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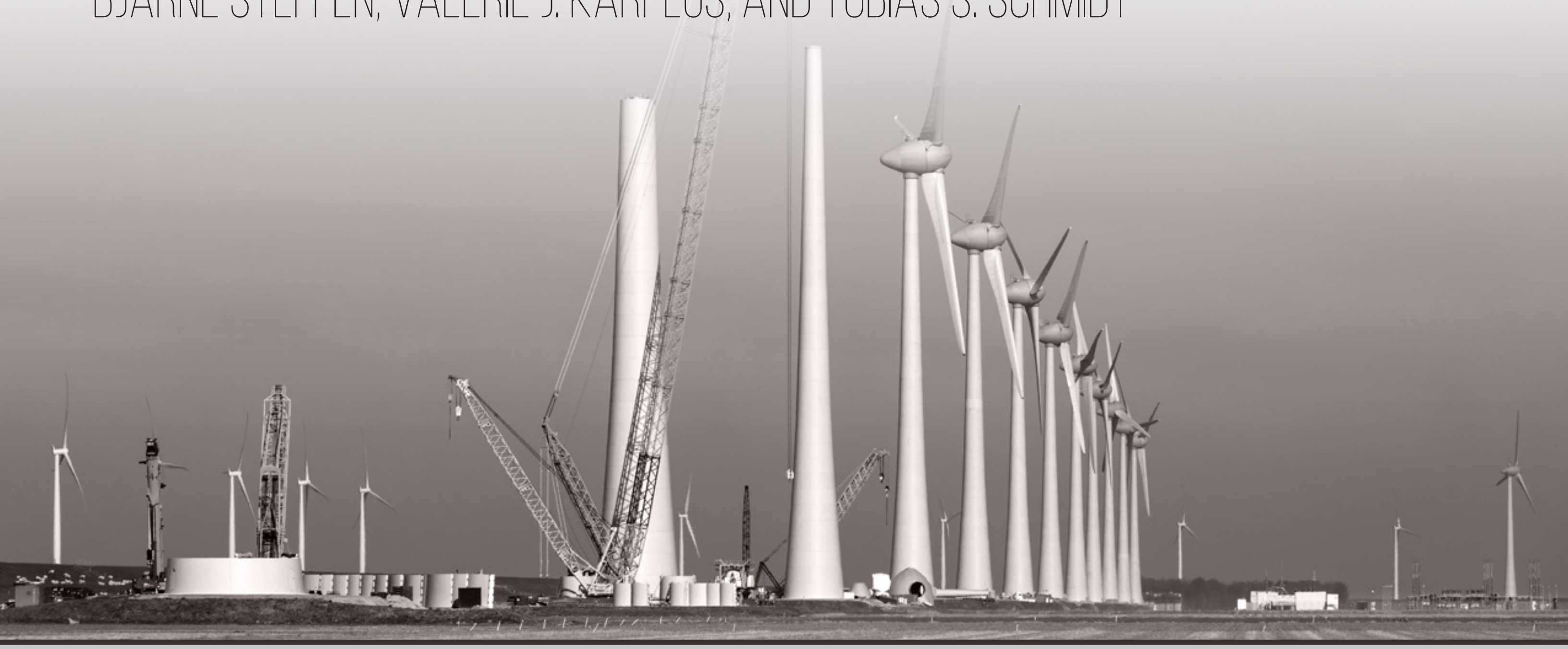

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State ownership and technology adoption: The case of electric utilities and renewable energy

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Abstract:
Technological change in industries that are characterized by large technical systems often occurs incrementally along given technological trajectories. Given pressing issues such as climate change, much research has studied how to induce and accelerate socio-technical transitions in such sectors, for instance the transition to renewables in electricity. The adoption of new technologies by players such as incumbent electric utilities is a key step in the transition, but not a given. Particularly, little is known on how the ownership structure of utilities affects technology adoption. Following liberalization, the electricity industry in many countries is now characterized by a co-existence of state-owned and private utilities. Economic ownership literature has studied pros and cons of these options in terms of productivity and market power, amongst other factors, but the role of ownership on the adoption of low-carbon technologies remains elusive. To fill this gap, here we bring together innovation literature and economic ownership literature to derive hypotheses how ownership could affect renewable energy adoption by utilities, including through drivers like incentives to innovate, the exploitation of state ownership to advance climate policy, the role of general climate policy stringency, and the impact of incomplete contracting. Taking incumbent utilities in the European Union (EU) during 2005–2016 as a case, we test the hypotheses using regression analyses and qualitative case studies. Results suggest that in the EU, state-owned utilities have a higher tendency to invest in renewables, though state ownership does not exert its influence in a vacuum: It interacts with the existence of pro-adoption policies and state enforcement capabilities. Based on our findings, we discuss the larger implications for the role of state-owned enterprises in directed technological change in the energy sector and beyond.

JEL classification: L33, L94, O33, Q42, Q48

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"Technological change is at once the most important and least understood feature driving the future cost of climate change mitigation" (Pizer and Popp, 2008, p. 2768).

1 Introduction

Technological change is not only the key driver of economic development (Romer, 1990; Schumpeter, 1942) but also plays a central role in addressing pressing societal issues (Markard et al., 2012). One such issue is climate change. Preventing dangerous levels of global warming requires a rapid and deep decarbonization of many industries by means of socio-technical transitions (Frank W Geels et al., 2017; IPCC, 2014; Masson-Delmotte et al., 2018). Besides the invention and innovation of new technologies, the adoption of low-carbon technologies also needs to be accelerated to this end (Grubler et al., 2016; IPCC, 2014).

This is particularly difficult in industries in which innovation typically only occurs incrementally along a given technological trajectory, and in which "lock-in" to established high-carbon technologies prevents the adoption of radically new technologies (Islas, 1997; Schmidt et al., 2016; Unruh, 2000). A number of those industries crucial for climate change mitigation are characterized by large, long-lived technical systems, in which interdependencies and standards are powerful barriers to the diffusion of new technologies (Hughes, 1987; Markard and Truffer, 2006; Seto et al., 2016). Accordingly, a broad literature has studied how public policy can induce and accelerate a socio-technical transition in these industries, including by subsidizing investment in or the operation of new technologies, enacting new technical standards, or more generally supporting a conducive environment for new technologies (for an overview, see Kern et al., 2019). Much of the empirical literature centers on the question of which policy instruments, mixes, and designs foster technology innovation and adoption efficiently and effectively (see e.g. Polzin et al., 2019; Schmalensee, 2012; Schmidt and Sewerin, 2019). By contrast, the impact of the ownership structure of companies on technology adoption has been little studied (an exeption is Rose and Joskow, 1990). This research gap is surprising given that the restructuring of industry ownership has been a key policy area in industrialized countries for decades, which encompasses the question of whether large technical systems should be operated by state-owned or privately-owned companies. However, past research on ownership has often been concerned with pressing topics other than technological change, such as how to increase operational efficiency and how to prevent the abuse of market power (cf. e.g. Boardman and Vining, 1989; Crew and Kleindorfer, 1979; Goldeng et al., 2008; Shleifer, 1998). Regarding innovation, ownership is eclipsed by a focus on how changing market concentration, liberalization, and regulatory treatment affect R&D in the electricity industry (Jamasb and Pollitt, 2008; Markard and Truffer, 2006). Hence, the impact of public versus private ownership on the *adoption* of new technologies remains elusive.

While the role of ownership in the adoption of (low-carbon) innovation is relevant in multiple (polluting) industries (e.g., aviation), here we focus on the electricity industry. While electricity is a ubiquitous input to many industries, its generation is the single largest contributor to anthropogenic CO_2 emissions (IPCC, 2014). At the same time, it is a hard-to-store commodity that can be produced using an array of different technologies, including very carbon-intensive (e.g., coal) as well as largely carbon-free technologies (renewables). Consequently, a massive shift toward non-CO_2-emitting renewable energy technologies is assumed in all pathways toward reaching the Paris Agreement's targets that are considered by climate economists (Luderer et al., 2018). Importantly, however, the industry was, until recently, characterized by a strong "lock-in" to high-carbon technologies (Carley, 2011). How to accelerate the transition of the electricity industry toward renewables is thus an important research area within the sustainability transition literature (Grubler, 2012; Schmidt and Sewerin, 2019; Strunz, 2014; Verbong and Geels, 2007; Wainstein and Bumpus, 2016). This literature has also addressed the question of which actors should undertake the required massive investments in innovative renewable energy technologies (Mazzucato and Semieniuk, 2018; McCollum et al., 2018).

Historically, power plants and grids were often built by state-owned utilities, as electricity was considered an essential service to be delivered by either local or central governments (Wollmann, 2011). While acknowledging that public ownership may be appropriate given the natural monopoly nature of the utility business, economic theory since the 1970s has emphasized that shifting to (regulated) private ownership models can increase the efficiency of utility operation (cf. Crew and Kleindorfer, 1979; Megginson and Netter, 2001; Shleifer, 1998). This argument is supported by a large empirical literature showing that private firms generally deliver better commercial performance compared to state-owned enterprises (e.g. Boardman and Vining, 1989; Dewenter and Malatesta, 2001; Ehrlich et al., 1994; Goldeng et al., 2008; Megginson and Netter, 2001). Accordingly, the privatization of electric utilities has been the general trend in many countries since the 1980s (Holburn and Zelner, 2010; Markard and Truffer, 2006; Wollmann, 2011). However, public ownership models nevertheless remained common alongside privately-owned utilities, resulting in the co-existence of state-owned and private utilities in the electricity industry in many countries (e.g., much of Europe). Governments generally motivate the residual public ownership of some utilities in terms of the non-commercial priorities the state may have for their operation, including preventing the abuse of monopoly power, incomplete contracting, and industrial policy strategies (Christiansen, 2013; Crew and Kleindorfer, 1979; Goldeng et al., 2008; Laffont and Tirole, 1993).

Since the 2010s, mitigating climate change has become an emerging priority of policymakers. Amid growing pressure to mitigate climate change and a growing dissatisfaction with private utility operation, political debates have emerged over whether state ownership of utilities is needed to accelerate the adoption of new low-carbon technologies in the industry. Some countries recently witnessed a trend of establishing new state-owned utilities, motivated in part by the expectation that state-owned enterprises would make more sustainable investment decisions (Wollmann, 2011). For instance, in Germany, two large utilities, EnBW and Steag, have been re-nationalized, and about 90 new municipal-owned utilities were founded over the last few years (Bönker et al., 2016). The nationalization of parts of the electricity industry was also fiercely debated during the U.K. election campaign and the U.S. primary election campaign in 2019 (Bade, 2020; Hodges, 2019).

The idea that state ownership accelerates technological change is contested. From a theoretical perspective, private companies are generally considered to be more innovative than state-owned enterprises, but past ownership literature mainly considered the pros and cons of state ownership in a *given* socio-technical regime. In the case of climate change mitigation, however, the key issue is how ownership contributes to *changes* in socio-technical regimes. At the same time, the large amount of interdisciplinary literature on socio-technical transitions remains largely detached from the economic ownership literature to date. From an empirical perspective, there are examples of high-carbon and low-carbon technologies chosen by state-owned and private utilities alike (Frei et al., 2018; Pahle, 2010; Richter, 2013), and no systematic assessment of the relationship between the ownership model and the tendency to adopt low-carbon technologies is currently available.

