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State-Owned Enterprises and the Low-Carbon Transition

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**STATE-OWNED ENTERPRISES AND THE LOW-CARBON TRANSITION - ENVIRONMENT
WORKING PAPER No. 129**

by Andrew Prag (IEA), Dirk Röttgers and Ivo Scherrer (OECD)

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ABSTRACT

This paper explores the role of state-owned enterprises (SOEs) in the low-carbon transition in OECD and G20 countries. It tracks GHG emissions and energy investments by SOEs and analyses the impact of SOEs on investments in renewable electricity. A descriptive analysis of SOEs' role in the electricity sector shows the continued importance of SOEs, including prominent investments in both renewables and fossil-fuel-based electricity generation. Using data gathered across OECD and G20 countries, including newly collected SOE ownership data, a regression analysis shows a positive influence of state ownership on renewables investments when controlling for other market structure effects, including market concentration. These results are consistent with the main hypothesis that SOEs have an overall positive effect on renewables investments. This could both be a sign that SOEs gain competitive advantage with respect to capital-intensive renewables investments through preferential treatment (e.g. lower capital costs), as well as that governments use SOEs as vehicles to implement renewable policy goals. These factors seem to outweigh any effect of crowding out private competitors. The analysis shows a negative effect of high market concentration on renewables investments, possibly due to restricted market access for more innovative market newcomers, and the negative interaction between SOE ownership and the amount of renewable capacity tendered for renewable capacity, pointing towards opportunities for improved tender design.

Keywords: climate change, renewable energy, decarbonisation, low-carbon transition, climate finance, public intervention, investment, estimation, regression, state-owned enterprises, SOEs, market power, China

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RÉSUMÉ

Ce document de travail explore le rôle des entreprises publiques dans la transition vers une économie bas-carbone dans les pays de l'OCDE et du G20. Il mesure les émissions de gaz à effet de serre et les investissements énergétiques des entreprises publiques, et analyse l'impact de ces entreprises sur les investissements en énergies renouvelables. Les entreprises publiques restent une pierre angulaire du secteur de l'électricité, et investissent massivement dans la production des énergies renouvelables et fossiles. Une analyse de régression linéaire, effectuée, notamment à partir de nouvelles données collectées sur la propriété des entreprises publiques, dans les pays de l'OCDE et du G20, montre que la participation de l'état a un impact positif sur les investissements en énergies renouvelables, lorsque l'on a déjà pris en compte les autres effets de structure telle que la concentration du marché considéré. Ces résultats sont cohérents avec l'hypothèse principale selon laquelle les entreprises publiques ont un effet positif sur les investissements en énergies renouvelables. Ces résultats peuvent être expliqués par le fait que les

entreprises publiques ont un avantage compétitif dans le domaine des investissements, et plus particulièrement capitalistiques, grâce au traitement préférentiel dont elles bénéficient (à titre exemplaire, les coûts de capitaux plus faibles). Ces résultats peuvent être également expliqués par le fait que les gouvernements utilisent les entreprises publiques pour mettre en œuvre et atteindre leurs objectifs politiques de déploiement des énergies renouvelables. Ces facteurs semblent l'emporter sur les effets d'éviction des concurrents du secteur privé. Cette analyse montre en outre / par ailleurs qu'un haut niveau de concentration du marché a un effet négatif sur les investissements en énergies renouvelables, potentiellement en raison d'un accès limité au marché pour des start-up innovantes d'une part, et d'autre part à cause de l'interaction négative entre la propriété des entreprises et la quantité de génération électrique renouvelable mise aux enchères, soulignant la nécessité d'améliorer les processus de mises aux enchères.

Keywords: changement climatique, énergies renouvelables, décarbonisation, transition à faible teneur en carbone, finance climatique, interventions publiques, investissement, estimation, régression, entreprises publiques, SOEs, puissance du marché, Chine

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EXECUTIVE SUMMARY

To achieve the long-term decarbonisation required by the goals of the Paris Agreement on climate change, the energy sector will need to undergo a deep transformation, including decarbonisation of the electricity sector. State-owned enterprises (SOEs) have an important role to play in the low-carbon transition as they remain prominent actors in global energy markets, despite on-going liberalisation and privatisation in many jurisdictions. This paper explores the role of SOEs in the low-carbon transition by: a) exploring the role and defining characteristics of SOEs active in the energy sector; b) tracking electricity investments by SOEs; and c) empirical analysis of the impact of state-ownership on investment in the sub-sector of renewable electricity generation.

State ownership is prevalent across the energy sector. Governments are still the majority owners of fossil fuel production assets globally, including through SOEs. SOEs remain important in the electricity sector also, including in several OECD countries. SOEs accounted for about 61% of total global electricity capacity installed in 2016 and for around 52% of capacity currently planned or under construction. The reasons for state ownership vary across countries. In developing economies where significant parts of the population do not yet have electricity access, domestic development can be a key driver. Governments may also use SOEs as a means to control strategically-sensitive energy supply chains, and energy SOEs can provide important public revenue. SOEs can also be vehicles to buy into foreign technologies and know-how.

Full decarbonisation of the power sector requires not only increasing zero-carbon electricity sources. It also requires a rapid phasing out of high-emitting generating plants, with unabated coal as a priority, as well as investment in supporting infrastructure for transmission and distribution and energy storage. New analysis in this paper shows that, globally, SOEs are important investors both in coal and renewable electricity generation. While SOEs have increased their market share in capacity additions of new renewables from 9% in 2000 to 23% in 2014, they still account for roughly 56% of the ownership of coal power plants and of 52% of coal power plants planned. Evidence suggests that SOEs are on average continuing to invest in coal power at a higher rate than their private counterparts. At the same time, SOEs are also investing heavily in renewables, having increased their market share of new capacity relative to private firms in recent years. These global trends do however mask heterogeneity among how different SOEs are investing, both across and within countries. Also, pursuing renewables and thermal generation investments are not mutually exclusive strategies, with many firms choosing both in varying proportions.

From an investment perspective, SOEs deserve particular attention due to their characteristics as market participants: notably the potential preferential treatment from governments that they may enjoy and the influence of policy mandates on their operations. While concerns have been raised that preferential treatment can lead to market distortions and can crowd out private investments, relatively little analysis has examined how government mandates could be beneficial to major policy-led industry transformation, such as that required by climate change mitigation. SOEs may benefit from preferential treatment from their government owners such as through preferential financing, regulatory derogation or other less tangible favours. Preferential financing and explicit or implicit state guarantees could translate into lower costs of capital, which in turn could be a competitive advantage for renewables where investments are characterised by high capital costs and relatively low operating costs. In addition, government mandates can mean that SOEs have performance objectives that go beyond maximising financial returns. These public policy objectives are often social in nature but can also be environmental, such as firm-level low-carbon mandates. On the other hand, some SOEs are bound by regulated electricity tariffs for consumers, which may be held artificially low for political reasons, thereby limiting the investment capacity of those firms.

