time horizons	Because elected officials are unlikely to be in office by the time that environmental benefits of energy transition materialise, there is political incentive for renewable deployment in democracies. However, this is counterbalanced by the relatively shorter time-period required to deploy decentralised solar and wind energy.	Autocratic rulers have longer time horizons and, therefore, greater political incentive to implement deployment projects which require longer time periods to deliver benefits.

Table 1: Note: Pathways describe the effect on renewable energy deployment.

Interest group politics and industry

While the political regime shapes the policymaking environment by, for example, determining which channels are open for nongovernmental interests to express their energy preferences, it is ultimately the stakeholders who exploit these available channels of activism, thereby bringing the political context to bear on policy outcomes. Thus the last part of our theoretical approach draws on the literature on interest group politics and energy security to look more closely at one of the pathways through which, we proposed, democracy affects energy deployment – namely; the opportunity for civil society activism.

A substantial literature explores how distributional conflicts between interest groups shape policy outcomes (e.g. Bueno de Mesquita et al. 2001; Foster and Rosenzweig 2001, Grossman and Helpman 2001). Cohering with the energy deployment scholarship, this approach attributes political actors’ decisions to political incentives (Henisz and Zelner 2006). Accordingly, the most powerful groups that wield the greatest political influence are those who are the most concentrated and stand to receive the highest per capita benefits (and losses) from policies, providing them with strong incentive to take advantage of available channels of political influence (; Milner 1987). Political influence can take various forms such as, for instance, voting, mobilising other interest groups to influence policymaking and using economic power to pressure political actors. Yet we focus on lobbying as a close approximation of civil society activism, which we argued comprises one of the pathways through which democracy influences energy deployment.

Which interest groups are salient in energy deployment policy? While there are several (competing) energy interests; industry, agriculture, environmental actors, residential consumers and local constituents are most frequently singled out. If we consider that industry consumes around 54 percent of energy worldwide (IEA 2018),[14] it is likely that this group will collectively experience most of the benefits and losses associated with energy deployment. So critical are industrial interests to the energy sector that energy security is often operationalised as industrial energy intensity (Sovacool et al. 2011). Furthermore, industry possesses political organizational advantages over other groups as members are relatively concentrated and likely to have pre-established communication channels through trade unions and other associations, allowing its members to lobby effectively for shared interests (Henisz and Zelner 2006).

If industrial energy consumers comprise an interest group in energy politics, it is an extremely diverse one indeed. Moreover, given that many industrial energy consumers (e.g. the fossil fuel and renewable energy producers) champion opposing policies towards energy transition, there might be an argument that industry would be better regarded as separate interest groups.[15] However, we concur with many others (e.g. Henisz and Zelner 2006; Sovacool et al. 2011; Xia et al. 2011; Brown and Mobarak 2009) that, despite their diversity, industrial energy consumers share certain fundamental interests in electricity deployment which warrants their treatment as a single interest group. First and foremost, since industry relies on energy as a critical input into just about all forms of activity, the group has a primary interest in energy security (Henisz and Zelner 2006; Brown and Mobarak 2008). While there is still much debate about the various attributes that constitute energy security, there seems to be an implicit consensus that reliability and stability of energy supply are at the core of the concept, with energy affordability and environmental sustainability frequently cited as secondary but integral concerns (Sovacool et al. 2011; Lucas et al. 2016).[16]

How does industry's fundamental interest in energy security influence its position towards energy deployment? At first glance, one might assume that energy security drives industry to favour fossil fuels over renewable energy. After all, traditional energy sources are more familiar and tend to be deployed through centralised energy structures, allaying some consumers' concerns about transmission and regulation failures. Such fears are reinforced by the conservative stance of the utility industries, which are generally reluctant to deploy more flexible transmission models that are usually associated with renewable sources (Bouffard and Kirschen 2008). Furthermore, the fluctuating nature of renewable sources means that complete deployment is not feasible when there are non-interruptible energy consumption needs (Lucas et al. 2016). Indeed, such issues are frequently emphasised by fossil fuel lobbies, which no doubt influence other industrial energy consumers and political actors to increase the political appetite for traditional energy deployment (Sovacool 2009). In terms of affordability, fossil fuel sources also seem favourable because, in the short-term

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[14] The average share of industrial electricity consumption of total electricity consumption in our dataset is 38.23 percent.

[15] Perhaps the first scenario that comes to mind on the mention of industry and energy is the obvious positions of the fossil fuel and renewable energy industries, which hold strong vested interests in promoting the deployment of their own respective energy source. Yet our focus is broader than the energy industry; it is the industrial sector as a whole, which consists of primary (agriculture, forestry, fishing, mining, quarrying and the extraction of minerals), secondary (manufacturing, energy and construction) and tertiary (services that produce intangible goods such as banking, finance, insurance, tourism, education and retail) sectors.

[16] The pioneering work by Sovacool and colleagues draw attention to multiple dimensions of energy security. (Sovacool et al. 2011; Sovacool and Brown 2010; Sovacool 2010; Sovacool 2011; Sovacool and Mukherjee 2011).

at least, fossil fuels tend to offer cost advantages due to economies of scale (Aguirre and Ibikunle 2014). Thus, it is only the third dimension of energy security – the environmental sustainability of energy preferences – that offers some redeeming qualities for renewables. Yet, although renewables have clear environmental advantages over fossil fuels and nuclear, the fossil fuels industry is making efforts to reduce the future carbon footprint of traditional energy sources by financing research into integrating sustainability practices such as carbon capture and storage and bioenergy into the industry, which could (eventually) alleviate some concerns over sustainability.