To fill these research gaps, we study the relationship between utility ownership structures, i.e., state-owned vs. private utilities, and investments in renewables (e.g., wind turbines, solar PV plants) as opposed to fossil fuel-based alternatives (e.g., coal-fired plants, gas-fired plants). Innovation scholars have suggested that the large-scale adoption of new renewable energy technologies is crucial for renewables to drive a low carbon transition, because innovation and cost reductions are largely driven by the processes of learning-by-doing and learning-by-using in commercial deployment (Hoppmann et al., 2013; Huenteler et al., 2016; Kavlak et al., 2018; Nemet, 2019). Improving understanding of ownership and technological change in the electricity industry is thus important in itself, but it can also serve to derive insights applicable to ownership and technological change more generally.

We start with a review of literature and a discussion of the theoretical rationales behind why state-owned utilities could have a lower or higher tendency to invest in renewables. Testable hypotheses are derived that add to previous literature on state-owned enterprises by considering the adoption of an emerging technology during transition periods featuring changing socio-technical regimes. Next, we empirically consider the case of incumbent utilities in European Union (EU) countries during 2005–2016 (a period in which the EU was bound by the Kyoto protocol, and all EU countries had binding targets to increase the share of renewable energy in their energy mix). A large-n regression analysis of state-owned and private utilities' investment decisions allows us to test our hypotheses with observational data. Third, we present a qualitative analysis of the investment motives for a selection of utilities with remarkable shifts to renewables, complementing the regression analysis with further evidence using an explanatory sequential research design. Finally, we discuss the larger implications for the role of state-owned enterprises in directed technological change, lay out an agenda for future research, and conclude.

2 Theory and hypotheses

While the literature, to our knowledge, has not explicitly addressed the role of ownership for technology adoption during transitions, two streams of literature relate to our research topic.

First, innovation literature analyzes the interplay between technological change and electricity market liberalization more generally, considering the broader changes in market structures coming with liberalization and privatization (but not the role of ownership in liberalized market structures specifically). Socio-technical transition scholars emphasize the importance of new entrants to break-up the socio-technical lock-in in industries such as electricity (Frank W. Geels et al., 2017; Unruh, 2000). The liberalization of electricity industries in many cases created such space for new entrants (even though "technical progress has neither been a driving force nor an objective of the [electricity sector liberalization] reform agenda" (Jamasb and Pollitt, 2008, p. 1007)). Markard and Truffer (2006) analyze how liberalization and privatization processes changed the environment for technological change in the electricity industry, tentatively concluding that a liberalized market environment allows for more heterogeneous utility strategies with respect to new technologies. Indeed, later empirical studies showed that private new entrants played an important role in the deployment of renewables in a number of countries (IEA, 2016; Steffen, 2018; Steffen et al., 2018). Notwithstanding the role of new entrants, it is a separate important question whether or not the ownership structure of the remaining incumbents affects their technology choices, a topic not analyzed by the literature on market liberalization. Still, today incumbent utilities remain major players in power generation in most countries (IEA, 2016). Given many utilities' integrated structure comprising both power generation and distribution, as well as their considerable organizational knowledge in electricity system operation, incumbent utilities might even become more important for integrating higher shares of renewables in the future (Frei et al., 2018; Markard, 2018). Comparing the German with the UK energy transition, Geels et al. (2016) identify the important role of incumbents in driving the transition toward renewables in the UK. In addition, incumbent utilities (both state-owned and private) typically have good access to decision-makers in the public administration, allowing them to lobby for regulations that keep them in business, even in a changing environment (Jacobsson and Lauber, 2006; Stokes, 2020). Hence, a rapid and deep low-carbon energy transition requires that also incumbent utilities adopt new low-carbon technologies. In many countries, the electricity sector liberalization led to the co-existence of private and state-owned companies in the same market[2], a heterogeneity that has largely been ignored by extant research. We thus extend the literature on market liberalization and technological change by analyzing the impact of specific ownership types on technology adoption by incumbents within liberalized industries.

Second, a separate stream of research, mainly from the economic ownership literature, compares the research and development (R&D) activities of state-owned and private firms in a variety of industries and settings. While classical R&D investments typically play a smaller role in electric utilities as compared to equipment manufacturers (as they are users of technologies, not developers) (Rogge et al., 2011; Schmidt et al., 2012), findings on ownership and R&D could be relevant to explain the adoption of innovative technologies as well. Analyzing privatization cases in various industries during the 1980s–1990s, Munari et al. (2002) developed a framework for how corporate R&D activities change with privatization. They conclude that efficiency pressure and tighter management control lead to lower R&D investment but also to a greater focus on using remaining investments toward applied research projects that increase productivity (as compared to basic research, which is often preferred by state-owned companies). Reviewing the industrial organization literature with a view to predict R&D activities after the liberalization of the electricity industry, Jamasb and Pollitt (2008) come to similar conclusions: privatization can change corporate governance towards viewing long-term R&D projects as candidates for quick cost-cutting but can also increase the incentive for appropriable (i.e., patentable) developments that create a competitive advantage in the liberalized market. In line with these theoretical considerations, several empirical studies of

[2] Note that, while somewhat special, this constellation exists in other industries as well (e.g., aviation, health services, higher education).

the electricity industry accordingly found that private electricity companies have lower R&D budgets but sometimes higher patenting activities compared to state-owned enterprises (Cambini et al., 2016; Defeuilley and Furtado, 2000; Jamasb and Pollitt, 2011). While the link between ownership and R&D is well-understood, R&D projects are, of course, only one of the steps required for technological change. As Markard and Truffer (2006, p. 624) underline, "innovation activities [...] might be well different from actual investment behavior of electric utilities". Not only R&D projects but also technology adoption (via large-scale investments) are required for technological change in large technical systems. The impact of private or state ownership on technology adoption might be different from the impact on R&D activities. Our analysis extends the literature on ownership and R&D to include the context of adoption.

In this paper, we combine insights from the innovation literature and ownership literature in economics to derive predictions of the potential impact of ownership on technology adoption. We derive five hypotheses and test them in the empirical analysis that follows. For clarity of analyses, the hypotheses are formulated directly with respect to the adoption of renewable energy technologies by incumbent utilities; the transferability to other industries will be taken up in the discussion section later.

2.1 Ownership and incentives to innovate

Well beyond the electricity industry, there is a broad consensus among economists that private firms are more productive than state-owned enterprises (Megginson and Netter, 2001; Shleifer, 1998). While empirical studies typically consider direct productivity measures (e.g., from accounting data), a common belief is that private firms are also superior in terms of the adoption of new technologies, which comprise a prerequisite for long-term productivity growth in what Shleifer (1998, p. 136) summarizes as the "appreciation of the innovative potential of entrepreneurial firms”, which contrasts with the “politicization of production” of state-owned enterprises. Theoretical explanations refer to managers of state-owned enterprises being subject to multiple and complex goals preventing them from making productivity-enhancing (innovative) investments (Tirole, 1994) as well as the soft incentives of public managers stemming from the contractual implications of the ownership setup. The argument concerning the latter is that public managers have weak incentives to invest in innovation because, if successful, they profit less from higher productivity when compared to private owners or their properly incentivized managers (Hart et al., 1997). While these arguments consider investments for innovation at the firm level, the line of thought can be extended to innovation and technological change at the industry level, of which widespread technology adoption is a major component. In the discussion of their review of empirical privatization studies, Megginson and Netter (2001, p. 382) accordingly suggest that “technological breakthroughs have transformed the global telecommunications industry during the past decade, and privatized telecom companies have been at the forefront of this revolution. Indeed, it is unlikely that this most dynamic of industries would have been able to grow nearly as rapidly under the former state ownership model.” In the electricity industry, utilities (both state-owned and private) have faced a new market environment since liberalization, in which entrepreneurial decisions to invest in new technologies can lead to a competitive advantage (Markard and Truffer, 2006). Particularly given the commodity nature of electricity, offering electricity generated from renewable energy sources is one of the few possibilities for differentiating a company’s output in the market and winning or retaining customers (Truffer et al., 2001). Applying the theory on ownership and innovation incentives thus leads us to our first hypothesis:

H 1: Assuming a general commercial viability of renewables, private utilities more often decide to invest in renewables than state-owned utilities.

2.2 Exploiting state ownership to advance climate policy

While our first hypothesis is largely based on the assumption that utilities pursue the objective of long-term profitability, it could be the case that the additional non-commercial priorities of state-owned utilities impact technology adoption. For example, either environmental objectives, or socio-economic objectives superseding any environmental concern, could play a role. While the literature on state ownership includes examples of state-owned enterprises as environmental laggards (e.g., in Eastern Europe (Grossman and Krueger, 1991)), this is not a foregone conclusion. After all, the priorities of governments can change. State-owned enterprises are essentially agents of the state and are thus bound by state policies and directives via a channel of direct influence or control, especially in the case of firms dependent on the state for resources, market access, or other essential support (Hart, 2003). Thus, a state authority that prioritized, for example, climate change mitigation, could direct state-owned utilities to reduce emissions by fiat. Governments can also exploit state ownership for policy targets by choosing managers whose worldviews (Lodge et al., 2010) are aligned with governmental priorities of changing technological trajectories and industry structures. Empirically, worldviews have been shown to impact the perception of the risks and opportunities related to investments in renewable energy (Chassot et al., 2014) as well as renewable energy deployment more generally (West et al., 2010).

While the investment decisions of both private and state-owned utilities likely to a large degree still reflect commercial priorities and technological necessities, for state-owned utilities, the owner's climate policy targets—which, in the electricity sector have typically been translated into targets of increasing the share of renewables (REN21, 2019)—can add to the variables to be considered. Direct fiat and choosing managers by worldview are two channels that could explain how such targets transmit to investment decisions. While the impact of climate policy targets might differ depending on the governance of individual state-owned utilities, the exploitation of state ownership for climate policy targets should lead to an effect in the aggregate, leading to a hypothesis that competes with H1 above:

H 2: When governments enact a political target to increase the share of renewables, state-owned utilities more often decide to invest in renewables than privately-owned utilities.

Indeed, many countries have targets for increasing the share of renewables, including all EU countries (REN21, 2019), but there is substantial variation in the *stringency* of policy interventions to that end (Schmidt and Sewerin, 2019). A large body of literature stresses the importance of ambitious policy interventions in redirecting technological change in the energy sector (e.g., Acemoglu et al., 2012; Nemet, 2009), and, more specifically, to induce investments into RE (see Polzin et al., 2019). Given the multiple market failures involved in technological change, particularly in the energy sector (Gillingham and Sweeney, 2012), an entire mix of stringent policy instruments is required (Kern et al., 2019). Empirically, it has been shown that more stringent policy mixes indeed result in wider RE technology diffusion (Schmidt and Sewerin, 2019). Hence, the stringency of renewable energy and climate policies reflects how serious a government is about climate policy, which should also be reflected in a higher propensity to exploit the state ownership of utilities for a low-carbon energy transition.