The econometric results of this paper suggest that state ownership itself has a positive effect on investment in the renewable electricity generation sector in OECD and G20 countries, controlling for other factors, including market concentration. This could be due to a number of reasons, including the influence of government mandates on low-carbon strategies or government preferential treatment, or both. Conclusive evidence for preferential treatment is difficult to find. Some indication of how markets perceive SOEs benefitting from their proximity to the government (in the form of guarantees) can be seen in enhanced credit ratings, but further work would be needed to investigate this rigorously.

State ownership is only one factor influencing investment in electricity generation, including renewables. In some markets, liberalisation and privatisation have diminished the direct role of the state as an owner, but the market is still controlled by a small number of powerful incumbent firms. Some advantages accruing to SOEs could also apply to these large privately-owned firms. Further, such incumbents, whether state-owned or not, may face commercial tensions between maintaining the profitability of their thermal power generating assets and investing in new renewables capacity – because renewables reduce the running hours (and therefore profitability) of conventional capacity. This may place incumbents, including SOEs, in opposition to policies supporting renewables in their home markets.

To disentangle ownership from market concentration and market regulation factors, effects of these possibly confounding variables were also tested in the econometric analysis. Results suggest that everything else being equal, high market concentration leads to less investment in renewable electricity in OECD and G20 countries. This shows that increased competition curbs market power and allows for entry of renewable electricity firms. Two variables capturing specific aspects of market regulation were also tested: third party access regulations, capturing the ease of market entry, and the degree of vertical separation, capturing competition dynamics specific to the electricity market. Results for neither variable show conclusive evidence for an effect on investments in renewable electricity generation.

In conclusion, the results of the econometric analysis – in particular the positive effect of state ownership on investment in renewables – point to an opportunity for governments to use their ownership of SOEs to accelerate the low-carbon transition. In countries with high levels of state ownership in the electricity sector, government influence over SOEs could be used as a complementary policy lever on top of sector-wide policies (given that SOEs might be less likely than other firms to respond to economic incentives). This could involve placing decarbonisation as part of the public policy mandates for state-owned enterprises, though such objectives would need to be explicit and transparent, in line with the OECD Guidelines on Corporate Governance of SOEs. In such cases, close coordination between general energy policy and SOE-specific objectives will be needed to maximise efficiency and limit spill-over effects for non-SOEs (for example where SOEs are operating under emissions trading). Moreover, it should be ensured that private players are able to compete on a level-playing field, for example by having access to the same financing conditions from state-owned banks.

Further research would be needed to fully understand the role of energy SOEs in the low-carbon transition, and how state-ownership itself relates to other factors influencing evolution of energy markets. The empirical analysis presented in this study looks only at effects of SOEs on renewable electricity investments. Beyond renewables, the role of SOEs in financing and building conventional power generation units warrants further exploration, as well as SOE investment in modern transmission and distribution infrastructure, important for increasing penetration of renewable electricity. The important role of SOEs in fossil-fuel supply chains could also be further analysed, in particular the political economy aspects of government reliance on those resources, as well as the role of non-energy SOEs on the low-carbon transition – both as heavy energy users (e.g. steel and cement) and as financiers (state-owned banks). Finally, further analysis could focus on the evolving role of incumbent electricity utilities more generally (whether state-owned or not), for example as falling technology costs increasingly open up opportunities for new business models, or show the long-term effect of state-ownership on the electricity market.

1. INTRODUCTION

This working paper explores the role of state-owned enterprises (SOEs) in the low-carbon transition of the energy sector as a whole, and specifically in the electricity sector in G20 and OECD countries. The paper aims to a) understand the role and defining characteristics of SOEs that are active in the energy sector; b) track electricity investments by SOEs; and c) analyse the impact of state ownership on investment in the sub-sector of renewable electricity. As part of the OECD's work on green finance and investment, the paper builds directly on the econometric analysis carried out in Ang et al. (2017).

To achieve the long-term decarbonisation required by the ambitious goals of the Paris Agreement on climate change, the energy sector will need to undergo a deep transformation, including decarbonising electricity, massive improvements in energy efficiency and a move away from direct use of fossil-fuels, for example by electrifying transport and heating. As major players in global energy markets, SOEs exert an important influence on the greenhouse gases (GHGs) responsible for climate change. SOEs own more than half of global coal, gas, and oil production assets (CPI, 2014). In many countries, SOEs are also prevalent in the electricity sector, where investment choices made in the coming years will determine GHG emissions far into the future. Global pathways for a low-carbon future foresee a rapid shift away from coal-fired power generation towards zero-carbon electricity generation technologies that may include nuclear, hydro, and non-hydro renewables, depending on country choices (OECD, 2017a). At the same time, the importance of electricity is likely to increase with increasing rates of electrification in energy end-uses (IEA, 2016a).

This report examines the role of SOEs in light of the continued importance of state-ownership in the energy sectors of OECD and G20 countries. State-owned enterprises deserve special attention not only due to their sustained importance in the electricity sector – despite the trend towards energy market liberalisation and privatisation – but also in light of their notable characteristics as market participants. Compared to privately-owned enterprises, SOEs are often part of complex governance structures involving government ministries, regulators, and the legislature. Moreover, SOEs are often mandated to pursue public policy objectives in addition to or instead of maximising profits. Accordingly, SOEs might be more politically influenced and respond differently to public policy changes than their privately-held competitors (Benoit, 2012).

Due to their relative proximity to governments, energy sector SOEs might benefit from preferential regulatory treatment or preferential financing. This raises questions as to whether SOEs benefit from undue competitive advantages relative to private competitors, and if so, whether there are implications for the competitive neutrality of the markets they are operating in, at home and abroad (OECD, 2016a; Capobianco and Christiansen, 2011). Importantly, these potential distortions are not necessarily restricted to SOEs; governments may offer preferential conditions to certain private enterprises also. This may be particularly the case in the electricity sector, where formerly vertically-integrated firms, even if now privatised and operating in a liberalised market, may still enjoy proximity to the government.

This working paper is structured as follows: Section 2 takes stock of the extent of state-ownership in the energy sector as a whole, specifically tracks state ownership and SOE investments in the electricity sectors of OECD and G20 countries, and explores the ways that state ownership may influence investment decisions. Section 3 presents an empirical analysis of the effect of state-ownership in the electricity sector on investments in renewable energy, while also taking account of general electricity sector regulation and market dynamics. Section 4 draws conclusions and highlights areas for future work.

2. STATE OWNERSHIP IN THE ENERGY SECTOR

2.1 Tracking State Ownership in the Energy Sector

This section first describes the rationale for state ownership of energy companies in G20 and OECD countries, and tracks how it has been evolving since the onset of liberalisation since the late 1980s. It then explores how SOEs have been investing in conventional and renewable electricity generation globally in recent years.