The arguments presented so far seem to suggest that industry's drive for energy security results in an unequivocal win for fossil fuel energy (excluding, of course, the position of the renewable energy industry). Yet, we argue that such a conclusion would be short-sighted as recent empirical experiences of hybrid deployment systems and the energy literature suggests a more nuanced understanding about the performance of both fossil fuel and renewable energy sources in delivering energy security. First, it is important to note that renewable energy sources and centralised energy structures are not mutually exclusive; rather, it is possible for renewable sources to be implemented in the traditional – large-scale centralised – way, which could alleviate some concerns about stability of supply arising from newer, flexible energy structures (Neuhoff 2005). Moreover, there is a strong case to be made that a diverse energy supply, encompassing both fossil fuels and renewable energy sources deployed via centralised and decentralised (hybrid) structures, reduces the risks that arise from relying on a narrow energy mix and supply system (Lucas et al. 2016; Xia et al. 2011; Bouffard and Kirschen 2008; Kuzemko et al. 2016; Burke and Stephens 2018). Bouffard and Kirschen (2008), for instance, argue that shifting from a few centralised energy systems to more numerous modular systems that have the capability to draw on multiple energy sources can significantly enhance supply reliability, especially in the face of natural disasters and geopolitical crises, which usually result in total blackouts. Similarly, energy diversification can enhance resilience in uncertain economic systems (Grubb et al. 2006) and facilitate the substitution of energy (Xia et al. 2011). Apparently, then, industrial energy consumers have a collective interest in deploying different energy sources (particularly renewables which lag behind fossil fuels) to obtain a better mix of benefits (e.g. to stabilise supplies at different times of day or demand spikes) from the different supply characteristics (Doern 2015).

Regarding the affordability concern, while renewable sources are currently costlier than fossil fuels, government interference (e.g. through carbon taxes and renewable subsidies) often adjusts the relative advantages of fossil fuel energy by passing on lower renewable electricity prices to industry (Carley 2009). Furthermore, since renewables do not need fuel to produce power, they are not affected by price volatility, unlike fossil fuels, rendering the former more secure from a price stability perspective (Lucas et al. 2016). Moreover, assuming that industrial energy consumers are likely to favour lower electricity prices, the deployment of additional energy (whether it be fossil fuel or renewable) is likely to drive down prices by increasing supply (Aguirre and Ibikunle 2014).

Thus, if the industrial lobby is driven by the desire for energy security, it should support the deployment of more energy all around. This is because: (a) a more diversified energy mix and hybrid system would result in a more stable and reliable energy supply; (b) more energy generation (from all sources) would increase supply and reduce electricity prices; and (c) increasing renewable electricity generation is consistent with the energy transition while sustainability concerns can also be met by increasing energy generation from 'enlightened' fossil fuel technologies that integrate sustainable practices. Collectively, these arguments suggest that stronger industrial lobbies wield more political power and, therefore, have the capacity to use the civil society pathway more efficiently to exert greater influence over political actors, thereby increasing the influence of civil society activism over energy deployment. Hence our industry-hypothesis is as follows:

For all energy sources; as industrial representation increases, the effect of democracy on energy deployment will become more positive.

Research Design

This article uses cross-section time series data to analyse the electricity deployment rates of 136 countries from 1990 to 2018. The unit of analysis is the country-year, bringing the total number of observations to 3,944. The spatial domain was cast as widely as possible to minimise the possibility that correlations are due to regional factors rather than political variables. The sample spans 33 geographical regions as defined by the United Nations Food and Agricultural Association's Aquastat classification system.[17] A country was excluded from the dataset if two or more independent variables were missing for the entire time period under investigation.

The temporal dimension of the sample represents a vibrant period in energy deployment. By the 1990s, the deployment of the modern renewable energy technologies was well underway. Moreover, global warming had secured its central place on the international agenda and mitigation efforts began to be regulated by the global climate regime with the adoption of the 1992 UNFCCC and 1997 KP, creating important incentives for energy transition. 2018 is the last year for which complete energy and democracy data was available.

Most quantitative research on the drivers of energy deployment employs single-level ordinary least squares (OLS) regression (e.g. Lucas et al. 2016; Aquirre and Ibikunle 2014; Marques et al. 2010; Wurster 2013; Henisz and Zelner 2006; Cadoret and Padovano 2016; Bayer and Urpelainen 2016). Yet a fundamental assumption of OLS analysis is that residuals are completely independent from each other. We argue that, due to a host of factors (only some of which are explicitly accounted for by energy models as control variables), observations of electricity deployment rates from the same country and region are more likely to be similar to each other than observations from different countries or regions. Indeed, the literature is replete with examples of group-level factors that have been found to impact on energy preferences such as social norms (Fornara et al. 2016), national culture (Stephenson et al. 2015), regional institutions (Papiez et al. 2018), national and regional economic conditions (Andreas et al. 2017) and even conflicts between national and regional factors (Bohne 2011). Thus we employ multilevel modelling to explicitly account for group

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[17] The Aquastat classifies countries according to geographical characteristics, population and water resources, thereby accounting for key geophysical factors which could influence energy preferences (e.g. subtropical latitudes might prefer solar energy and windy countries wind power etc.).

clustering, thereby isolating the effects of political variables from those of group-level factors. Specifically, we build a three-level model consisting of country-years nested in countries, which are further nested in supranational regions. The proposed hierarchical data structure is shown in figure one.