Beyond direct fiat and the deliberate choice of managers, state influence could affect the investment decisions of state-owned utilities because populations and stakeholders generally expect that state-owned enterprises act in greater alignment with social preferences compared to private companies (Christiansen, 2013). More stringent climate policies reflect a greater social preference for ambitious action toward climate change mitigation (Drummond et al., 2018). Accordingly, managers of state-owned utilities might tend toward investment decisions that comply with the social norm of shifting toward RE and more readily so compared to managers of private utilities given that society holds them to higher standards of prosocial behavior (Christiansen, 2013). The literature on management in public service provision underlines that behavior in such organizations also follows non-commercial "missions" that are shared between principals and agents (Besley and Ghatak, 2003), for which the transition to RE is a prime example (Mendonça et al., 2018). Both reasons result in a more specific hypothesis concerning the impact of climate policy targets:

H3: The greater propensity to invest in renewables of state-owned utilities vis-à-vis private utilities is more pronounced in countries with more stringent climate policies.

While H2 and H3 concern government priorities and the reaction of managers, it is important to also consider in which context the exploitation of state ownership for climate policy could be beneficial from a societal point of view. Given that state-owned enterprises often come at a societal cost of less efficient operation (Boardman and Vining, 1989; Dewenter and Malatesta, 2001), one would expect benevolent policymakers to only resort to exploiting state ownership if doing so addresses specific market or government failures better than regulation or contracts (Crew and Kleindorfer, 1979; Shleifer, 1998; compare Shleifer and Vishny, 1994), as we discuss next.

2.3 State ownership and regulatory quality

In markets where private ownership dominates, governments rely primarily on regulation to influence the behavior of private firms. This "contracting" channel affects policy stringency, as the state dictates or negotiates with regulated parties, and its sway over firms depends on the enforcement incentives and capabilities of the state (Hart, 2010). Prior work has found that, in weak enforcement environments, state ownership is effective as a tool for advancing environmental goals. For example, energy intensity reduction target achievement was included among the "binding targets" for China's state-owned enterprises (SOEs), whereas private firms faced no such channel (Karplus et al., 2020). SOEs in China's coal power sector were also found to account for a larger share of the overall SO_2 pollution reduction achieved during the Eleventh Five-Year Plan (Karplus et al., 2017). Hence, governments could resort to exploiting state ownership for climate policy targets, especially in such weak enforcement environments, leading us to formulate the first of two competing hypotheses with respect to regulatory quality:

H4: The greater propensity of state-owned utilities vis-à-vis private utilities to invest in renewables is more pronounced in countries with a weak enforcement environment.

However, the effectiveness of state ownership as a driver of prosocial technological change is not a given if a weak institutional environment means that policy directives exist only on paper and, due to the relative influence of established industries, are not well enforced through official channels (Hallward-Driemeier and Pritchett, 2015). If risk aversion toward new technologies is a general feature of utilities, public companies could exploit their close entanglement with the government to maintain their established way of doing business. In the present case of renewable energy in Europe, this would result in lower levels of adoption by state-owned companies compared to private companies. The strength of these influences will depend on how "capture-prone" the political system in a country is. Capture may be easier to achieve in settings when state capacity is weak.

H5: The greater propensity to invest in renewables of public utilities vis-à-vis private utilities is less pronounced in countries with a weak enforcement environment.

In sum, these five hypotheses describe rationales that are potentially relevant for utilities in the renewable energy transition. It should be noted that, in this case, one classical effect of state ownership is less relevant, namely the possibility to *enhance access to capital via implicit state guarantees* (Christiansen, 2013; Tõnurist and Karo, 2016). In the context of low-carbon transitions, Mazzucato and Semieniuk (2018) argue that the private sector lacks patient capital for large-scale investments in innovative technologies; indeed, renewables like solar photovoltaics and wind power are more capital-intensive then many fossil fuel-based technologies (Schmidt et al., 2019). However, in industrialized countries during our study period, access to capital for investments in new renewables typically did not depend on the financial strength of the sponsor (utilities or independent project developers): in most EU countries, for instance, electricity generated by renewables received a fixed remuneration over the lifetime of the plant, e.g., through feed-in tariff or auctioned power purchase agreements. These investments are typically realized in project finance structures (Henderson, 2016; Steffen, 2018)[3]. In many EU countries, long-term debt for the realization of renewable energy projects is partly provided by state investment banks (e.g., the German KfW is active in renewables project finance across Europe (Geddes et al., 2018)) for projects sponsored by state-owned and private utilities alike. Commercial bank debt is provided based on the viability of the individual project, not the project sponsor (Henderson, 2016; Steffen, 2018). In the United States, non-recourse YieldCo structures are common (Urdanick, 2014). In sum, project-financed renewable energy investments are a special case concerning access to the capital market. We recognize that, in other industries, state ownership might still play a role in improving access to capital. We thus take up the topic in the discussion section.

[3] "In project finance, the sponsor creates a self-contained legal entity (or special purpose vehicle, SPV) to hold the renewable energy asset, which then is financed by debt and equity on the level of the SPV. For repayment, equity investors and debt providers depend solely on the future cash flows of the project, and cannot recourse on other assets of the project sponsor." (Steffen, 2020)

3 Empirical approach

3.1 Research case

Our empirical study considers the development in the EU during 2005–2016, a "typical case" that allows for an in-case analysis of the phenomena described by our hypotheses (Seawright and Gerring, 2008). Analyzing EU countries is a typical case for several reasons. First, since the 2000s, the European electricity industry has been liberalized, with the Electricity Market Directive 03/54/EC requiring free entry into electricity generation in all EU countries (EC, 2003). In the process, many countries privatized some utilities and took further measures to introduce competition into the electricity supply. As a consequence, in many EU countries, the industry is now characterized by the co-existence of state-owned and private utilities, which operate under essentially the same regulatory conditions (Pollitt, 2009).[4] This includes regulation around renewables; so, within a given country and year, whether certain technologies are profitable to invest in should be no different for state-owned versus private utilities. Second, EU countries added a significant amount of power generation capacity during 2005–2016, from both fossil fuel-based and renewable energy plants (see analysis below). Third, the 28 EU countries exhibit some variance in climate policy stringency and the quality of regulation that can be exploited. At the same time, however, all countries had a clear policy goal of increasing the share of RE during the study period: since 2005, the EU was bound by the Kyoto protocol, which required significant CO_2 emission reductions (UNFCCC, 1997). To ensure that all countries contribute to reaching the EU commitments, binding targets for increasing the share of renewable energy in final energy consumption were fixed at a country level (EC, 2009). The levels to be reached thus differed depending on each country's starting

[4] Unlike in the United States, there are only very few cooperative-owned utilities in the EU. While cooperative models exist among new-entrant independent power producers for renewable energy, the incumbent electric utilities we analyze in this paper are, with few exceptions, either state-owned or privately-owned (the latter are typically listed stock companies).

position; for instance, Malta had to increase the RE share from 0% from 10% during 2005–2020, while Sweden had to achieve an increase from 39.8% to 49% during the same period (see table S1 in the appendix). As a result, all EU countries had to take measures to foster the deployment of renewable energy technologies and thus typically focused on the electricity sector (where increasing the share of renewables proved easier when compared to transport, buildings, etc.). Hence, the EU is a suitable case for studying the impact of utility ownership structures in countries with a political goal of increasing the share of renewables.

Given the importance of incumbent utilities in terms of creating fundamental change in the electricity industry structure (see introduction), we focus on utilities that were active in electricity generation and/or distribution before 2005 already. Most of these companies are active in both power generation and sales and, in some cases, in the operation of distribution grids as well (in the EU, transmission grids are unbundled from power generation). We are interested in all utilities that expanded their electricity capacity during 2005–2016, including both large (inter-) national and medium-sized regional utilities. In addition, some European countries have many small regional or municipal utilities. Most of these, however, do not own power generation capacity (but purchase electricity on the wholesale market), and are hence not within the scope of our analysis.

3.2 Research methodology

We follow a mixed method research design that primarily relies on a quantitative analysis of investment portfolios from the full set of relevant utilities. In a second step, the quantitative analysis is complemented by qualitative case studies to add further evidence concerning the mechanisms involved.

For the quantitative analysis, we take the utility as the unit of analysis. We consider the share of investments that are allocated to non-hydro RE technologies as the variable of interest, since choosing the technologies to meet electricity demand is a prime responsibility of utilities (overall capacity additions, in contrast, are, to a greater extent, driven by factors that are external to utilities, such as electricity demand growth, age of the incumbent plant fleet, etc.). As power plant investments are lumpy (decisions are not being made every year), we consider the share of non-hydro RE in total power plant investments leading to capacities added during the multi-year period 2005–2016 (the starting point being defined by the Kyoto protocol, the end point by data availability). While the analysis primarily exploits the cross-section variance (including between state-owned and private utilities within the same country), we also study temporal patterns by dividing the time range into several sub-periods. Variation in the explanatory variables at the country level are used to assess the hypotheses derived in Section 2.

As the quantitative results are consistent with the hypotheses related to using state control to advance climate policy targets, we complement the large n-analysis by a qualitative analyses of influential observations (Seawright and Gerring, 2008). These case studies add evidence that cannot be obtained from the large n-analysis of observational data alone.

3.3 Quantitative data

Our analysis is based on the S&P 2017 World Electric Power Plants Data Base (also known as the "Platts database"), a comprehensive inventory of power generation units globally (S&P Global Market Intelligence, 2017). The database contains technical parameters as well as location, commission date, and ownership information at the unit level. We filter the entries, aggregate the data at the level of utilities, and add further utility-level information in several steps.

First, we limit the analysis to operational power plant units owned by a utility[5] located in the EU-28 countries and that have a commissioning date between 2005–2016. Based on Platts' information on unit type (e.g., gas turbine, steam turbine) and fuel type (e.g., natural gas, biogas), we classify all units into power plant types, which are then marked as renewables, non-hydro renewables, or non-renewables. We exclude combined heat and power plants as well as waste-to-energy plants, as these technologies are typically not built for the purpose of generating electricity alone. Pumped-hydro storage plants are also excluded. Table 1 shows capacity additions during the study period by country, which vary between 83 MW in Croatia and 16'501 MW in Italy. About two thirds of the countries added both conventional power plants and non-hydro renewables. In the subsequent analysis, we focus on the share

[5] The Platts database distinguishes between three types of owners/operating companies, namely utilities (companies engaging in electricity generation and the distribution of electricity for sale generally in a regulated market); auto-producers (industrial or commercial enterprises generating their own electricity), and independent power plant/merchant plant developers (private companies that have built new power plants but excluding those that have taken over distribution and/or retail functions previously under the control of state-owned entities, with or without associated power plants). Here, we focus on utilities, which includes companies of various ownership structures, e.g., investor-owned utilities, municipal and provincial utilities, national state-owned utilities, and cooperative utilities). See S&P Global Market Intelligence (2017) for details.

of non-hydro renewables (i.e., primarily wind and solar, but not hydro), because the possibility to add hydro power capacity depends largely whether any unexploited hydro capacity remains in a utility's area.