2.1.1 *The Evolving Rationale for State Ownership in the Energy Sector*

Energy-sector SOEs are still important in many countries, including in OECD member countries. Previous OECD work (OECD, 2014) counted 144 SOEs in the electricity and gas sectors across 34 countries (including China, Russia and most OECD members) in 2012, together valued at over USD 500 billion. Measured in terms of company value, electricity and gas accounted for almost a quarter of total SOE value in this set of countries (OECD, 2014). Moreover, of the world's 2000 largest publicly-listed companies (as measured in the Forbes Global 2000 list), 326 are partially state-owned, 30% of which are active in the wider energy market, including electricity and gas, petroleum, as well as metals and mining (OECD, 2016a).

There are many reasons why governments have established and maintained state ownership in the energy sector. The reasons vary across countries depending on prevailing economic policy preferences and stages of development. In some countries, governments have mandated SOEs to deliver electricity or gas to all residents through public service obligations (IEA, 2016b), often delivered through state-owned vertically-integrated monopolies. In developing countries where large numbers of people do not yet have access to electricity or other modern energy services, governments may see SOEs as a key development actor prioritising energy access over other commercial or environmental goals. Moreover, some governments consider SOEs as a means to control strategically sensitive energy supply chains (Wehrle and Pohl, 2016), especially in fossil fuel extraction and production, with SOEs providing important revenue to the government from these high-value resources, in addition to taxes and royalties (Torso, 2011). SOEs can also be vehicles to pursue development strategies of the energy sector, or as tools to buy into foreign technologies and know-how (OECD, 2016a).

Governments and SOEs are still major players in fossil fuel market and were estimated to own roughly 70% of oil and gas production assets, and around 60% of coal mines and coal power plants globally (CPI, 2014).¹ An alternative method for visualising the importance of SOEs and other firms for GHG emissions is to attribute downstream CO₂ and methane emissions to individual incorporated entities. Using this method, IEA (2016c) estimates that 50 selected SOEs in the power, oil and gas, iron and steel, and cement industries together accounted for over 4 GtCO₂eq in 2013, which was more than the national emissions of any country except the US and China. Taking a historical firm-level approach, CDP (2017), building on Heede (2013), identifies 100 oil, natural gas, coal, and cement producers, which have cumulatively accounted for 923 GtCO₂e, or 52% of all CO₂ and methane emissions from industrial activity from 1854 to 2015. Out of these 100 entities, 43 are state-owned (36 SOEs and 7 former or existing national producers).

1 In the definition used by CPI (2014) ownership of fossil fuel production assets comprises the ownership of oil, gas, and coal resources, the ownership of production equipment as well as licences and rights that allow for the exploitation of the mineral resources.

The extent and role of state enterprises in the energy sector has evolved over the past two decades. Many governments – particularly within the OECD – have introduced privatisation, competition and market regulation to previously nationally owned monopolies. This has been most noticeable through structural separation and full- or part-privatisation of previously vertically integrated SOEs in the electricity sector. The role of electricity utilities changed considerably in countries that underwent such electricity market reform since the late 1980s, first in the UK, Chile, and parts of the US, later also in other European countries and to lesser degrees in non-OECD countries including China and Russia (see for example Joskow, 2008; IEA, 2016b). In vertically integrated electricity markets, state-owned utilities constituted geographically confined monopolies and were tasked with planning and operating the entire electricity supply-chain. Under liberalisation, utilities have been broken up to allow for competition in generation, trading, and supply while transmission and distribution grids tend to remain monopolies under the oversight of government ministries or independent regulators. The liberalisation of electricity generation has also facilitated the international integration of national electricity markets; in the EU for example, cross-border electricity trade has increased significantly since 2000 at a time when physical interconnection capacity grew modestly (Bahar and Sauvage, 2013).

The degree of liberalisation and of privatisation varies widely across OECD and G20 countries, due to diverse factors such as differing political and economic ideologies, national fossil-fuel resource endowments and levels of economic development. Some governments have retained regulated monopolies and state-ownership in the electricity sector as well as fossil-fuel production, whereas others retain little or no direct ownership anywhere in the energy sector. In other countries "mixed markets" have, where governments retain part or full ownership of companies competing with domestic private sector entrants and foreign firms. The importance of energy SOEs for local and national governments also differs greatly. In some energy exporting countries, the performance of energy SOEs is of crucial importance for public budgets and the overall economy. Box 1 explores different ways in which governments might be "entangled" with and dependent upon their fossil fuel industries, including SOEs. Overall, SOEs remain dominant players in global oil and electricity markets in spite of on-going reforms.

2.1.2 Diversity of Energy SOEs

State-ownership in the energy sector comes in many different legal forms, with heterogeneous forms of governance, differing degrees of state ownership, and a diverse set of public owners from municipalities to central governments. Energy SOEs cover a wide range from vast unlisted companies wielding considerable political power to small SOEs with multiple local and regional government holdings. Some SOEs are also active on global stock markets in the form of listed companies with partial state-ownership. Given this diversity across OECD and G20 countries, firms can be categorised as follows, using a state-ownership lens:

- fully state-owned, unlisted, enterprises such as Vattenfall (Sweden), Eskom (South Africa), or the Comision Federal (Mexico),
- listed companies with majority state-ownership such as EDF (France) or Gazprom (Russia),
- listed companies with minority state ownership such as Enel (Italy) or Engie (France),
- fully private or listed companies without any state ownership, such as E.on (Germany), NRG (United States), and Royal Dutch Shell (Netherlands/UK).

It can, however, be challenging to trace the ownership of particular firms and assets. Some unlisted state-owned companies have established listed subsidiaries in which they retain majority but not full ownership; this is the case for the companies dominating the electricity, gas and oil sector in China. In these cases, it

can be difficult to ascertain the level of state ownership for the company as a whole. In addition, energy SOEs often take part in joint ventures to finance large-scale energy infrastructure projects, further complicating the ownership picture.

This diversity makes it difficult to provide a single definition of SOEs. The OECD Guidelines on Corporate Governance of State-Owned Enterprises state that “any corporate entity recognised by national law as an enterprise, and in which the state exercises ownership, should be considered as an SOE” (OECD, 2015). Other definitions distinguish between full state-ownership, majority-ownership and other state-influenced or state-invested enterprises. Governments can also retain some control through minority ownership, either via so-called “golden shares” (OECD 2015b; Kowalski and Perepechay, 2015) or if it remains the largest of a number of minority shareholders as is the case with Eni in Italy. To simplify the analysis, this paper distinguishes between full, majority and minority SOEs, given the different ways in which governments can potentially exert control over enterprises in which they hold a stake.