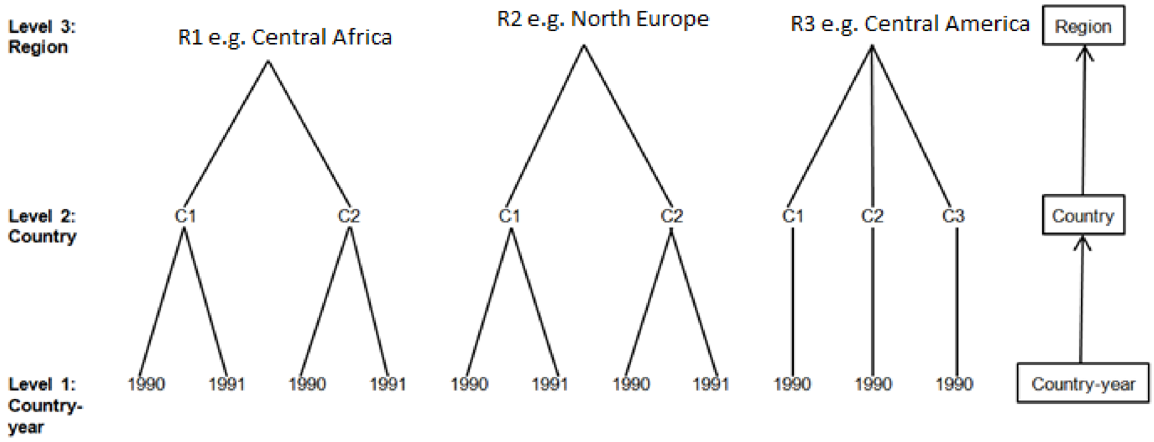

Figure 1: Unit and classification diagram showing the proposed three-level clustering structure.

In order to validate our claim that energy deployment rates are clustered in countries and regions, the deployment rate data was fitted to a null version of the proposed three-level model.[18] Table two shows the amounts of unexplained variance in deployment rates and variance partition coefficients (VPCs) (in parentheses) at each level of the model.[19] The VPCs show that for all energy sources, most variance in deployment rates lies within regions between countries and within countries between country-years.[20] All country-year and country-level variances are significant at the 0.001 level, providing strong evidence that deployment rates are clustered at the country-level.

Variance (VPC)	Solar	Wind	Hydro	Geoth.	Gas	Coal	Oil	Nuclear
Region	0.04 (0.61)	0.47 (7.28)	4.86e-18 (0.00)	1.82e-18 (0)	4.91e-20 (0)	1.21 (18.11)	1.64e-12 (0)	0.03 (0.95)
Country	1.76*** (26.87)	2.12*** (32.82)	2.71*** (48.05)	2.08*** (50.61)	2.47*** (48.81)	3.81*** (57.04)	2.49*** (43.68)	1.22*** (38.49)
Country-year	4.75*** (72.51)	3.87*** (59.91)	2.93*** (51.95)	2.03*** (49.39)	2.59*** (51.19)	1.66*** (24.85)	3.21*** (56.32)	1.92*** (60.57)

Table 2: VPCs and Chi2 results of the proposed three-level model.

In contrast, regional VPCs only comprise a negligible share of total variance for most energy technologies (except for wind and coal energy) and are not statistically significant.[21] Therefore, the goodness of fit of the proposed three-level model was compared to that of simpler two-level models (consisting of country-years nested in countries or regions only)

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[18] Null models do not include any independent variables or controls, but are informative in multilevel model design as they show how variation in the dependent variable of interest (in this case, energy deployment rates) is distributed across the different levels.

[19] VPCs denote the percentage share of between-level variance of total variance in the dependent variable.

[20] For the majority of energy sources, the country-year VPC exceeds the country-level VPC, with geothermal and coal energy being the only exceptions.

[21] The lack of significance is likely due to the small sample size at the regional level (n=33).

and the equivalent single-level OLS to evaluate whether the third level was warranted. Table three shows the likelihood values[22] and pairwise likelihood ratio (LR) test statistics.[23]

Parameter	Solar	Wind	Hydro	Geoth.	Gas	Coal	Oil	Nuclear
Likelihood value	-1911.59	-2191.22	-3699.00	-622.00	-3365.37	-2001.65	-3794.94	-968.60
OLS	166.22***	323.42***	831.77***	112.93***	711.73***	1251.31***	697.66***	203.48***
Country-years and countries	4.64*	12.78***	81.12***	-0.01***	140.62***	45.38***	61.34***	0.01
Country-years and regions	109.20***	191.80***	685.96***	69.46***	633.03***	855.42***	574.98***	99.68***

Table 3: Likelihood values and pairwise LR statistics.

In all but one of the pairwise comparisons, the LR statistics are significant at the 0.01 level or lower, providing strong evidence that the three-level model performs significantly better than the two-level and single-level alternatives. The only exception to this is the nuclear energy column, which obtains an insignificant LR statistic for the comparison between the three-level and the two-level models (with country-years nested in countries), suggesting that the regional level is superfluous when modelling nuclear deployment rates.[24] Thus, we employ the three-level model for analysing solar, wind, hydro, geothermal, gas, coal and oil energy deployment, and the two-level model without regions for nuclear energy.