Second, we aggregate capacity additions during different time periods (compare Section 3.4) at the level of utilities, taking the utility name and country as identifiers. To ensure that only incumbents are included, we check whether the utilities own any power plant that was commissioned before 2005. If not, observations were only kept if hand-collected archives showed that they had other electricity sector activity before 2005 (e.g., distribution and sales) and were otherwise deleted. We also dropped utilities that added capacity during 2005–2016 of less than 1 MW (to prevent bias, since the coverage of very small plants in Platts is not comprehensive or representative). In sum, we retained 202 incumbent utilities for our analysis period (compare Table 2).

Third, we calculate the *share of capacity additions* using non-hydro renewable energy technologies for each utility company and time period. To get an estimate of investments dedicated to each technology, the capital expenditure per MW installed capacity is assumed per plant type, using average European values and taking into account the cost reductions over time for solar PV (see Table S2 in the appendix). The *share of investment* dedicated to non-hydro renewable energy technologies by company is then calculated in the same way as the share of capacities. While we report all results with respect to these investment shares (which relates more closely to the hypotheses), considering capacity shares yields comparable results—hence, the findings are not driven by the capex assumptions (see appendix for descriptives, regression results available on request).

Table 1: Capacity additions during 2005–2016 (including all utilities in our sample)**.**

Country	**Total capacity additions (MW)**	**Share of non-hydro renewable capacity additions**
Austria	2'395	18%
Belgium	1'218	45%
Bulgaria	123	13%
Croatia	86	0%
Cyprus	673	0%
Republic	176	71%
Denmark	820	100%
Estonia	385	22%
Finland	725	2%
France	4'441	14%
Germany	12'099	13%
Greece	2'170	0%
Hungary	829	0%
Ireland	597	3%
Italy	16'501	8%
Latvia	144	0%
Lithuania	479	5%
Luxembourg	202	1%
Malta	149	0%
Netherlands	5'889	12%
Poland	1'768	47%
Portugal	2'660	1%
Romania	951	0%
Slovakia	479	0%
Slovenia	318	0%
Spain	10'518	3%
Sweden	1'424	61%
Kingdom	7'231	28%
Total	**75'450**	**14%**

Fourth, the ownership structure of utilities is assessed with great scrutiny, as it is the key variable for our analysis. The Platts database indicates the "business type" of the utilities, differentiating between investor-owned utilities, national/regional/municipal government-owned utilities, cooperative-owned utilities, and others. However, an inspection of the data showed that this information is not always accurate, such as in cases where utilities were privatized before 2005 (but are still coded as state-owned in Platts). We therefore matched the utility names[6] to the Orbis company database (Moody's/Bureau van Dijk) and extracted the *global ultimate owner* of the utilities, i.e., the highest-level entity when tracing back the ownership structures. Manual research was conducted for all entities,[7] and they were marked "state-owned" if at least 50% of the global ultimate owner during 2005–2016 was a public entity and "private" otherwise. State ownership can thereby include different levels of government (national, federal states or regions, municipalities). Table 2 shows the number of utilities in our sample by country: 14 countries saw both state-owned and private utilities add power generation capacity during 2005–2016, whereas, in 12 countries, there were only state-owned, while, in 2 countries, there were only privately-owned companies with power generation investment during the period.

Finally, we add data for the explanatory variables, which are defined in terms of our hypotheses at the country level. To control for **country characteristics in general** when evaluating H1 and H2, we consider the *GDP per capita* [purchasing power standards EU-28] per country and year (Eurostat, 2019), the *CO_2 emission intensity from electricity generation* [g CO_2/kWh] per country and year (European Environment Agency, 2018), and country-fixed effects in some specifications.

[6] Country, city, sector and business descriptions were used as further information to ensure matching to the right companies.

[7] The ORBIS database provides the type of global ultimate owner, namely "public authority, state, government" or "corporate". However, inspections showed that this was not always accurate, e.g., coding utilities in Germany and Italy that are whole owned by regionals states as corporate. Hence, the classification of all the utilities was verified by manual desk research.

Table 2: Sample of utilities with capacity additions above 1 MW in 2005–2016

Country	**No. of privately-owned utilities**	**No. of state-owned utilities**
Austria	4	23
Belgium	1	3
Bulgaria	-	3
Croatia	-	1
Cyprus	-	1
Czech Republic	1	1
Denmark	-	3
Estonia	-	1
Finland	1	10
France	3	8
Germany	11	38
Greece	-	1
Hungary	3	1
Ireland	-	1
Italy	6	13
Latvia	-	1
Lithuania	-	1
Luxembourg	2	-
Malta	-	1
Netherlands	3	3
Poland	3	3
Portugal	3	3
Romania	-	2
Slovakia	2	1
Slovenia	-	3
Spain	7	-
Sweden	2	17
United Kingdom	5	2
Total	**57**	**145**

For the more specific hypotheses H3–H5, we use two different measures for each variable of interest. Concerning **climate policy stringency**, we consider the *climate and energy policy density* (i.e., the number of enacted policies in the domain), a common measure to compare policy stringency between countries (Albrecht and Arts, 2005; Jahn and Kuitto, 2011; Knill et al., 2010). We use data from the International Energy Agency's Policies Database, which includes energy policies related to renewables, energy efficiency, climate change, and carbon capture and storage (IEA, 2020). As an alternative measure, we use a qualitative rating from the Climate Change Performance Index (CCPI) that has been published by the NGO Germanwatch annually since 2005. The CCPI *climate policy score* is a performance rating by climate and energy policy experts from non-governmental organizations, universities, and think tanks in the different countries being analyzed (Burck et al., 2020).

Concerning the **enforcement of regulation**, we resort to the Worldwide Governance Indicators (WGI), a research dataset summarizing the views on the quality of governance from a large number of enterprise, citizen, and expert survey respondents, curated by World Bank economists (World Bank, 2020). Specifically, we use the indicator for *regulatory quality*, which reflects "perceptions of the ability of government to formulate and implement sound policies and regulations", and the indicator for *control of corruption*, which reflects "perceptions of the extent to which public power is exercised for private gain, including both petty and grand forms of corruption, as well as "capture" of the state by elites and private interests" (World Bank, 2020). Like with all other explanatory variables, the values are averaged across the different years within a period. To simplify a comparison of regression coefficients, we follow the standard approach to scale the non-binary variables by dividing by two standard deviations (compare Gelman, 2008).

3.4 Model specifications

To assess whether the hypotheses hold for our case, we first present descriptive analyses of state-owned vs. private utility investment behavior at the country level. Next, we show regression analyses with the utility as the unit of analysis, taking the share of non-hydro renewables in investments as the dependent variable. The independent variables include a dummy indicating whether the utility is state-owned as well as further explanatory variables at the country level, as described above. We estimate both an ordinary least square (OLS) and a Tobit model (given the censored nature of the dependent variable ranging between 0% and 100% only). For the simplicity of exposition, only the OLS results are shown in the main text, while the Tobit results, which are qualitatively comparable, are available on request.

All regressions are shown for data considering the entire study period of 2005–2016 (see Section 3.2) as well as for data broken up into three sub-periods (2005–2008, 2009–2012, and 2013–2016) to assess how effects might change over time. We split the time into three periods, because differentiating only two periods allows for fewer insights into temporal patterns, and differentiating four periods would reduce the data points significantly (due to the lumpiness of power plant investments).

3.5 Case study analysis

The qualitative analysis aims to complement the quantitative analysis with further evidence, particularly concerning the mechanisms behind the effect of general climate policy priorities observed in the regressions, as reported below. To this end, we follow a sequential explanatory mixed-method research design, taking influential observations as case studies (Seawright and Gerring, 2008). As the quantitative analyses underline that the effect of state ownership has been driven by an increasing renewables share among state-owned utilities from 2009 on (see results section), we consider the ten utilities with the highest increases in their non-hydro renewables investment shares between the 2005–2008 and 2009–2012 periods. We focus on these utilities that pivoted towards renewables, because changes in strategy are typically explained to investors and the public, allowing us to analyze the underlying motivations for the investment decisions. For the ten case study utilities, we searched public archival information for discussions of their (renewables) investment strategies, using the research tool *Factiva*, which includes business-relevant sources, such as press statements and interviews with utility CEOs, annual reports, and reports from financial statement press conferences. The search terms include the name of the utility (including the names of major subsidiaries, where applicable) AND the terms strategy OR energy transition OR renewable OR regenerative OR wind OR photovoltaics OR solar OR biomass—both in English and the respective local languages. The resulting texts were scanned for whether they describe power generation investment plans/strategies or specific investment decisions of the respective utility—for those that do, the reasons given to choose conventional or renewable energy technologies are summarized. Then, each entry is classified according to whether (i) the decision tends to increase the share of renewables, tends to decrease the share of renewables, or is ambiguous concerning the share of renewables and (ii) with respect to the type of motivation provided for the decision (primarily a commercial/profitability-related argument, primarily a public policy priority-related argument, or another argument). Summaries of all entries and classifications are provided in Table 8 in the results section.

4 Quantitative results

4.1 Overall impact of state-ownership on renewable energy investment

To assess the two most general—and competing—hypotheses H1 (state-owned utilities invest *less* in renewables) and H2 (state-owned utilities invest *more* in renewables), we first show the share of investments dedicated to non-hydro renewables by utility ownership in the different countries (Figure 1). In total for the EU, state-owned utilities clearly dedicated a higher share of investment in non-hydro renewables (33%) when compared to private players (11%). In our data, 14 countries featured power generation investment from both state-owned and private utilities. In 11 of these, the non-hydro renewables share of the state-owned utilities is higher at a country level, including countries with large total investments like France, Germany, Netherlands, Poland, Portugal, and the United Kingdom. The only exceptions are Hungary and Slovakia, in which both state-owned and private utilities have non-hydro renewables shares of close to zero, and Italy, where private companies have a much higher share in renewables. In sum, these descriptive results suggest that H2 (state-owned utilities invest *more* in renewables) is an appropriate description of the pattern in our data, as will be further evaluated via the regression analysis below.