A further definitional and analytical challenge is posed by SOEs operating outside of their home countries. SOEs are bound by local laws and regulations in foreign jurisdictions like any other firm, but are nevertheless likely to be influenced by the mandate and policies of their home government (also see Box 3 in Section 3). In Europe, cross-border market entry of state-owned companies increased rapidly in the 2000s, following the liberalisation of electricity markets (ACER, 2014). In fossil fuel markets, the “going abroad” strategy of Chinese SOEs has been significant, with Chinese SOEs investing large amounts in the exploration and production of overseas oil and gas reserves with the backing of the China Development Bank Jiang and Sinton (2011). Moreover, Chinese state-owned banks are estimated to have financed up to USD 38 billion of international coal power investments between 2004 and 2014 (CPI, 2015b). At the same time, Chinese energy SOEs belong to the main investors in the world’s least developed regions, and were responsible for almost 30% of new electricity capacity built in sub-Saharan Africa between 2010 and 2015 (IEA, 2016d). Given the increasing internationalisation of SOEs in general (OECD, 2016a), foreign SOEs are considered as SOEs in this paper.

Box 1 - SOEs and Carbon Entanglement

Most countries’ economies are “entangled” with fossil fuels – either extraction or use or both – reflecting the significant contribution of these activities to past economic development. In fossil-fuel-producing countries, government budgets can depend heavily on royalties from exploitation of domestic reserves, regardless of whether the producers are state-owned. For example, estimates of government rents arising from fossil fuel production have grown from USD 458 billion on average during 2001-2005 to 1130 billion in 2011-2015, up from 4.7% to 6.8% of total government revenues (OECD, 2017a). Rents are particularly important in Saudi Arabia and Russia (>90% and 35.6% of revenues respectively), but are also notable in Indonesia (25.3%), Mexico (20.9%) and India (13.4%).

Even in countries that are not fossil fuel producers, taxes on fossil fuel use can be an important part of government revenues. Elsewhere in the economy, financial markets, pension funds, industry and jobs depend to varying degrees on GHG-emitting activities, which can place governments in a position of significant conflict should they try to implement strong climate policies. Often, this entanglement can render climate action ambivalent at best unless governments adopt an inter-ministry, cross-cutting approach to climate action.

The presence of SOEs can add another level to this entanglement. If the enterprises themselves are heavily entangled with fossil fuels, whether through fossil-fuel production or conversion, they may be placed under severe financial strain when faced with stringent climate policy. This may add another disincentive for governments to pursue ambitious policy, fearful of the lost value from faltering SOEs and the political ramifications of lost employment from government-owned enterprises

Source: OECD (2017a).

2.1.3. State Ownership Trends in the Electricity Sector

This section focusses on how the role of SOEs in the electricity sector is evolving. It explores three avenues: the trends of SOE ownership overall in the power sector; a focus on trends in coal and renewables investments; and an analysis of overseas investments within the electricity sector. The electricity sector is at the heart of the low-carbon transition, currently accounting for 42% of global CO₂ emissions from energy use, and likely to become more important as energy-use sectors such as transport are increasingly electrified (IEA, 2016a).

SOEs still account for 62% of total electricity generation capacity installed or under construction globally, totalling roughly 3750 GW in 2016, despite the wave of privatisations over recent decades (Figure 1). The remaining 38% of generation capacity is owned by non-state energy companies (both listed and non-listed). Unlisted SOEs, including unlisted Chinese SOEs with partially listed subsidiaries, constitute around 32% of ownership in the electricity sector (around 1930 GW). Listed companies with majority state ownership constitute another large group of market players with 13% (around 800 GW) while those with minority state ownership accounted for 4% (around 220 GW) of capacity. A further 8% (around 463 GW) is owned by other state-invested companies where the exact level of state ownership could not be ascertained.

Figure 1. Ownership of total global electricity generation in operation and under construction as of 2016

Source: Authors calculations based on UDI (2016) and 2di (2017).

Table 1 shows the ownership status of the 50 largest electricity producers worldwide and illustrates the continued relevance of state-owned enterprises. Together, these companies represent an estimated 34% (or almost 2400 GW) of electricity generation capacity in operation or under construction in early 2016. Among these 50, fully-privately owned companies constitute a minority with 18 companies, owning a total of roughly 657 GW. Although some of the firms are not primarily electricity generation companies, they own enough capacity to warrant inclusion in this list.

Table 1. Levels of state ownership of largest 50 electricity generating companies worldwide

Accounting for a total of 2400 GW or 34% of total capacity installed in 2016 (parent companies where known)

Company	Main Country of Operation	Ownership Form	State ownership (%)
COMISION FEDERAL CORPOELEC-EMP ELEC SOCIALISTA	Mexico	Unlisted	100
EGYPTIAN ELEC HOLDING CO	Venezuela	Unlisted	100
ELECTRICITY OF VIETNAM (EVN)	Egypt	Unlisted	100
ESKOM HOLDINGS SOC LTD	Vietnam	Unlisted	100
HYDRO-QUEBEC	South Africa	Unlisted	100
PT PLN PERSERO	Canada	Unlisted	100
ROSENERGOATOM OJSC	Indonesia	Unlisted	100
STATE GRID CORP OF CHINA	Russia	Unlisted	100
TAIWAN POWER COMPANY	China	Unlisted	100
TENNESSEE VALLEY AUTHORITY	Chinese Taipei	Unlisted	100
VATTENFALL GROUP	USA	Unlisted	100
CHINA DATANG CORP	Sweden	Unlisted	100
CHINA GENERAL NUC POWER GROUP	China	Unlisted with listed subsidiaries	<100*
CHINA GUODIAN CORP	China	Unlisted with listed subsidiaries	<100*
CHINA HUADIAN GROUP CORP	China	Unlisted with listed subsidiaries	<100*
CHINA HUANENG GROUP CORP	China	Unlisted with listed subsidiaries	<100*
CHINA THREE GORGES CORP	China	Unlisted with listed subsidiaries	<100*
GUANGDONG YUDEAN GROUP CO LTD	China	Unlisted with listed subsidiaries	<100*
SHENHUA GROUP CORP LTD	China	Unlisted with listed subsidiaries	<100*
STATE POWER INVESTMENT CORP	China	Unlisted with listed subsidiaries	<100*
CHINA RESOURCES POWER HOLDINGS	China	Listed with majority state ownership	64
EDF GROUP	France	Listed with majority state ownership	85
ELETRORBRAS SA	Brazil	Listed with majority state ownership	52
GAZPROM	Russia	Listed with majority state ownership	50
INTER RAO UES	Russia	Listed with majority state ownership	71
KOREA ELECTRIC POWER CORP	Korea	Listed with majority state ownership	51
NTPC LTD	India	Listed with majority state ownership	70
RAO UES RUSSIA	Russia	Listed with majority state ownership	80
SAUDI ELECTRICITY CO	Saudi Arabia	Listed with majority state ownership	81
TOKYO ELECTRIC POWER CO	Japan	Listed with majority state ownership	55
ENEL SPA	Italy	Listed with minority state ownership	24
ENGIE	France	Listed with minority state ownership	33
AES CORP	USA	Listed without state ownership	0
AMERICAN ELECTRIC POWER CO INC	USA	Listed without state ownership	0
BERKSHIRE HATHAWAY	USA	Listed without state ownership	0
CALPINE CORP	USA	Listed without state ownership	0
CHUBU ELECTRIC POWER CO INC	Japan	Listed without state ownership	0
DOMINION	USA	Listed without state ownership	0
DUKE ENERGY CORP	USA	Listed without state ownership	0
DYNEGY HOLDINGS INC	USA	Listed without state ownership	0
E.ON SE	Germany	Listed without state ownership	0
ENTERGY CORP	USA	Listed without state ownership	0
EXELON CORP	USA	Listed without state ownership	0
IBERDROLA SA	Spain	Listed without state ownership	0
J-POWER	Japan	Listed without state ownership	0
KANSAI ELECTRIC POWER CO	Japan	Listed without state ownership	0
NEXTERA ENERGY INC	USA	Listed without state ownership	0
NRG ENERGY INC	USA	Listed without state ownership	0
RWE AG	Germany	Listed without state ownership	0
SOUTHERN CO	USA	Listed without state ownership	0