Table four summarises the variables and data sources. We operationalise the dependent variable, annual deployment rates of electricity technology, by taking the natural logarithm of the change in electricity generation (in GWh) from the previous year for each technology. Deployment data comes from the International Energy Agency (IEA) World Extended Energy Balances and Summary database. Logarithmic values were used to transform the spread of data in accordance with the normal curve to improve the goodness of fit.[25]

Variable	Definition	Source
$\text{lnDEPRATE}_{(tech)ijk}$	Logged change in electricity generation (GWh) from the previous year in a country-year	International Energy Agency World Extended Energy Balances and Summary
DEMOCRACY_{ijk}	Level of democracy in a country-year	V-Dem additive polity index multiplied by 100
INDUSTRY_{ijk}	Share of industrial to total electricity consumption	International Energy Agency World Extended Energy Balances and Summary

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[22] The likelihood value is the probability of obtaining the observed data (deployment rates for the sampled observations) if that model were true.

[23] LR test statistics were obtained by doubling the difference between the likelihood values of the three-level model and pairwise comparison and p-values were from the Chi2 distribution (with the degrees of freedom set to one).

[24] This result is unsurprising given that only 31 countries currently deploy nuclear energy.

[25] Figure one in the appendix shows a representative visual comparison of raw and logged deployment rates to illustrate the improvement in goodness of fit.

LAGDEP$_{ijk,(t-x)}$	Lagged electricity deployment x years ago	International Energy Agency World Extended Energy Balances and Summary
TOTALENERGYCONS	Growth in total energy consumption as a percentage change from the previous year	International Energy Agency World Extended Energy Balances and Summary
POPGROWTH	Population growth as a percentage change from the previous year	World Bank Development Indicators
GDP	Per capita GDP (in US$)	World Bank Development Indicators
RESREV	Share of per capita income derived from fossil fuels	V-Dem per capita total fuel income variable

Table 4: Variables and sources.

Data for democracy come from the V-Dem additive policy index (API), which assigns scores from zero to one to reflect the fulfilment of the electoral principle of democracy based on aggregate performance in a range of sub-democracy indices encompassing: freedom of association, clean elections, freedom of expression, elected executive and suffrage in a country in a given year.[26] API scores range from 0.03 to 0.98, denoting the lowest and highest levels of democracy recorded in a country over the time period under investigation (1990 to 2017) respectively. API scores were multiplied by one hundred to stretch the spread of values.

Industrial representation is operationalised as the share of industrial to total electricity consumption in a country year. Data for this variable comes from the IEA database and ranges from zero to 0.93, respectively denoting the weakest to strongest share of industrial representation in our dataset.

In order to isolate the effects of democracy and industrial representation from the influence of other factors, the models introduce several variables to hold constant other drivers of electricity deployment. The existing level of deployment of each technology was included to account for the effect of previous deployment trends and associated factors such as accumulated capital stock, expertise and familiarity over future deployment rates.[27] We use two variables to operationalise rise in energy demand, which we expect should increase deployment rates: growth in total energy consumption, which is calculated as a percentage change from total energy consumption in the previous year using IEA data and population growth data obtained from the World Bank Development Indicators (WBDI) database. Per capita GDP is a proxy for living standards, which are associated with higher energy consumption and should therefore create upward pressure on electricity deployment. GDP data comes from the WBDI database and is measured in US Dollars. Poor uptake of low-

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[26] Interested readers are referred to the V-Dem codebook for a detailed discussion of the index methodology at: https://www.v-dem.net/media/filer_public/e0/7f/e07f672b-b91e-4e98-b9a3-78f8cd4de696/v-dem_codebook_v8.pdf.

[27] A series of preliminary regressions were carried out to identify the most substantively and statistically significant lag period (in years) for each energy technology and are reported in the appendix.

carbon technology is often attributed to high dependency on fossil fuel-derived income. We therefore include a resource revenue variable to measure the per capita income that is accrued from fossil fuel-intensive activities - either as an export or component of production. We use the V-Dem per capita total fuel income variable to measure resource revenue.

Our econometric specification is:

$$\text{lnDEPRATE}_{(tech)ijk} = \beta_0 + \beta_1\text{DEMOCRACY}_{ijk} + \beta_2\text{LAGDEP}_{ijk,(t-x)} + \beta_3\text{TOTALENERGYCONS}_{ijk} + \beta_4\text{POP}_{ijk} + \beta_5\text{GDP}_{ijk} + \beta_6\text{INDUSTRY}_{ijk} + \beta_7\text{RESREV}_{ijk} + \beta_8\text{INDUSTRY}_{ijk}\text{XDEM}_{ijk} + \beta_9\text{LAGDEP}_{ijk,(t-x)} \text{ X } \text{DEMOCRACY}_{ijk} + \beta_{10}\text{LAGDEP}_{ijk,(t-x)} \text{ X } \text{INDUSTRY}_{ijk} + \beta_{11}\text{LAGDEP}_{ijk,(t-x)} \text{ X } \text{DEMOCRACY}_{ijk} \text{ X } \text{INDUSTRY}_{ijk} + u_{1jk}\text{DEMOCRACY}_{ijk} + v_k + u_{jk} + e_{ijk}$$

where $\text{lnDEPRATE}_{(tech)ijk}$ is the observed logged deployment rate of a given technology in country-year i (i = 1,…,3,808) in country j (j = 1,…,136) in region k (k = 1,…,33) and v_k, u_{jk} and e_{ijk} denote country-year, country and regional residual error respectively.