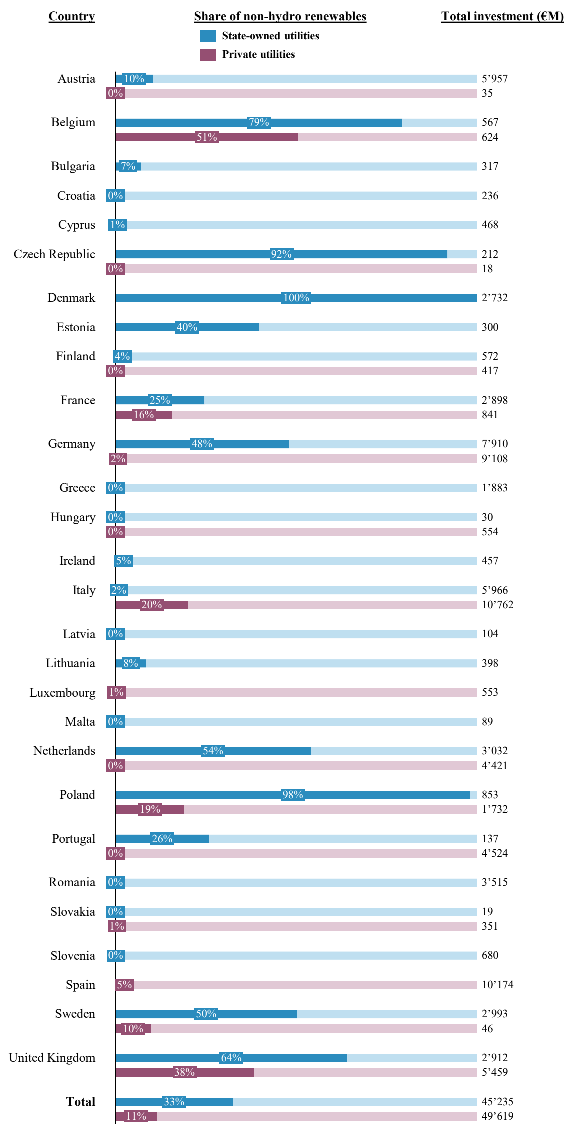

Figure 1: Investment by technology type and utility ownership at the country level

To analyze how the differences between state-owned and private companies develop over time, Figure 2 shows the non-hydro renewables shares for different time periods for the EU-28 and those 14 countries with investments in both types of utilities. For the EU overall, the figure illustrates that the higher renewables share of state-owned utilities is driven by the higher propensity pursue these new technologies in later years: While during 2005–2008, the share was relatively similar for private and state-owned utilities at 17% and 19%, respectively, it significantly increased after 2009 for state-owned companies (to 41% in 2013–2016) while decreasing for private companies (to 9% in 2013–2016). This same pattern is also visible in some countries, like Austria, Germany, and Portugal. In others, however, the pattern is less clear, with the renewables share sometimes also increasing and decreasing for state-owned utilities (e.g., in Finland) or private ones (e.g., in Sweden). When interpreting this chart, one should note that some smaller countries only saw a few large investments during the sub-periods.

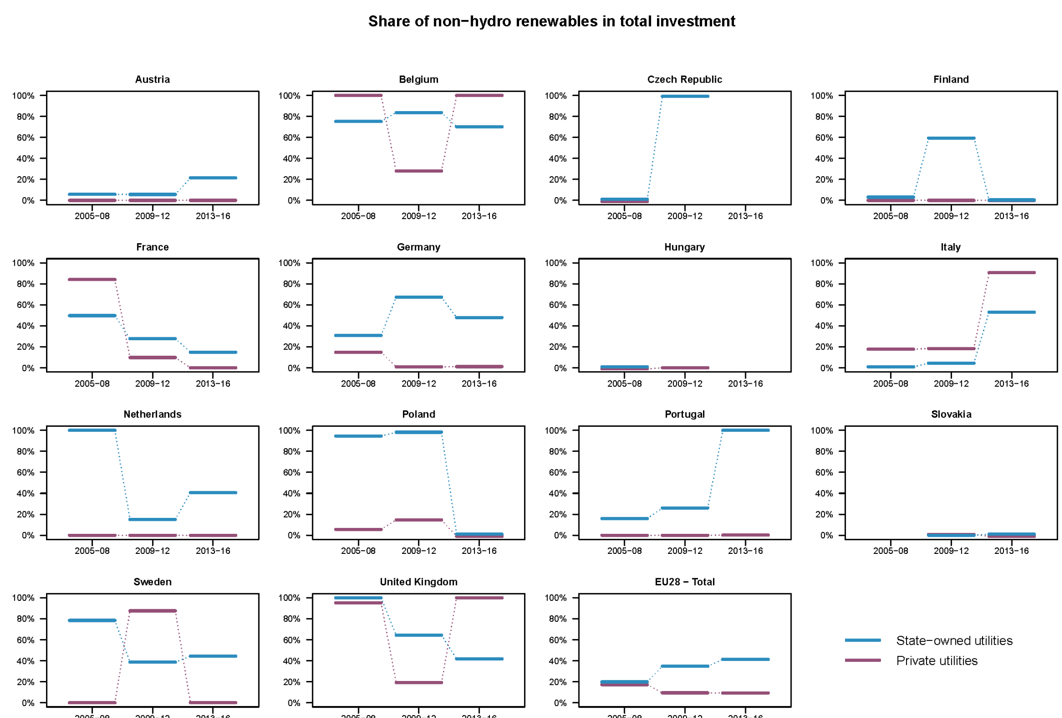

Figure 2: Investment shares over time

To gain further insight, we switch to the utility as the unit of analysis. To test hypotheses H1 and H2, the first set of regressions in Table 3 includes an indicator as to whether the utilities are state-owned, in addition to general country characteristics in columns 1–4 and country-fixed effects in columns 5–8. Column 1 shows that, over the entire period, state ownership has a statistically significant positive effect on investments in non-hydro renewables, even when controls are included (the CO_2 intensity of the power mix as a proxy for the "urgency to act" shows no effect, and the GDP per capita as a proxy for country wealth level and investment ability shows a positive effect). When country-fixed effects are considered instead of country-level controls, the effect of state ownership remains significant at the 10% level (column 5 for the entire period). Country-fixed effects explain much of the differences in the share of non-hydro renewables (compared the high R-squared in columns 5–8); however, even in this specification, there is a positive effect of state ownership, which is driven by the differences between state-owned and private utilities in the same country. Indeed, the indicator for state ownership has a positive coefficient in all the regression specifications we will discuss below (although, in a few cases it is not statistically significant).[8] Hence, based on our data, hypothesis H1 can be rejected, and there is evidence supporting H2. State-owned utilities show a higher propensity to invest in non-hydro renewables.

Concerning the pattern over time, columns 2–4 and 6–8 analyze the different time periods for the specifications with country-level controls and country-fixed effects, respectively. In these shorter time periods, there are fewer utilities that undertook power plant investments, reducing the number of observations. Nevertheless, the results suggest that the positive effect of state ownership is primarily driven by investments in the second and third periods (the

[8] Some specifications include an interaction term between the state ownership indicator and a country-level variable; in these cases, there are positive coefficients for these interaction terms. See discussion below.

latter of which is only significant with country-fixed effects), an observation in line with the pattern observed in Figure 2.

Table 3: Regression results regarding overall impact of state ownership on renewable energy investment

	Dependent variable: Share of non-hydro renewables in investments							
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
	2005-2016	2005-2008	2009-2012	2013-2016	2005-2016	2005-2008	2009-2012	2013-2016
State-owned utility	0.142**	0.0625	0.163*	0.166	0.149*	0.0726	0.178*	0.220*
	(0.0706)	(0.0884)	(0.0890)	(0.113)	(0.0779)	(0.101)	(0.0969)	(0.122)
CO_2 intensity	0.000192	0.000363*	0.000265	0.000384				
	(0.000163)	(0.000213)	(0.000203)	(0.000240)				
GDP per capita	1.30e-05***	2.23e-05***	1.68e-05**	2.84e-06				
	(4.77e-06)	(6.87e-06)	(7.86e-06)	(6.86e-06)				
Constant	-0.159	-0.420*	-0.233	0.125	0.0788	0.117	0.0586	0.0880
	(0.175)	(0.251)	(0.258)	(0.268)	(0.105)	(0.135)	(0.147)	(0.169)
Country-fixed effects	No	No	No	No	Yes	Yes	Yes	Yes
Observations	202	125	138	98	202	125	138	98
R-squared	0.054	0.082	0.064	0.042	0.262	0.300	0.318	0.322

Standard errors in parentheses. *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$

4.2 Interaction of state ownership and climate policy stringency

To further assess the interaction of state ownership and climate policy, our third hypothesis relates the higher propensity to invest in renewables of state-owned utilities to the stringency of climate policy in their countries. To test H3, Table 4 and 5 show regressions that include two measures for policy stringency, namely climate policy density (columns 1–4 of each table) and the CCPI climate policy score (columns 5–8 of each table). For both measures, Table 4 shows a strong effect of stringent climate policy on the share of utility investments in renewables, as would be expected if climate policies are effective (note that, in the EU, climate policies generally affect state-owned and private utilities alike). Nevertheless, the regressions still show a significantly higher renewables investment share for state-owned utilities for the entire time period (columns 1 and 5) as well as for the second sub-period (columns 3 and 7). Thus, the effect of state ownership remains in place when controlling for climate policy stringency at the country level.

In Table 5, we introduce interaction terms between state ownership and the climate policy measures. In these specifications, the coefficient for the state ownership dummy alone is no longer significant, as much of the effect moves to the interaction term. While the significance levels are generally lower, the analysis of the sub-periods shows an interesting time pattern (compare columns 2–4 and 6–8): In the first period (2005–2008), there is a clear effect of climate policy on renewables investment, independently from utility ownership (compare the coefficients for policy stringency measures without interaction). In later years, however, the coefficients of the interaction terms become significantly positive, meaning that, from 2009 on, especially state-owned utilities in countries with stringent climate policies dedicate a high share of their investments to renewables. This pattern is in line with H3 (claiming that the higher propensity to invest in renewables of state-owned utilities is more pronounced in countries with more stringent climate policies). Nevertheless, the evidence for H3 is not very strong given the low significance level in the regressions shown in Table 5, so we will revisit the impact of climate policy priorities in the qualitiative analysis.

Table 4: Regression results regarding impact of state ownership and climate policy targets (part 1)

	Dependent variable: Share of non-hydro renewables in investments							
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
	2005-2016	2005-2008	2009-2012	2013-2016	2005-2016	2005-2008	2009-2012	2013-2016
State-owned utility	0.140**	0.0387	0.197**	0.149	0.116*	0.0344	0.176**	0.115
	(0.0695)	(0.0865)	(0.0874)	(0.111)	(0.0668)	(0.0859)	(0.0847)	(0.108)
Climate policy density	0.198***	0.276***	0.200**	0.141				
	(0.0623)	(0.0829)	(0.0804)	(0.0965)				
CCPI clim. policy score					0.322***	0.294***	0.305***	0.301***
					(0.0608)	(0.0824)	(0.0786)	(0.0978)
Constant	0.103	0.110	0.124	0.204	-0.285**	-0.294	-0.133	-0.108
	(0.0821)	(0.100)	(0.104)	(0.136)	(0.121)	(0.192)	(0.133)	(0.174)
Country-fixed effects	No	No	No	No	No	No	No	No
Observations	202	125	138	98	202	125	138	98
R-squared	0.066	0.084	0.073	0.037	0.140	0.096	0.128	0.105

Standard errors in parentheses. *** p < 0.01, ** p < 0.05, * p < 0.1

Table 5: Regression results regarding impact of state ownership and climate policy targets (part 2)