Note: Ownership levels of <100*% refer to unlisted companies with listed subsidiaries, in which the ultimate parent company still holds a controlling share in a number of listed subsidiaries.

Source: Own data; capacity figure based on UDI (2016).

Two analytical lenses are used to better understand how SOE investments in the power sector are evolving: a snapshot of ownership of new plants coming online, and an assessment of the pipeline of new projects under construction or planned for coming years. Figure 2 shows a breakdown of new 2015 plants by ownership and value, for investments in generation and power networks, based on data from IEA (2016e). For power generation overall, zero carbon investments dominate the overall total, with around USD 328bn, 71% of the total. Non-hydro renewables account for nearly three quarters of the zero-carbon

total, with nuclear and hydro making up the rest. In terms of ownership, governments and SOEs account for about 40% of the total new power generation investments, with roughly equal total investments in fossil and non-hydro renewables, accounting for around 50% of new fossil-fuel plants and for around 25% of renewables (excluding hydro). The government and SOE share of nuclear and hydro plants is higher, at around 75%, reflecting the larger scale of these projects and traditional dominance of state-financing, in particular for nuclear.² This snapshot suggests that while SOE investment in renewables is significant, their fossil-fuel portfolios are set to remain important (as is nuclear); this is further explored by looking at project pipelines below.

Figure 2 also highlights the importance of investments in power networks, totalling USD 262 billion in 2015, relative to 461 billion for all power generation investment combined. Governments and SOEs are noticeably dominant as network investors, accounting for about two thirds of the total. This is unsurprising given that in many countries transmission and distribution network operators are still state-owned even where generation has been privatised. Further research would be warranted to better understand network investment drivers and trends (see section on further work).

Figure 2. Snapshot of new power sector investments in 2015

Source: Authors' calculations based on IEA (2016e).

2 Although high, government and SOE investment in nuclear and hydro as a proportion of their total zero-carbon investments is considerably lower than has historically been the case. Hydro and nuclear investment in 2015 represents about 53% of government and SOE zero-carbon investments by value. Across the whole portfolio of active plants, nuclear and hydro account for 79% of zero-carbon capacity of SOEs (relative to 41% in the private sector).

To assess how planned electricity investments of SOEs compare against the existing fleet of power plants, Figure 3 relates existing capacity to future investment pipelines, which includes plants that are already under construction or that are at different stages of planning. For this analysis, electricity generation technologies are grouped into two main categories: fossil-fuel capacity (including oil, gas, and coal) and zero-carbon capacity (including wind, solar, geothermal, marine, hydro and nuclear).

In 2016, there was more than twice as much fossil fuel capacity in operation (3600 GW) than zero-carbon capacity (1788 GW). As Figure 3 shows, in both categories electricity producers with some state-ownership (state-interest) dominated the market with shares of 60% of fossil fuel capacity and 64% of zero-carbon capacity respectively. In the electricity generation construction pipeline there is still more than 1.5 as much fossil fuel capacity (1842 GW) than zero-carbon capacity (1160 GW); SOEs are more prevalent in the zero-carbon pipeline (56% of projects) than in the pipeline for fossil fuel capacity (around 50%). Overall, state-owned enterprises seem to be maintaining their market shares both in fossil and zero-carbon electricity generation. The proportion of state-ownership is particularly high for capacity under construction, averaged across all technologies (66%).

Globally, the electricity pipeline appears to be “greening”: a higher proportion of planned and under-construction plants are zero-carbon (40%), relative to currently operating capacity (30%). However, the level of fossil fuel plants that are currently under construction or being planned will substantially add to future CO₂ emissions from electricity generation. OECD (2017a) finds that although low-carbon capacity has been making strong progress, the proportion of planned coal-fired additions is still considerably greater than that required under an IEA scenario for limiting global temperature increases to well below 2°C.

Figure 3. Existing and planned privately-owned and state-interest electricity generating capacity (GW), global, 2016

Note: “State interest” includes firms that had some level of state ownership at some point in the period 2000-16 (including government ministries, unlisted SOEs, unlisted SOEs with subsidiaries, listed SOEs with state-majority or state-minority share, and private companies with partially state-owned subsidiaries).

Source: Authors’ calculations based on Coal Swarm (2017) and 2di (2017).

Focus on SOEs in coal and renewables

To better understand the role of SOEs in the electricity sector’s low-carbon transition, this section looks at two critical subsectors: coal and renewables (excluding large hydro). Within the global coal power fleet, fully state-owned enterprises own roughly 40% of total operating coal power capacity (Figure 4). If listed companies with majority and minority state-ownership as well as joint ventures involving SOEs are included, the market share of state-invested companies increases to 56%. Looking to the pipeline of new projects, the same state-invested enterprises cover almost the same proportion with 52% of the coal power

pipeline (projects that have been announced, permitted, or are under construction). On the other hand, companies identified as having no state ownership own 14% of operational coal power capacity while only accounting for 3% of the coal power pipeline. This would suggest that privately-owned firms are moving out of the coal sector faster than state-owned enterprises, by investing in fewer newer plants. However, it should be noted that the ownership of both 45% of coal power plants in the pipeline and of 30% of operational plants are not known in this dataset.