The specification includes four interaction terms between DEMOCRACY, INDUSTRY and LAGDEP, which enables the statistical evaluation of the conditional effects proposed above. The interaction between INDUSTRY and DEMOCRACY flows directly from our theorisation of industrial energy consumers as an interest group which seeks to influence deployment decisions by utilising democratic channels for civil society involvement in policymaking such as lobbying. Yet it is also possible for democracy and industry to affect deployment indirectly. Drawing in Henisz and Zelner's (2006) approach[28], we model these indirect effects by including three additional interaction terms. The separate interactions between LAGDEP and DEMOCRACY and INDUSTRY model the possibility that that previous deployment patterns interact with current prevailing levels of democracy and industrial representation to influence present deployment rates. For example, industry might exert a stronger positive influence on this year's solar energy deployment rates when deployment levels were higher x years ago than if solar energy was negligible. The three-way interaction between LAGDEP, DEMOCRACY and INDUSTRY allows f0or higher-order multiplicative effects between the three variables.

Results

Tables five to seven report the results of various versions of the specification above. Table five displays the estimates of the model excluding the interaction terms using the V-Dem API as the democracy measure. It addresses our first set of hypotheses relating to the 'pure' effects of democracy (and other independent variables) on energy deployment.

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[28] The authors use a similar set of interaction terms to study the effect of veto points and industry over electricity infrastructure deployment.

Parameter	Solar	Wind	Hydro	Geoth.	Gas	Coal	Oil	Nuclear
Fixed effects								
Constant	0.93	1.37	4.95****	3.56**	5.71***	4.95***	4.66***	8.11***
Democracy	**-0.03***	**-0.02***	0.01	0.01	0.01	0.01	4.95e-4	**-0.01†**
Lagdep	3.54e-4	1.37e-4**	-1.58e-5***	9.81e-5	5.46e-6***	2.24e-6***	2.97e-5***	2.61e-6**
Totenergycon	4.79e-5	-3.08e-5	-2.70e-5	-0.15e-5	-3.11e-5	-3.74e-5	2.18e-5	-1.49e-5
Pop	0.11	0.36	0.04	0.22	0.03	-0.09	0.03	0.027
GDP	1,16e-4***	1.37e-4***	6.89e-6	-4.6e-5†	1.03e-5	2.59e-5	2.22e-5†	-2.00e-5
Industry	4.12e4	-1.85e5	1.09e3	-2.14e4	-3.25e3	1.64e3	1.99e3	3.37e4**
Resrev	-3.98e-4†	-1.41e-4†	-2.1e-5	1.34e-4	-3.21e-5	-7.35e-5	-1.48e5	6.35e-5
Random effects								
Dem random effect (u_{1jk})	8.48e-16	9.91e-9	**1.56e-4*** **	2.97e-21	3.73e-20	6.74e-13	4.69e-5	5.90e-14
Regional variance	0.99	0.25	0.19	8.19e-21	7.64e-20	3.53e-12	1.50e-18	1.79e-13
Country variance	1.07***	1.85***	0.82***	2.27***	1.91***	2.78***	2.36***	0.72***
Country-year variance	0.66***	1.82***	2.04***	1.84***	2.09***	1.28***	1.92***	1.76***
LR testOLS	150.06***	94.87***	338.60***	20.73***	276.50***	438.60***	270.02***	20.50***

Table 5: Effects of democracy on energy deployment rates without interaction effects.

A significant fixed or random democracy coefficient indicates that democracy has a significant effect on the deployment rates of three of the eight electricity technologies - namely: solar, wind and hydro energy. The significant negative fixed effect in the solar and wind models (p-value = 0.05) indicates that a small increase in the level of democracy (measured by a one-point increase in the stretched API scale) within a given country is associated with a three and two percent decline in solar and wind energy deployment rates respectively. It is also worth noting that the fixed democracy coefficient approaches significance in the nuclear model (p-value = 0.08) and is associated with a negative effect of one percent. Apparently, then, the increased opportunity for freedom of expression and civil society participation in democratic policymaking, reluctance of elected governments to intervene in individual lifestyle decisions and shorter time-horizons of elected leaders creates important obstacles for the deployment of these technologies. The random country-level democracy effect is significant at the 0.001 level in the hydro model, indicating that the effect of democracy on hydro deployment rates varies substantially between countries, making it difficult to generalise about the typical pooled effect of democracy across the sample.

Table six reports the results from the core specification including the interaction terms, allowing us to evaluate our hypothesis regarding the role of industry in moderating the effect of democracy on deployment rates.