	Dependent variable: Share of non-hydro renewables in investments							
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
	2005-2016	2005-2008	2009-2012	2013-2016	2005-2016	2005-2008	2009-2012	2013-2016
State-owned utility	0.0589	0.123	-0.00418	-0.282	-0.120	-0.0322	-0.395	-0.331
	(0.155)	(0.184)	(0.189)	(0.254)	(0.245)	(0.384)	(0.257)	(0.348)
Climate policy density	0.129	0.352**	0.0281	-0.203				
	(0.133)	(0.170)	(0.164)	(0.206)				
State-owned utility × Climate policy density	0.0888	-0.100	0.226	0.437*				
	(0.151)	(0.195)	(0.188)	(0.232)				
CCPI clim. policy score					0.230**	0.274*	0.0293	0.0924
					(0.110)	(0.139)	(0.141)	(0.183)
State-owned utility × CCPI clim. policy score					0.132	0.0309	0.395**	0.291
					(0.132)	(0.173)	(0.168)	(0.216)
Constant	0.166	0.0460	0.280*	0.549**	-0.122	-0.250	0.263	0.206
	(0.136)	(0.160)	(0.166)	(0.227)	(0.203)	(0.310)	(0.214)	(0.291)
Country-fixed effects	No	No	No	No	No	No	No	No
Observations	202	125	138	98	202	125	138	98
R-squared	0.067	0.086	0.083	0.072	0.144	0.096	0.163	0.122

Standard errors in parentheses. *** p < 0.01, ** p < 0.05, * p < 0.1

4.3 Interaction of state ownership and regulatory quality

Our last two competing hypotheses H4 and H5 concern the moderating effect of the enforcement environment on state-owned utilities' higher tendency to invest in renewables. To study this effect, Table 6 and 7 show regressions including two different variables describing the regulatory environment (see Section 3.2): "regulatory quality", measuring the extent to which governments are able to implement regulations (higher values indicating better governance performance), and "corruption control", measuring the exercise of public power for private gain or the capture of the state by private interest (higher values again indicating better governance performance). Table 6 shows that both these measures have a strong positive effect on renewable energy investment. The coefficient for state ownership stays positive, although it is only significant in the second period (where the effect of state ownership is largest, as previously shown). Table 7 includes interaction effects between state ownership and regulatory quality, showing that state ownership has a positive effect on renewables investment in countries where regulatory quality is high and where corruption is being well-controlled. The corresponding coefficients are significant for the second and third periods (where state-owned and private utilities differ), compare columns 3–4 and 7–8. Hence, H4 can be rejected: it is not the case that weak enforcement environments amplify the positive effect of state ownership on renewables investment. In contrast, there is some evidence for the competing H5, suggesting that only when the quality of regulation is high and corruption is low does the state ownership of utilities lead to more renewable energy investment.

Table 6: Regression results regarding impact of state ownership and regulatory quality (part 1)

	Dependent variable: Share of non-hydro renewables in investments							
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
	2005-2016	2005-2008	2009-2012	2013-2016	2005-2016	2005-2008	2009-2012	2013-2016
State-owned utility	0.110	0.0234	0.147*	0.131	0.102	0.00473	0.145*	0.128
	(0.0691)	(0.0876)	(0.0865)	(0.112)	(0.0693)	(0.0882)	(0.0863)	(0.112)
Regulatory quality	0.606***	0.646***	0.651***	0.271				
	(0.159)	(0.228)	(0.194)	(0.217)				
Corruption control					0.463***	0.441***	0.493***	0.234
					(0.120)	(0.159)	(0.143)	(0.199)
Constant	-0.104	-0.0774	-0.0939	0.159	0.0244	0.0915	0.0403	0.202
	(0.118)	(0.165)	(0.139)	(0.178)	(0.0891)	(0.116)	(0.105)	(0.156)
Country-fixed effects	No	No	No	No	No	No	No	No
Observations	202	125	138	98	202	125	138	98
R-squared	0.085	0.063	0.106	0.032	0.087	0.060	0.109	0.030

Standard errors in parentheses. *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$

Table 7: Regression results regarding impact of state ownership and climate policy targets (part 2)

	Dependent variable: Share of non-hydro renewables in investments							
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
	2005-2016	2005-2008	2009-2012	2013-2016	2005-2016	2005-2008	2009-2012	2013-2016
State-owned utility	-0.151	0.0123	-0.442	-0.434	-0.0919	-0.0890	-0.301	-0.424
	(0.246)	(0.357)	(0.301)	(0.353)	(0.175)	(0.235)	(0.202)	(0.301)
Regulatory quality	0.313	0.633	-0.0828	-0.318				
	(0.310)	(0.458)	(0.408)	(0.410)				
State-owned utility × Regulatory quality	0.399	0.0169	0.942**	0.810*				
	(0.361)	(0.529)	(0.462)	(0.481)				
Corruption control					0.215	0.320	-0.120	-0.416
					(0.238)	(0.323)	(0.289)	(0.384)
State-owned utility × Corruption control					0.333	0.161	0.802**	0.880*
					(0.276)	(0.372)	(0.330)	(0.446)
Constant	0.0837	-0.0691	0.356	0.565*	0.164	0.160	0.370**	0.602**
	(0.207)	(0.306)	(0.260)	(0.299)	(0.146)	(0.198)	(0.171)	(0.255)
Country-fixed effects	No	No	No	No	No	No	No	No
Observations	202	125	138	98	202	125	138	98
R-squared	0.090	0.063	0.132	0.060	0.093	0.062	0.147	0.068

Standard errors in parentheses. *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$

5 Qualitative results

While the regressions show that state-owned utilities show a higher tendency to invest in renewables (H2) and even more so in countries with stringent climate policies (H3), the quantitative analysis alone cannot tell whether the mechanisms leading to this pattern are in line with the theoretical considerations that lead to the hypotheses. We thus draw further evidence from a case study analysis of the ten utilities that between 2005–2008 and 2009–2012 increased their non-hydro renewables investment share the most. Table 8 shows the analysis of the investment strategies/decisions as well as the motivations behind them. While the public explanation of managers should not be taken entirely at face value (e.g., they might tactically refer to environmental considerations if politically opportune), the variety of arguments allow for insights into investment motives across utilities and over time.

All ten utilities that undertook major shifts to renewables investment in Table 8 are state-owned (which is in line with the quantitative result that primarily state-owned utilities pivoted to renewables) and represent six different countries: Germany, Sweden, Czech Republic, Austria, Portugal, and Estonia. The case studies thus span countries with varying electricity mixes and thus varying need for action to comply with energy transition targets (compare Table A.1). We found arguments describing the choice of power generation investment during the study period for all companies. For two of the utilities (Skelleftea Kraft and Rheinenergie), the arguments are primarily commercial-/ profitability-related, but, for the other eight companies, there is evidence that the policy priorities of state owners also played a role. Such policy priorities mostly relate to climate policy targets (for Enervie, Mainova, CEZ, EnBW, Energie AG Oberösterreich, EDA, Stadtwerke München, Eesti Energia), but, in some cases, they also include other policy priorities, such as reducing local pollution (for Eesti Energie) and gaining/keeping independency from fuel imports (for CEZ). Typically, these utilities also mention commercial-/profitability-related investment motives, so the political motives do not replace economic considerations. However, given the economic viability of renewables investments, here, governments seem to exert influence on state-owned utilities in line with climate policy targets, as per hypotheses H2 and H3.

The case studies also provide some insights into the mechanisms employed by governments to exploit utility state control for climate policy targets. There are examples of direct fiat, with government and parliament decisions made to mandate utilities to develop ambitious renewable energy investment strategies (Mainova, EnBW, EDA), forbid investments in coal-fired power plants (EnBW, Stadtwerke München), or mandate meeting a certain share of electricity demand by renewables only (Stadtwerke München). Using a different mechanism, the utility EnBW is also an example for governments choosing managers (supervisory board members and, subsequently, the CEO) whose worldviews are aligned with governmental climate policy priorities. The same utility also receives a capital increase that shall enhance its capacity to invest in power generation, including renewables. All these mechanisms are in line with the theoretical considerations as to how state control could affect renewable energy investment. A final observation concerns to the level of government that influences the utilities: especially the German utilities respond not only to European or national policy targets but also to specific objectives at the level of their federal state (e.g., North-Rhine Westphalia, Baden-Württemberg) or large municipality (e.g., Frankfurt, Munich). This fact illustrates that exploiting state ownership can also serve as a policy instrument for subnational governments, who cannot resort to the many other policy instruments reserved for the national government. In sum, the qualitative evidence supports the notion that state ownership can result in higher renewable energy investment if it is a policy priority of the government owner.

Table 8: Stated motivations for investments in power generation technologies by case study utilities

(Commercial) Primarily commercial/profitability-related arguments (Public policy) Primarily public policy priority-related arguments (Other) Other arguments

Utility name (Country)	Ownership (RE share)	Investment strategies/decisions and stated motivation for technology choice	Effect on RE share	Type of argument
ENERVIE Südwestfalen Energie (Germany)	State-owned (0% ↗ 100%)	– Utility defines company target to increase share of wind power until 2020 and plans to build pumped-hydro plant as a complement, stating that it thereby aims to make a notable contribution to the energy transition in North-Rhine Westphalia (the federal state where the utility operates) (press reports 2010 and 2011)	Pro RE	Public policy
		– Utility stops all planned investments in gas CCGT plants, arguing that gas plants are no longer profitable with low wholesale prices for conventional electricity (would be willing to invest again in conventional plants if market situation improved) (annual report 2011, financial statement press conference, 2012)	Pro RE	Commercial
		– Utility will focus future power generation investments on wind power and potentially pumped-storage, (also) to fully align with the politically pushed energy transition (annual report 2011, financial statement press conference, 2012)	Pro RE	Public policy
		– Utility stops all investments in solar PV plants, because operating new plants is considered to be no longer profitable after changes in renewable energy law (annual report 2012)	Contra RE	Commercial
Mainova AG (Germany)	State-owned (0% ↗ 100%)	– Utility announces to invest €500M in power generation, in both high-efficiency gas-powered plants and renewables, as part of new company strategy to increase the share of self-produced electricity from 40% to 100% (financial statement press conference, 2009, strategy presentation 2010)	Ambiguous	Other
		– Climate strategy of the city of Frankfurt (main shareholder of utility) foresees an important role for renewables; accordingly, utility underlines to channel half of €500M investment budget to wind power (press report 2010)	Pro RE	Public policy
		– Utility puts into question investment in gas-powered plant as nuclear lifetime extension reduces their profitability but keeps plans for new wind power and biomass plants (which remain profitable due to feed-in tariff) in place. Also plans investment in offshore wind power (press reports, 2011)	Pro RE	Commercial
		– Utility conducts strategy review after huge losses from conventional power generation, announces to primarily focus investments on wind power in the future, increases planned amount for onshore wind from €250M to €355M (financial statement press conference, 2012, press reports, 2012)	Pro RE	Commercial
		– Utility decreases planned investment in bioenergy from €100M to €15M because study showed limited bioenergy feedstock potential in home region (financial statement press conference, 2012)	Contra RE	Other
Skellefteakraft AB (Sweden)	State-owned (0% ↗ 100%)	– After previously primarily relying on hydropower and nuclear, utility announces big program to invest USD464M in wind power, arguing that wind power fits well with environmental profile of the utility and became a profitable investment given green certificate system (press report, 2006)	Pro RE	Commercial, Other
CEZ AS (Czech Republic)	State-owned (0% ↗ 96%)	– In the mid-term, a new generation of coal-fired plants is foreseen by utility, in line with the Czech Republic's energy strategy priority to be independent from external sources and use domestic energy sources like lignite and uranium (press reports, 2006)	Contra RE	Public policy
		– Utility is hesitant to commit investment in coal power generation plants after EU energy strategy aims at reducing emissions and fixes legally binding renewable energy targets for the Czech Republic (press report 2007)	Pro RE	Public policy
		– Utility steps up investment in wind power because of economic profitability with high remuneration (press reports, 2007 and 2008)	Pro RE	Commercial
		– Utility changes strategy to stop investments in coal-fired power plants or renewables in the Czech Republic for economic reasons, keeping investment in renewables abroad where governments are supportive (strategy presentation, 2011)	Ambiguous	Commercial