The long-lived nature of coal power plants means that new investments currently in the pipeline will, if built and fully operated as planned, continue to produce significant CO₂ emissions far into the future. If governments allow these investments to go ahead but then decide later to take stringent policy action to avoid this “lock in” effect, these plants would become less profitable quite suddenly due to increased carbon taxes or other means of shifting competitiveness to other sources of electricity. Current investors in coal are therefore faced with a risk of having their assets economically stranded at a later date. The increasing proportion of SOEs as investors in coal plants therefore suggests that, by allowing these investments to go ahead, governments are potentially creating future dilemma between placing SOE assets under financial risk or facing lock-in of GHG emissions.

Figure 4. Ownership breakdown of coal power plant operators, 2017 (GW)

Notes: Unlisted SOEs include Government Ministries and Chinese SOEs with partially listed subsidiaries.

Source: Authors' calculations based on data provided by Coal Swarm (2017).

In renewables, SOEs have rapidly increased their investments including solar PV, wind, small-scale hydro, geothermal, biomass and marine. Between 2000 and 2014, unlisted SOEs and governments increased their yearly capacity additions of renewables (excluding large hydro and nuclear) from 0.63 GW to almost 34 GW, boosting their share in the market for new renewables from 9% to 23% (see Figure 5).

Figure 5. Yearly global additions of renewable electricity generation, 2000-2014, in GW

Notes: Renewable electricity generation capacity includes wind, solar, small hydro, biomass, geothermal, and marine. In case of multiple project sponsors, ownership of project was assigned according to the main deal sponsor. The dataset includes renewable electricity generation projects of 1 MW and larger.

Source: Authors calculations based on BNEF (2016).

International investments by SOEs

Internationalisation of SOEs has become a key area of interest across economic sectors; SOEs have increasingly extended their activities beyond their home jurisdictions through increased activity in global mergers and acquisitions both during and after the financial crisis (OECD, 2016a). More detailed information on international activity of SOEs is important to better understand their role in the low-carbon transition. If SOEs target international investments towards low-carbon generation sources this could have important implications for other investors in those overseas markets.

An analysis of a subset of merger and acquisition deals, for which the merged or acquired companies were active in electricity generation, transmission, or distribution, shows trends in SOE internationalisation in the electricity sector. When measured by number of M&A deals, SOE presence has been steadily decreasing for both domestic and cross-border deals from 2000-2015, from a peak of around 30% in the early 2000s to roughly 10% (domestic) and 15-20% (international). By contrast, when measuring in terms of deal values, SOEs captured considerably higher shares of M&A deals, reaching up to 60% in domestic markets in 2013 (see Figure 6) and up to 70% in international markets in 2009 (see Figure 7). This suggests that in contrast to the trend seen for SOEs across all sectors, SOEs have not been increasing their market share of electricity M&A deals. However, they nevertheless remain prominent actors in terms of the total value of deals, implying a continued appetite for larger deals, both domestically and internationally.

Figure 6. Market Share of SOEs in Domestic M&A in the Electricity Sector (2000 – 2015), by deal value, global

Note: The underlying Dealogic data-set does not take into account majority or minority state-ownership of companies when they are listed. In order to paint a more nuanced picture, we corrected the ownership status of over 200 individual companies. Moreover, an M&A deal is considered to be cross-border when the nationality between the target company and at least one its acquirers differs. Out of 12599 transactions more than a third was cross-border. The deal values are known for slightly more than 60% of the deals.

Source: Authors' calculations (2017) based on Dealogic.

Figure 7. Market Share of SOEs in Cross-Border M&A in the Electricity Sector (2000 – 2015), by deal value, global

Source: Authors' calculations (2017) based on Dealogic.

2.2. Implications of state ownership for energy investment

The prevalence of SOEs in the energy sector means their investment decisions are important for the future of the sector. Understanding how these decisions may be influenced by policy is therefore important for policymakers wanting to create conditions for an accelerated low-carbon transition. The characteristics of SOEs, including their incentive structures and proximity to government might lead them to behave differently to their privately-held competitors, including in their approach to the low-carbon transition. This includes both how policy may affect SOE investments, and also how SOE investments may positively or negatively influence the level and type of investment by privately held firms.

SOEs may benefit from a number of advantages that are linked to their state ownership and close proximity to the government, including price support, preferential financing rates and low return expectations, implicit or explicit state guarantees, grants, outright subsidies and tax concessions, in-kind subsidies, privileged access to information, regulatory exemptions, preferential treatment public procurement, commercial diplomacy support and other forms of support (see OECD, 2016a). A large

literature has considered the characteristics of state ownership relative to private enterprise (e.g. Brealy et al., 1997; Hart et al., 1997, Brophy Haney and Pollit, 2010). This section lays out the characteristics and potential advantages and disadvantages faced by SOEs as they compete in global energy markets, with a specific focus on three aspects: SOE governance; preferential treatment of SOEs; and incumbency advantages potentially enjoyed by both SOEs and other firms.

2.2.1 Specificities of SOE governance and objectives

The governance of SOEs often involves a more complex chain of agents than private sector firms, including the general public (as indirect owners), the legislative and executive branch of government and state institutions, as well as the board and management of the SOEs themselves (OECD, 2015a). Company principals are not easy to identify and can be remote from the agents who are tasked to manage the organisation on their behalf. Previous analysis suggests that the behaviour of SOEs depends on how their management is influenced by their government owners (OECD, 2015a). This can range from passive or distant owners, with management lacking incentives to perform in the best interest of the enterprise, to politically motivated interference in SOE operations (going beyond public service obligations), leading to inefficiencies and a lack of accountability. Further, SOE management may be insulated from key disciplining market forces that act on private firms, such as the threat of bankruptcy or takeover by another company. In general, proximity to government can be detrimental to efficient operation of SOEs, for example due to the absence of capital market monitoring and hard budget constraints, the lack of precise strategic and operational objectives and the vulnerability to lobbying (Laffont and Tirole, 1993).

Given the prevalence of state ownership in China, the country provides an interesting case to analyse SOE governance, especially as forthcoming policy changes suggest an emphasis on more efficient management rather than on privatisation. Most Chinese national energy SOEs are supervised by the State-owned Assets Supervision and Administration Commission (SASAC), which manages the 128 largest SOEs, including 3 oil, 5 electricity generation, and 3 coal companies. SOE managers in the energy sector are government officials with political status and supervised both by SASAC and the HR department of the Communist Party (Ji, 2016). Moreover, SOE managers might face incentives to pursue objectives that are different to profit maximisations. For example, managers of large energy SOEs are often mandated to achieve capacity addition targets, which are relevant for their benefits and promotion prospects (CPI, 2015a). Moreover, Chinese energy SOEs are reported to sometimes sacrifice short term profits to accommodate goals of the government to retire plants early – for example phasing out less efficient coal plants – with the expectation to be compensated for losses in the future.