Parameter	Solar	Wind	Hydro	Geoth.	Gas	Coal	Oil	Nuclear
Fixed effects								
Democracy	-0.03*	-0.02*	0.01	0.01	2.08e-3	0.01	-2.82e-4	-0.01
Industry	-1.27e6	-1.20e6*	676.32	-4.45e6***	1.26e4	1.32e4	3.10e4	1.93e5*
IndustryXdem	1.42e4	**1.28e5***	-74.49	**6491.50*****	-397.29	-112.56	-490.68	-1817.93
LagdepXdem	**7.42e-5***	-2.79e-6	-6.10e-8	-1.70e-7	**6.86e08***	-1.77e-8	2.23e-7	4.91e-9
LaddepXindustry	2.13e4†	**1.22e5***	-0.78	416.42	-0.17	-2.22	-1.90	**-1.28***
LagdepXdemXindustry	-240.00†	-1273.65†	**0.03****	-4.86	4.85e-3	0.01	0.01	0.02†
Random effects								
Dem random effect (u_{1jk})	2.94e-14	2.07e-4***	1.52e-4***	7.94e-13	4.07e-22	5.69e-15	5.30e-5	2.40e-16
Regional variance	1.42	0.15	0.20	7.00e-17	6.72e-21	2.39e-22	3.62e-19	5.77e-16
Country variance	1.00***	2.34e-16	0.73*	0.92*	1.69***	2.83***	2.20***	0.70***
Country-year variance	0.63***	1.75***	2.02***	1.77***	2.11***	1.27***	1.91***	1.69***
LR testOLS	122.02***	82.89***	324.24***	8.49*	233.94***	347.83***	267.58***	18.36***

Table 6: Effects of democracy on energy deployment rates with interaction terms.

At least one of the four interaction terms is significant at a p-value of 0.05 level or less in six of the eight energy columns analysed, suggesting that industry does indeed play a significant role in conditioning the marginal effect of democracy on solar, wind, hydro, geothermal, gas and nuclear energy deployment rates. Conversely, industry does not appear to have a similar moderating effect on coal or oil energy deployment.

The inclusion of the interaction terms renders the coefficients of the primary independent variables of interest – democracy and industry – meaningless. Therefore, following conventional practice, we investigate the interaction effects of democracy and industry (and lagged deployment) on deployment rates by estimating the marginal effects on deployment at different values of the independent variables using the equations:

$$\mathrm{lnDEPRATE}_{(tech)ijk} = \beta_1 + \beta_8 \mathrm{INDUSTRY} + \beta_9 \mathrm{LAGDEP}_{ijk,(t-x)} + \beta_{11} \mathrm{LAGDEP}_{ijk,(t-x)} \mathrm{\ X\ INDUSTRY}_{ijk}$$

at different levels of industrial representation, and:

$$\mathrm{lnDEPRATE}_{(tech)ijk} = \beta_6 + \beta_8 \mathrm{XDEM}_{ijk} + \beta_{10} \mathrm{LAGDEP}_{ijk,(t-x)} + \beta_{11} \mathrm{LAGDEP}_{ijk,(t-x)} \mathrm{\ X\ DEMOCRACY}_{ijk}$$

at different levels of democracy.

The democracy coefficients from table six are used to define the estimators for each energy technology. Thus, for example, the marginal effects of democracy on solar energy are estimated at different levels of industrial representation (with constant lagged deployment) using the equation:

$$\mathrm{lnDEPRATE}_{(tech)ijk} = -0.03 + 1.42\mathrm{e}4\mathrm{INDUSTRY} + 7.42\mathrm{e}{-5}{*}\mathrm{LAGDEP}_{ijk,(t-x)} - 240\mathrm{LAGDEP}_{ijk,(t-x)}\mathrm{X\ INDUSTRY}_{ijk}$$

The top half of table seven shows the predicted marginal effects of democracy on energy generation when lagged deployment is set to the sample mean and industrial representation is made to vary from low (sample mean minus one standard deviation) to high (sample mean plus one standard deviation).[29] The equivalent marginal effects of industrial representation on energy generation are shown in the lower half of the table across a range of democracy scores.

Parameter	Solar	Wind	Hydro	Geo	Gas	Coal	Nuclear	Oil
Value of Industry								
Mean – 1SD	324.27	1368.39	2.53E4	441.08	58672.15	81249.35	19063.25	8040.93
Mean	324.43	1369.05	2.53E4	441.08	58674.29	91992.67	19065.25	8041.58
Mean + 1SD	324.58	1369.72	2.53E4	441.08	58676.42	102735.98	19066.81	8042.24
Value of Democracy								
Mean – 1SD	9.49E4	4.01E5	1.27E6	3605.27	1.30E6	1.87	9.41E5	3.92E5
Mean	1.42E5	6.00E5	1.89E6	3916.27	1.94E6	2.19	1.41E6	5.88E5
Mean + 1SD	1.89E5	8.00E5	2.52E6	4228.56	2.59E6	2.51	1.88E6	7.84E5

Table 7: Estimated marginal effects of democracy-industrial representation interaction on electricity deployment rates.

The positive values of the results in the upper half of the table suggest that for all technologies, more democratic conditions are always associated with higher deployment rates across the range of industrial representation scores. However, this is not to say that industry does not matter. Rather, the increase in estimated marginal effects that takes place as we move from low to high levels of industrial representation shows that an increase in democracy is associated with a stronger positive effect on the deployment of all energies as industry grows stronger.