EnBW Energie Baden-Württemberg (Germany)	State-owned (0% ↗ 82%)	– Utility invests in geothermal power plant to demonstrate technology feasibility and build-up competencies (press reports 2005–2008)	Pro RE
		– Utility invests heavily in efficient coal-fired power plants and renewables like offshore wind to replace nuclear capacity and as a commercial growth area (press reports, 2008)	Ambiguous
		– Utility reconsiders investment in new coal plants, as increasing carbon prices could make them unviable (press report, 2009)	Pro RE
		– Utility announces strategy review concerning renewables after large ownership share went from French government to German federal state Baden-Württemberg (2010)	Pro RE
		– Following elections, the new state parliament and government announce the utility should restructure toward renewables. The coalition agreement of the new government regulates that no investments in new coal plants by the utility will be allowed. New supervisory board member from pro-renewables parties (greens, socio-democrats) are appointed (press reports, 2011)	Pro RE
		– Utility receives capital increase from public owners to accelerate investment in renewables (press reports, 2012)	Pro RE
		– Supervisory board does not extent contract of long-time (pro nuclear and pro coal) CEO, as new state government prefers a change. Renewable energy expert appointed as new CEO (press reports, 2012)	Pro RE
Rheinenergie AG (Germany)	State-owned (27%↗100%)	– Utility plans to invest in renewables (bioenergy and solar PV) as element of strategy to make company "future-proof", partly because it is economically viable given support policies and partly to build-up competencies early-on (press report 2005)	Pro RE
		– Utility stops plans for investment in hard coal power plant, because increased construction costs render it economically unviable (press report, 2007)	Pro RE
		– Utility plans to invest in new gas plant and potentially later in offshore wind power, motivated by opportunities created by nuclear phase-out (financial statement press conference, 2011)	Ambiguous
		– Utility reconsiders investment in gas plant as political will to prioritize renewables worsens commercial outlook for gas plants (press report, 2012)	Pro RE
		– Utility announces to only invest in renewables going forward because market has no need for additional conventional capacity, rendering it uneconomical (2015)	Pro RE
Energie AG Oberösterreich (Austria)	State-owned (1% ↗ 72%)	– Utility evaluates how to reinforce investments in renewables because of clear political will to increase renewables, both from the national government, aiming to make the electricity system more green, and the regional government Oberösterreich, aiming to increase local renewables, such as from remaining hydro resources, solar PV, and wind at a few suitable sites (press reports 2010, 2011)	Pro RE
		– Utility reconsiders power generation investment because un-subsidized power plants are considered no longer economically viable. Accordingly, it cancels new hydro power plant and decommissions coal-fired plant (instead of soon re-fitting it as CCGT gas plant, which was planned previously) (press reports, 2013)	Ambiguous
EMP Electricidade Acores (EDA) (Portugal)	State-owned (36%↗100%)	– Utility is reminded by the president of the regional government of the Azores to define a strategy that allows for investment in renewable energy; regional minister underlines that government aims to double renewables generation within three years (press reports 2005 and 2006)	Pro RE
		– Utility plans investment in solar and storage systems, since a new strategic plan by the regional government aims at increasing renewables share on the island from 28% to 75% within 10 years (press report 2008)	Pro RE
Stadtwerke München GmbH (Germany)	State-owned (35% ↗ 90%)	– City council decides that the city-owned utility must not invest in new coal plant considered to replace nuclear and requires utility to develop strategy to increase share of renewables to 20% by 2020 (press reports 2007–2009)	Pro RE
		– City council raises mid-term renewables target for the utility to 100% by 2025; utility invests heavily in renewables to comply with target (press reports 2008–2009)	Pro RE
		– Utility stops investment in domestic renewables project given uncertainty on profitability with pending changes to renewable energy law (press report 2013)	Contra RE
		– Utility re-starts investment in renewables after renewable energy law changes are less unfavorable for profitability as feared (press report2014)	Pro RE
Eesti Energia SA (Estonia)	State-owned (57%↗100%)	– Utility will start investing on a large scale in wind power, in line with its mid-term goal to produce more from renewables (wind, biomass) and less from shale oil-fired plants (its main fuel source) due to tightening environmental requirements and Estonia's need to comply with EU targets (press report, 2007)	Pro RE
		– Utility intends to double biomass generation; the extent to which biomass will be used in new plant shall depend on competitiveness given carbon prices and electricity prices (press report 2012)	Pro RE

6 Discussion and conclusion

Taken together, the quantitative and qualitative results in this paper show a consistent pattern concerning the role of ownership on renewable energy investment among European utilities: state-owned utilities dedicate higher shares of investments to renewables, particularly in countries with stringent climate policies and when the general quality of regulation is high. These findings have implications for research, policy, and practice as it relates to the low carbon energy transition. Further, some findings may be relevant for other industries as well, and the insights from our analysis can enhance understanding of how ownership matters in different institutional settings. These three perspectives—implications for the energy transition, other industries, and the role of institutional settings—are discussed in the following sections.

6.1 State ownership and the renewable energy transition

Our results are important in terms of the understanding and management of the ongoing energy transition. The analyses show that, among the incumbent utilities in Europe, state-owned companies have shown a higher tendency to invest in renewables, with much evidence supporting the hypothesis that this effect is driven by governments exploiting state control to achieve climate policy targets. Hence, from a societal point of view, state ownership can help accelerate the adoption of socially desirable technologies; however, this does not seem to be an effect of state ownership *per se* and requires clear policy targets and dedicated government action to use state ownership toward these objectives. Exploiting state ownership in this sense has not previously been documented in the context of renewable energy support policies, but it should be included in comparative analyses of renewable energy support policy instruments in the future.

In this context, it is important to note that, in the European countries we studied, exploiting state ownership was typically not the only policy instrument used to accelerate the deployment of renewables (Schmidt and Sewerin, 2019). Past research suggests that inducing transitions effectively requires well-balanced policy mixes (Kern et al., 2019; Kern and Howlett, 2009; Rogge and Reichardt, 2016; Schmidt and Sewerin, 2019). This requirement is also apparent in our qualitative analyses, in which the existence of adequate renewable energy support instruments (feed-in tariffs, green certificates) are often cited as a prerequisite for investments in renewables by state-owned utilities as well. Thus, it seems to be the interplay of (i) support policies that make renewables economically viable (for all types of utilities) and (ii) pressure from governments on their utilities to actually use these economic opportunities that results in the high propensity to invest in renewables among state-owned utilities.

From a sustainability transitions perspective, the temporal development of investment activities matters. Here, we studied incumbent utilities, and it seems that, for them, state ownership only made a difference in the second and third periods considered (i.e., from 2009 onward)—periods in which both wind power and solar photovoltaic reached technological maturity, and investment in wind and solar became mainstreamed (Egli et al., 2018). It could be the case that, in the early days of a new technology, when it is still developing in niches, (private) new entrants are important technology adopters (e.g., private project developers opened the local markets for new renewables in a number of countries (Steffen et al., 2018)). However, when the technology shall enter the regime and how fast it scales up by being adopted by large incumbent companies may be influenced by state ownership.

Given that the energy transition has now arguably entered such a second phase (Markard, 2018), there is a growing amount of literature on the role of incumbents in sustainability transitions (Berggren et al., 2015; Berlo et al., 2016; Frei et al., 2018; Smink et al., 2015; Steen and Weaver, 2017; van Mossel et al., 2018). Based on our results, we suggest that this stream of research should also consider ownership structures (Mühlemeier, 2019) in addition to how state-owned versus private incumbents might play different roles in the transition.

From an empirical point of view, we consider the present analysis as a starting point for broader analyses of the dynamics of new technology adoption in the energy industry at large. Besides new renewables, future research should analyze the adoption of other low-carbon technologies as well, such as innovations in the electricity transmission and distribution systems, energy storage technologies, and low-carbon options in the heating sector. Our results suggest that policy may complement ownership in important ways in these cases as well. Importantly, such assets are typically not realized in project finance structures but on the balance sheet of utilities; thus, the potential advantages of state-owned utilities in capital access could add to the effects discussed in this article.

Finally, we would like to emphasize that, in this research, we analyzed the impact of state ownership on renewable energy investment, but not on other outcomes. The question of how ownership structures affect socially desirable technology adoption is separate from the question of how ownership affects commercial performance; hence, the present results do not contradict past research underlining the productivity challenges associated with state ownership in many cases. Thus, potential advantages of state ownership from a technology adoption point of view will need to be weighed against any disadvantages from a productivity point of view. In this sense, our results should not be considered an argument for nationalization. However, we suggest that, in the cases where state ownership anyway exists—such as among electric utilities in Europe—policymakers can strategically exploit this ownership structure for climate policy targets.

6.2 State ownership and technology adoption in other industries

While we focused on the electricity industry in this paper, the potential relationship between ownership and technology adoption can be of interest in many other industries as well. On principle, the effects such as those described in this paper might exist in all industries where both ownership types can and do co-exist. Examples include many network industries, such as gas and water utilities, railways, and telecommunications, as well as industries like health care and higher education. Indeed these industries differ in many aspects, so findings from the electricity industry will not necessarily be transferable. Instead, we believe that additional industry studies—building on the theoretical and methodological contributions of this work—are both relevant in their own right and could facilitate an understanding of the generalizability of some of the insights developed here.

Fueled by the general digitization of many business processes, technological change matters to most industries. The adoption of innovative technologies by companies is often socially desirable, as many new technologies allow for increased productivity. Of particular interest to transition researchers, however, should be the role of ownership structures in industries that require a radical, directed transition toward a new technological regime, such as the transition towards low-carbon technologies. Particularly industries characterized by extensive government regulation and large technical systems prone to a "lock-in" in established regimes are worth studying in this regard. One example worth analyzing is *airlines*. On many travel routes, state-owned and private airlines compete for customers. Clearly, the industry requires a radical transformation to achieve a climate pathway in line with the Paris Agreement, and airlines will have to adopt new technologies to that end (Kim et al., 2019; Schäfer et al., 2019; Wise et al., 2017). As in the case of utilities, the development of new technologies is primarily driven by technology suppliers, but the adoption of these innovations is crucial for large-scale technological change. Analyzing whether and how state ownership can make a difference in that regard could aid decarbonization policymaking in the industry.

A potential impact of airline ownership on new technology adoption recently gained in importance. While state ownership of airlines has been common before, in 2020 many countries significantly increased their ownership shares of and influence on airlines through bailout packages during the COVID-19 crisis, raising the question of how to potentially exploit this position for climate policy targets (Steffen et al., 2020). A related example is the bailout of U.S. automakers following the global financial crisis in 2009, where growing government influence was linked to a tightening of fuel economy standards (Hall, 2011). These cases illustrate that state ownership can not only affect low-carbon innovation in situations where state ownership is a historical legacy, but also in situations of temporal state ownership e.g. caused by bail-outs during economic crises.