On a strategic level, SOEs often differ from privately held companies by being mandated to pursue public policy objectives determined by the government, broadening the goals of the company beyond profit maximisation (see Benoit, 2012; Ji, 2016; OECD, 2016a). These objectives, often related to social welfare improvements, can be a key reason for governments to retain state-ownership holdings (Laffont and Tirole, 1993). In terms of market competition, SOEs could face competitive disadvantage due to the pursuit of public policy objectives, e.g. the obligation to deliver power at regulated tariffs to all consumers, or to abide by particular employment obligations. The former can constrain investment ability for SOEs for new capacity, including renewables, as has reportedly been the case in Indonesia (PV Tech, 2017). Public policy objectives could also be environmental in nature, for example relating to decarbonisation (as discussed in Section 3).

These governance structures and social objectives mean that SOEs (and their managers) may face different incentive structures to their private counterparts, i.e. they might invest differently and not respond to public policies the same way (for example, respond less effectively to carbon pricing policies, see IEA, 2016c). Further, their governance processes might also be a disadvantage if SOEs suffer from inefficient operational and investment decisions made based on political rather than business rationales,

including requirements to purchase materials or feedstock from other SOEs at above-market prices (see OECD, 2015a). However, these potential market disadvantages from state-ownership need to be seen in the light of potential commercial advantages resulting from their proximity to government, as discussed in the following section.

2.2.2 Concerns over preferential treatment of SOEs

Concerns have been raised that potential preferential treatment of SOEs by their home governments, and in particular preferential financing, can lead to market distortions and “crowding out” of private investments. This could occur domestically in the home nation of the SOE, if private companies (domestic or foreign) struggle to compete with SOEs in their home markets due to the advantages and protections the SOEs might enjoy from the government. The effect could also occur internationally, if competitive advantages granted to SOEs in their home markets translate into distortions of international competition (Kowalski et al., 2013 and OECD 2016a).

In the highly regulated electricity sector, the close relationship of SOEs with regulators, energy ministries and transmission system operators – which in some cases might have formerly been part of the same company – might render it easier to anticipate and influence regulation, receive permits, easier grid connection and achieve optimal dispatch. For example, in South Africa Eskom is still vertically integrated and controls transmission as well as conventional large-scale power generation, mainly based on coal. Eskom remains the most powerful player in the market, with the Department of Energy, its formal owner, reportedly lacking the resources to effectively regulate the market (Baker et al., 2015 and Baker 2016). In 2011 the ministry introduced an auction mechanism under the South African Renewable Energy Independent Power Producers Procurement Programme (REIPPP), to contract renewable electricity generation from independent producers. However, Eskom recently announced that it would refuse signing further offtake agreements with Independent Power Producers (IPPs) under the auction mechanism, citing technical concerns for grid stability. The announcement demonstrated the degree of Eskom's independence from the regulator and formal owner, and thereby caused substantial regulatory and market uncertainty for IPPs (Baker, 2016; Montmasson-Clair, 2017).

Preferential financing is often cited as a key form of SOE advantage. In the electricity sector, access to preferential financing could constitute a substantial competitive advantage, where capital costs weigh heavily compared to operational costs for most projects, especially in renewable electricity generation. If SOEs have access to explicit or implicit forms of preferential finance, such as preferential loans from governments or state-controlled financial institutions this can restrict access for new entrants (Capobianco and Christiansen, 2011). Electricity SOEs might also be subject to less stringent budget constraints, for example by having to pay their government owners lower dividends than they would have to pay private owners (CPI 2015; Bahar et al., 2013; Guerin and Shiavo, 2011; KPMG, 2011; OECD 2016c).

Preferential financing, for example credit at below-market rates provided by state-owned banks, is hard to identify directly due to data limitations. Two techniques have been used to shed light on SOE financing using indirect methods: analysing companies' credit rating and the analysis of M&A financing.

Credit ratings of state-related energy companies can generate some insight into the degree to which a firm's financial credibility – and by implication its financing costs – are impacted by proximity to government. To this end, baseline credit assessment (BCA), also known as stand-alone ratings, can be compared to the final credit ratings of a company. BCAs measure the creditworthiness of a company based on the intrinsic strength of its balance sheet, i.e. the ability of the company to service and repay outstanding debt on its own. Explicit subsidies that governments extend to SOEs on a regular basis are already factored in the BCA. In contrast, the final credit ratings also take into account the probability that the government

may provide extraordinary support in case of a looming default, factoring in both proximity to the government and the financial strength of the government itself. Analysing the difference between baseline-credit assessments and final credit ratings provides information about the value of implicit state guarantees that are expected to be provided to SOEs, as perceived by ratings agencies (see Economist, 2016 and Meister and Scherrer, 2012 for similar approaches).

Figure 8 compares baseline credit assessment to final credit ratings by the rating agency Moody's for 89 government-related energy companies³ (see Moody's Investor Services, 2016). Each line in the graph represents one company and shows the values for their respective BCA and Final Credit Rating. The distance between the two points on every line shows the increase in rating notches that a company received thanks to its proximity to the government, and allows for a comparison of the inherent strength of their balance sheet.

Figure 8. Comparison between Baseline Credit Assessments (BCAs) and Final Credit Ratings of State-Related Energy Companies

Note: Ratings have been translated into numbers with 21 representing the top rating of AAA and 1 representing the poorest possible rating of C. Credit ratings of Baa3 and above (corresponding to values of 12 and above in the chart) are considered to be at least medium-grade and subject to moderate credit risk or lower. All values of 11 and below are considered to be speculative and subject to increasing degrees of risk. Table 2 identifies individual companies (numbered 1 to 89). Final Credit Ratings are given capital letters (e.g. AAA) while Baseline Credit Assessments are designated in lower-case letters.

Source: Authors' interpretation based on Moody's (2016).

³ Government-related issuers are defined by Moody's Investor Services the following way: "Entities with full or partial government ownership or control, a special charter, or a public policy mandate from their respective national, regional or local governments (see Moody's, 2016)".