While the direction of the moderating effect is in the expected direction and supports our hypothesis that the desire for energy security drives industrial actors to utilise the (increased) available channels for policy influence that emerge in heightened democratic conditions, the estimates show that the magnitude of the change in marginal democracy effects is not huge. Moreover, it is only in the deployment of coal electricity that the move from weak to strong industry is associated with a substantively significant increase in the positive effect of democracy. On the other end of the spectrum, similar growth in industrial strength is not associated with any substantive moderating effect on geothermal deployment rates, with the substantive effect of the interaction on the other technologies falling somewhere in-between these extremes.

The lower half of the table shows the mirror image estimates for the predicted marginal effects of a one-point increase in industrial representation under different levels of democracy. The positive direction of these estimates suggest that, like democratization, growth in industrial representation tends to be conducive to the deployment of all energies whether this takes place in autocratic or highly democratic contexts. However, the

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[29] The marginal effect referred to here is the estimated effect of a one-point increase in the stretched API score on energy deployment rates when there is a one-point increase in the per unit GDP level of industrial representation. It can also be thought of as the gradient of the API – DEPRATE equation at a defined level of industrial representation.

magnitudes of the differences observed on moving from low to high levels of democracy are much more striking than those obtained in the preceding estimates, suggesting that democracy's role in moderating the marginal effect of industry is more substantively significant than industry's. Collectively, these results suggest that the democratic nature of the political environment is more influential than the strength of political actors in shaping the political returns that are associated with different technology options.

Robustness tests

This section discusses the results of two sets of tests that were conducted to evaluate the robustness of the above findings and identify which, if any, of the dimensions of democracy are more influential over the deployment of the various energy technologies analysed. First, the regressions from the last section were repeated using two alternative broad democracy indices to determine whether the influence of democracy and the interaction effects remain constant when the API is replaced with different proxies. Second, the RCMs without interaction effects were repeated using narrower subset-indices pertaining to specific dimensions of democracy to evaluate whether the deployment of different technologies are more sensitive to different aspects of democratic regimes.

Test one: Alternative democracy proxies

Quantitative democracy research is often criticised for being highly dependent on proxy selection (e.g. Coppedge et al. 2011; Teorell et al. 2016). While this is not the place for an in-depth discussion of such issues, definitional and precision issues are among the fundamental concerns. Thus we evaluate whether our findings are robust to these types of concerns by repeating the above models using two alternative leading democracy proxies in the IR literature – the Freedom House (FH) index on civil liberties and political freedoms and Polity II (P2) variable from the Polity IV database. The broad definitional focus of these proxies on several democratic rights and freedoms renders them comparable to the API.

Table eight shows the democracy estimates for the RCM without interaction effects using the alternative proxies alongside the previous coefficients from the API model for reference. While the API estimates suggest that democracy has a significant (fixed or random) effect on solar, wind and hydro electricity deployment, the results are more muted in the other proxy models. The FH regression reports a similar negative significant fixed effect on solar deployment, where a one-point increase in the FH democracy score is associated with a two percent lower deployment rate of solar energy. The results also suggest that democracy has a significant random effect on solar deployment. Furthermore, democracy is also estimated to have a significant positive effect on hydro energy such that a one-point increase in the FH score is associated with one percent higher deployment rates. This is somewhat consistent with the API model because democracy was found to have a significant random effect on hydro deployment. The P2 results are the most conservative of the three proxies, with only one significant (random) effect reported for solar deployment rates. Collectively, these results suggest that while democracy appears to play a significant role in shaping solar and hydro energy deployment, the reported effect on wind (and more tentatively nuclear) in the FH model are less robust to the choice of proxy. Since the API encompasses a wider range of democracy attributes beyond the FH and P2, which focus more narrowly on the 'traditional' aspects of democracy (i.e. fair elections and fundamental political rights and freedoms), the findings suggest that the more unconventional dimensions of democracy might perform a more determinative role over wind and nuclear deployment – a thesis that we test in the second robustness exercise below.

Parameter	Solar	Wind	Hydro	Geoth.	Gas	Coal	Oil	Nuclear
Fixed dem effects								
API	__-0.03*__	__-0.02*__	0.01	0.01	0.01	0.01	4.95e-4	__-0.01†__
FH	-0.02**	-3.62E-4	0.01*	0.01	-1.65E-3	0.01	0.01	-0.01
P2	-0.01	-0.07	0.01	0.07	-2.40E-3	0.01	0.01	-0.01
Dem random effect (u_{1jk})								
API	8.48e-16	9.91e-9	__1.56e-4***__	2.97e-21	3.73e-20	6.74e-13	4.69e-5	5.90e-14
FH	7.09E-5**	6.37E-5	5.91E-5	3.22E-24	3.67E-5	1.37E-18	3.65E-13	8.09E-19
P2	9.70E-5*	6.94E-5	8.43E-5	6.08E-10	8.68E-5	2.08E-9	1.20E-5	8.19E-5

Table 8: Democracy estimates using different proxies (without interaction effects).

Table nine summarises the estimates of the interaction terms obtained from the different iterations of the model with interaction effects by using asterisk to indicate the significance level of the interaction coefficient. While the API model reported significant interaction terms under the solar, wind, hydro, geothermal, gas and nuclear columns, only four columns contain significant coefficients in the FH and P2 iterations. Moreover, the energy columns without any significant entries varies between the models, suggesting that different dimensions of democracy which are emphasised by the various proxies are more influential for different technologies.