6.3 State ownership and institutional context

Beyond the complementarities with climate policy, our findings illustrate that the role of state ownership can hinge on the ability of the state to enforce its agenda at the company level. Regulatory capture is a global phenomenon in which companies seek to influence their interests by exerting influence through the political process (Dal Bó, 2006). However, the balance of influence in the relationship between state-owned enterprises and their government overseers can determine the extent to which state ownership advances prosocial goals via SOEs or SOEs realize their own interests via the government. Comparing the Chinese and European settings is instructive here, in China, the empirical evidence suggests that state control was a substitute for systematic enforcement, resulting in greater regulatory responses by SOEs compared to private firms (Karplus et al., 2017, 2020). In Europe, which has arguably a more arms-length relationship with its SOEs, we find that systematic enforcement complements state ownership, limiting capture and providing a credible signal that policy will be enforced, even if it is not aligned with commercial priorities. Given this contextual importance, we suggest that scholars replicate our study in other contexts. Specifically, comparing technology adoption under different ownership structures in the United States—where both state-owned and private electric utilities also exist (though typically do not compete in the same region and are subject to different regulatory requirements)—could add to the emerging literature on electric utility regulation and the energy transition (Downie, 2017; cf. Stokes, 2020).

6.4 Conclusion

In sum, our analysis has shed new light on the role of ownership in industrial transitions by studying the case of renewable energy adoption in a major regulated industry: electric utilities. Our analysis highlights that ownership is important, but it does not exert its influence in a vacuum, but it interacts with the existence of pro-adoption policy and state enforcement capabilities to determine the extent to which the sector as a whole tilts toward renewable alternatives.

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Appendix

A Background information and input data

Table A1: EU targets for share of energy from renewable sources in gross final consumption of energy by country. Note that these values refer to total final energy consumption (including sectors in which the transition to renewable sources has been more difficult than in the electricity sector, such as transport, heating, etc.). Hence, in order to reach these targets, countries had to increase their share of renewable energy in electricity disproportionately. Source: (EC, 2009)

Country	Actual 2005	Binding target 2020
Belgium	2.2 %	13 %
Bulgaria	9.4 %	16 %
Czech Republic	6.1 %	13 %
Denmark	17.0 %	30 %
Germany	5.8 %	18 %
Estonia	18.0 %	25 %
Ireland	3.1 %	16 %
Greece	6.9 %	18 %
Spain	8.7 %	20 %
France	10.3 %	23 %
Italy	5.2 %	17 %
Cyprus	2.9 %	13 %
Latvia	32.6 %	40 %
Lithuania	15.0 %	23 %
Luxembourg	0.9 %	11 %
Hungary	4.3 %	13 %
Malta	0.0 %	10 %
Netherlands	2.4 %	14 %
Austria	23.3 %	34 %
Poland	7.2 %	15 %
Portugal	20.5 %	31 %
Romania	17.8 %	24 %
Slovenia	16.0 %	25 %
Slovak Republic	6.7 %	14 %
Finland	28.5 %	38 %
Sweden	39.8 %	49 %
United Kingdom	1.3 %	15 %

Table A2: Assumptions for capital expenditure (CAPEX) per installed capacity of different power generation technologies. For simplicity and due to a lack of better data, uniform values across countries and over time are assumed—except for solar PV, which experienced a threefold cost reduction during the study period (wind turbines, in contrast, also saw a large cost reduction per MWh electricity produced but less per MW capacity, as improvements primarily came from increased turbine sizes and capacity factors during the study period). To test whether the results hold irrespective of these simplified CAPEX assumptions, the analysis has been repeated considering capacity shares instead of investment shares (compare Appendix B). Sources: (IRENA, 2012; Konstantin, 2009; Nahmmacher et al., 2014; Schröder et al., 2013; Steffen, 2018; Steffen and Weber, 2013)

Power plant type	**CAPEX assumption** (EUR per kW)
Coal plant	1,500
Gas plant (combined cycle)	800
Gas plant (open cycle)	400
Hydropower plant	2,750
Nuclear plant	4,000
Solar PV plant (2005–2016)	3,500–1,250
Wind turbine plant (onshore)	1,400
Wind turbine plant (offshore)	4,000
Other renewables plant (concentrated solar power, geothermal, marine)	4,000
Other non-renewables plant (heavy fuel oil, other fuels)	600

B Descriptive results concerning capacity additions

Figure S1: Capacity additions by technology type and utility ownership at a country level. All qualitative results described with respect to investment volumes (Figure 1 in the main text) also hold with respect to capacity additions (this figure).

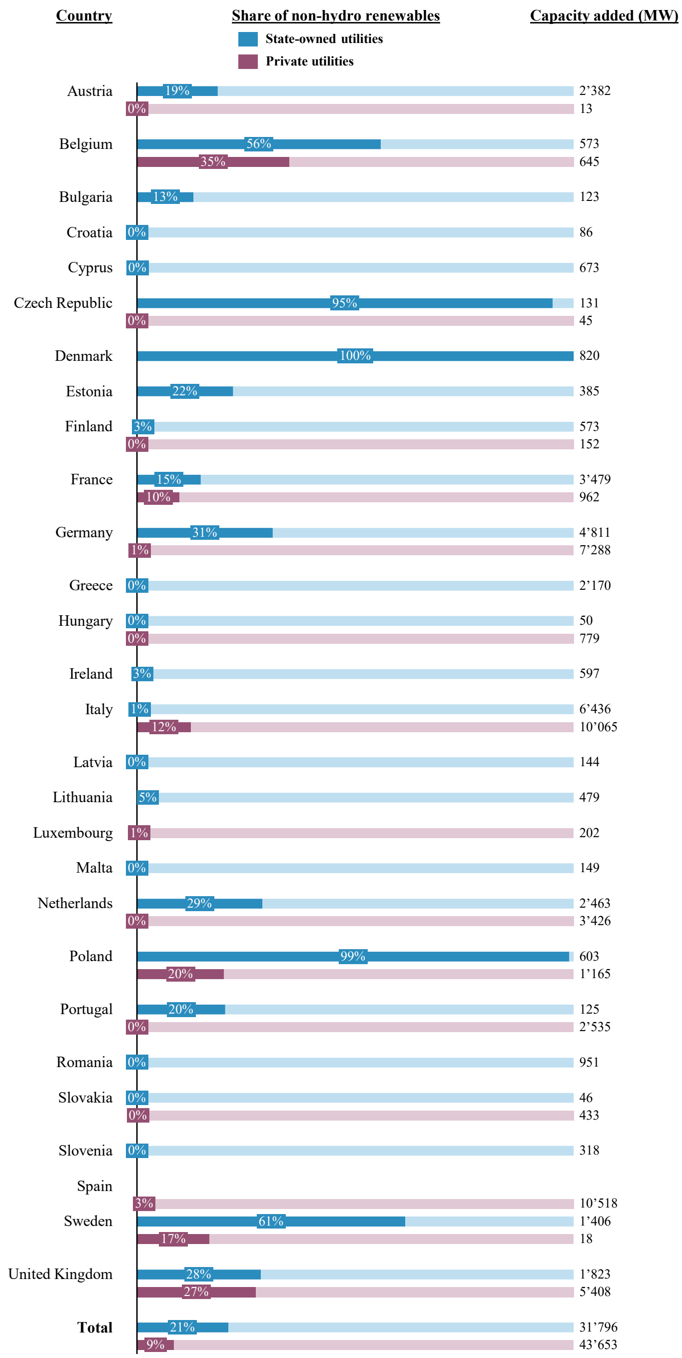
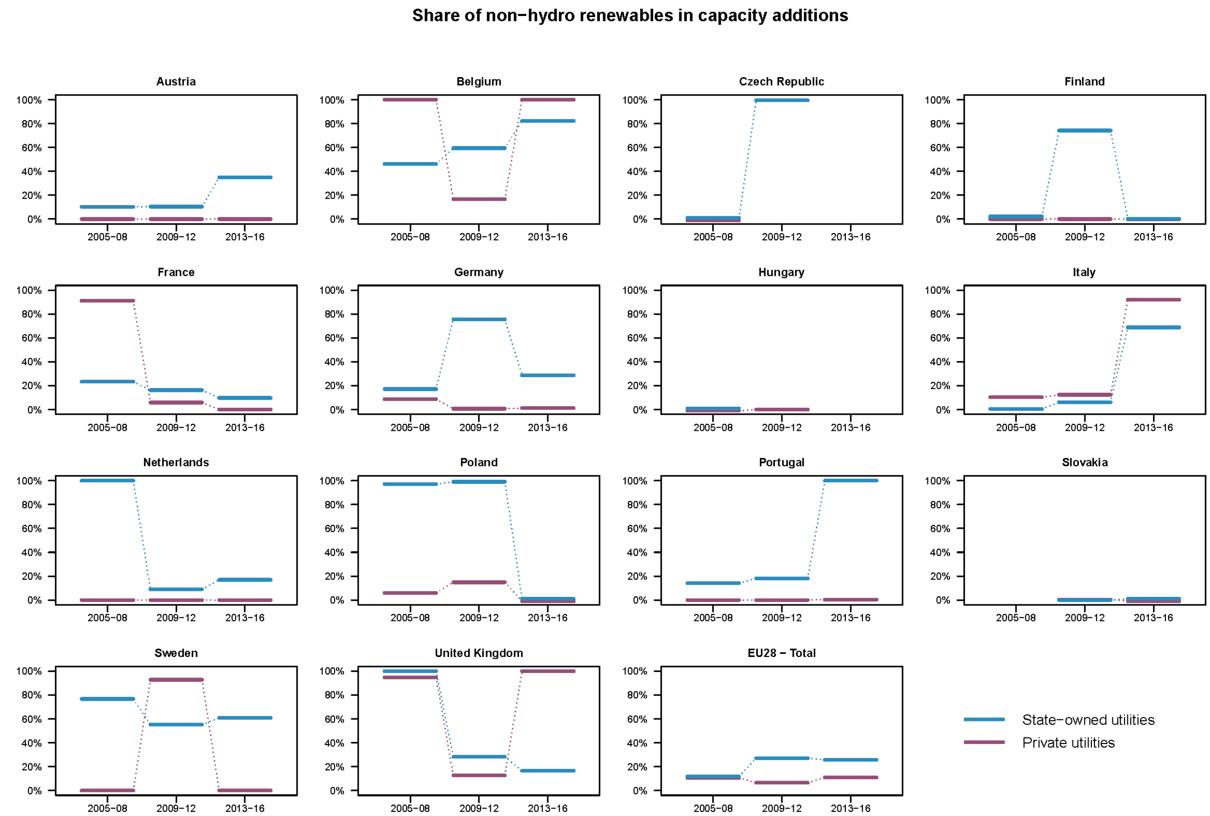


Figure S2: Capacity addition shares over time. All qualitative results described with respect to investment shares (Figure 2 in the main text) also hold with respect to capacity additions (this figure).



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