Parameter	Solar	Wind	Hydro	Geoth.	Gas	Coal	Oil	Nuclear
API (reference)								
IndustryXdem	-	*	-	***	-	-	-	-
LagdepXdem	*	-	-	-	*	-	-	-
LaddepXindustry	-	*	-	-	-	-	-	*
LagdepXdemXindustry	-	†	**	-	-	-	-	†
FH								
IndustryXdem	-	-	-	†	-	-	-	-
LagdepXdem	*	-	-	-	-	*	-	-
LaddepXindustry	-	-	-	-	-	***	*	-
LagdepXdemXindustry	-	-	*	-	-	*	-	-
P2								
IndustryXdem	**	*	-	*	-	-	-	-
LagdepXdem	-	**	-	†	-	-	-	-
LaddepXindustry	-	-	-	-	-	**	-	-
LagdepXdemXindustry	-	-	†	†	-	-	-	-

Table 9: Interaction term estimates using different proxies (with interaction effects).

Test two: Democracy attributes

The second robustness exercise uses data pertaining to specific components of democracy from the V-Dem dataset to investigate whether certain regime attributes could play more important roles in influencing the deployment of different technologies. Returning to the regime pathways described in table one, we employ the following indices to measure the key democratic attributes discussed above:

Attribute	**Measure (V-dem variable)**
Accountability	Accountability (v2x_accountability)
Prevalence of corruption	Corruption (v2x_corr)
Opportunity for freedom of expression and civil society activism	Civil society participation in policymaking (v2csprtcpt)
Protection of individual freedoms	Liberal democracy index (v2x_libdem)
Time horizons	Fair elections (v2xel_frefair)

Table 10: Democratic attributes and measures.
Note: V-Dem variables are shown in parentheses.

Table eleven shows the fixed and random democracy coefficients obtained from the different iterations of the RCMs without interaction effects.

Parameter	Solar	Wind	Hydro	Geoth.	Gas	Coal	Oil	Nuclear
Fixed dem effects								
Accountability	-0.48	-0.31	0.04	0.28	0.17	0.40*	-0.03	-0.33†
Corruption	3.58**	3.11**	0.08	-1.58	0.16	-0.72	-0.19	1.14
Civil society activism	-0.22	0.04	0.12	0.09	0.20†	0.11	-0.01	-0.09
Individual freedoms	-3.13***	-2.52*	0.07	0.38	0.65	1.05†	0.34	-1.3*
Time horizons	-1.31	-2.27**	-0.09	0.58	0.15	0.87†	0.06	-1.09*
Random dem effects								
Accountability	0.29**	0.08	0.56*	2.02E-17	0.21	1.95E-12	0.08	6.79E-13
Corruption	3.80E-17	2.30	6.10E-11	3.88	1.17	5.73E-12	0.32	1.09
Civil society activism	0.13	0.27†	0.13	1.03E-8	0.26*	0.24	0.05	0.04
Individual freedoms	1.98E-15	0.15	2.00	2.24E-17	4.32E-17	1.37E-16	0.36	8.56E-16
Time horizons	1.22***	1.01	1.89***	3.74E-19	0.04	5.95E-16	0.39	6.62E-21

Table 11: Democracy estimates using narrow proxies.

Several points are noteworthy. First, six of the eight energy columns (namely: solar, wind, hydro, gas, coal and nuclear) contain statistically significant entries, suggesting that at least one aspect of democracy influences the deployment of these technologies. Second, the significant aspect of democracy varies across the technologies, implying that different technologies are more sensitive to different aspects of democracy. Solar energy appears to be the most sensitive of all the technologies as the significant estimates indicate that its deployment is shaped by levels of accountability, corruption, individual freedoms and time horizons. Wind energy is the second-most sensitive and is significantly influenced by corruption, individual freedoms and time horizons, followed by hydro and nuclear, which are affected by two democratic attributes and gas and coal, which are affected by one attribute each. No significant effects are reported for geothermal or oil energy deployment rates, which is consistent with the results of the regressions employing broad democracy proxies in table eight. Third, it is possible to draw out some generalisations about the effects of the regime attributes with significant fixed estimates. Accountability appears to promote coal deployment, which supports our hypothesis that the desire to please constituents can drive policymakers to deploy high-carbon technologies that employ large segments of the population. The negative sign of the significant corruption estimates suggest that corruption levels are unexpectedly positively associated with solar and wind energy deployment. Individual freedoms have a significant inhibitory effect on solar, wind and nuclear deployment, which coheres with our hypothesis that democratic regimes are reluctant to intervene in individual lifestyle and consumption decisions by deploying more of the relatively newer energy technologies. Lastly, short time horizons, as measured by the expectation of frequent and fair elections, are negatively associated with the deployment of solar, wind and nuclear energy. This is consistent with our proposition that elected policymakers who have less expectation of remaining in office by the time that the benefits of low-carbon projects materialise face lower political incentives to deploy such options.

While it is not possible to infer general conclusions from the random estimates, significant entries indicate that accountability and time horizons have significant heterogenous effects on solar and hydro deployment rates that vary substantially in sign and magnitude between countries. For example, while a one-point increase in accountability levels is estimated to cause a 0.77 point decline in solar energy deployment rates in Switzerland, the same rise in accountability is predicted to increase deployment rates by 1.33 points in Germany. Similarly, civil society participation in policymaking is reported to have significant random effects on gas energy deployment.

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