Table 2. Company information for companies listed in Figure 8

No	Company	Final Rating	Increase in Credit Notches*	No	Issuer	Final Rating	Increase in Credit Notches*
1	British Columbia Hydro & Power Authority	Aaa	0	46	Oman Electricity Transmission Company SAOC	Baa1	0
2	Korea Gas Corporation	Aa2	7	47	Red Electrica de Espana, S.A.U.	Baa1	0
3	Hydro-Quebec	Aa2	5	48	Dubai Electricity & Water Authority	Baa1	0
4	Korea Electric Power Corporation	Aa2	5	49	Oman Power & Water Procur. Co. (S.A.O.C.)	Baa1	0
5	Singapore Power Limited	Aa2	4	50	Compagnia Valdostana delle Acque S.p.A.	Baa1	0
6	Alliander N.V.	Aa2	2	51	EWE AG	Baa1	0
7	Independent Electricity System Operator	Aa2	2	52	Israel Electric Corporation Limited (The)	Baa2	5
8	Ontario Electricity Financial Corporation	Aa2	2	53	Power Sector Assets & Liabilities Mgmt Corp.	Baa2	4
9	Ras Laffan Liquefied Natural Gas Co.Ltd (3)	Aa3	5	54	Latvenergo AS	Baa2	2
10	Ras Laffan Liquefied Natural Gas Co.Ltd (II)	Aa3	5	55	VERBUND AG	Baa2	2
11	China Three Gorges Corporation	Aa3	5	56	Dhofar Power Company SAOC	Baa2	1
12	China Southern Power Grid Co., Ltd.	Aa3	4	57	Empresa de Energia de Bogota S.A. ESP. (EEB)	Baa2	1
13	State Grid Corporation of China	Aa3	3	58	Interconexion Electrica S.A. E.S.P.	Baa2	0
14	Enexis Holding N.V.	Aa3	2	59	Majan Electricity Company SAOC	Baa2	0
15	Korea District Heating Corporation	A1	4	60	Mazoon Electricity Company SAOC	Baa2	0
16	Zhejiang Provincial Energy Group Co. Ltd	A1	4	61	Muscat Electricity Distribution Company SAOC	Baa2	0
17	Transpower New Zealand Limited	A1	3	62	ENEL S.p.A.	Baa2	0
18	Qatar Electricity and Water Company Q.S.C.	A1	3	63	Kazakhstan Electricity Grid Operating Company	Baa3	3
19	Brilliant Power Corporation	A1	1	64	Landsvirkjun	Baa3	3
20	Fingrid Oyj	A1	1	65	Perusahaan Listrik Negara (P.T.)	Baa3	2
21	Statnett SF	A2	3	66	Eesti Energia AS	Baa3	2
22	Elering AS	A2	2	67	Empresas Publicas de Medellin E.S.P	Baa3	1
23	N.V. Nederlandse Gasunie	A2	2	68	Gail (India) Limited	Baa3	0
24	Saudi Electricity Company	A2	2	69	NTPC Limited	Baa3	0
25	CEPS a.s.	A2	1	70	Perusahaan Gas Negara (P.T.)	Baa3	0
26	ENGIE SA	A2	1	71	A2A S.p.A.	Baa3	0
27	Abu Dhabi National Energy Company	A3	8	72	Eskom Holdings SOC Limited	Ba1	5
28	China General Nuclear Power Corporation	A3	6	73	Bulgarian Energy Holding EAD	Ba1	3
29	Beijing Energy Holding Co., Ltd.	A3	4	74	Instituto Costarricense de Electricidad (ICE)	Ba1	2
30	TenneT Holding B.V.	A3	2	75	FGC UES, JSC	Ba1	1
31	Tenaga Nasional Berhad	A3	2	76	Transelectrica S.A.	Ba1	1
32	Electricite de France	A3	2	77	Atomenergoprom, JSC	Ba1	1
33	Ervia	A3	1	78	OA O AK Transneft	Ba1	0
34	Hydro One Inc.	A3	1	79	Holding Slovenske elektrarne d.o.o.	(P)Ba2	3
35	EnBW Energie Baden-Wuerttemberg AG	A3	1	80	ROSSETI, PJSC	Ba2	1
36	EVN AG	A3	1	81	Hrvatska Elektroprivreda d.d.	Ba2	1
37	Vattenfall AB	A3	1	82	RusHydro, PJSC	Ba2	1
38	Comision Federal de Electricidad	Baa1	3	83	Inter RAO, PJSC	Ba2	0
39	Statkraft AS	Baa1	2	84	Tokyo Electric Power Company Holdings, Inc.	Ba3	4
40	CEZ, a.s.	Baa1	1	85	Centrais Eletricas Brasileiras SA-Eletronbras	Ba3	2
41	DONG Energy A/S	Baa1	1	86	EDA - Electricidade dos Acores, S.A.	Ba3	0
42	Energia S.A.	Baa1	1	87	Companhia Energetica de Minas Gerais - CEMIG	B1	-3
43	Fortum Oyj	Baa1	1	88	Empresa Provincial de Energia de Cordoba	B3	1
44	PGE Polska Grupa Energetyczna S.A.	Baa1	1	89	Empresa de Electricidade da Madeira, S.A.	B3	0
45	Electricity Supply Board (ESB)	Baa1	0				

Note: Company numbering matches company numbering of Figure 8. Final Credit Ratings are given capital letters (e.g. AAA) while Baseline Credit Assessments are designated in lower-case letters. Increase in credit notches measured as the difference between Final Credit Rating and Baseline Credit Assessment

Source: Authors based on data provided by Moody's Investor Services

Overall, 67 out of the 89 the credit rating of the SOEs in this sample were boosted by the presence of an explicit or implicit state guarantee, by an average of 1.85 notches. For a number of companies, the increases in ratings are substantial and are subsequently expected to lead to lower cost of credit. The energy companies that experienced the highest uplift include the Abu Dhabi Energy Company whose credit rating was uplifted by 8 credit notches from b2 to A3, the Korea Gas Corporation, which benefits from a 7-notch boost from baa3 to Aa2, and the China General Nuclear Power Generation Corporation, whose rating was uplifted by 6 notches from ba3 to A3 (see Table 2). For other companies, the effect of their proximity to the government is less pronounced. For example, the credit ratings of Vattenfall, EnBW, and Engie were all increased by only a single notch.

A second technique to look for evidence of preferential financing is to analyse how SOEs finance their merger and acquisition (M&A) deals. This was done using a set over 12 500 M&A deals between 2000 and 2014, in which the target, that is the company being acquired, was active in either electricity

generation, transmission or distribution. Deals were analysed to look for systematic differences in financing techniques between state-owned companies and privately-held companies. This was done using the “pecking order theory of finance”⁴ (Myers and Majuf, 1984; Lehmann and Lehmann-Tavares, 2014).⁵ The results showed no systematic, statistically-meaningful differences in financing tools employed by state-owned and privately-held companies. This method did not lead to conclusive results on the electricity M&A dataset that could hint at loose capital constraints and potential preferential financing of SOEs.

2.2.3 Incumbency advantages

While SOEs might be more likely to receive preferential treatment through their linkages with the government, private enterprises might also benefit from the same kinds of government support – in particular where formally state-owned utilities continue to dominate electricity markets, and are seen as strategically important for security or employment reasons. In addition, regardless of state ownership, large incumbent firms may enjoy advantages and market power in concentrated markets, whether they are SOEs or not. They may also use that power to influence policy. For example, in the case of renewable energy, firms with many carbon-intensive thermal power assets may have a commercial incentive to avoid investing in (and potentially to oppose policy support to) renewable generating capacity. This is because they may suffer a loss of value of their conventional fossil-fuel generation assets. The more fossil power plants a company owns and the higher their combined net present value, the more it stems to lose from energy policies that support and promote market entry of producers of renewable electricity. SOEs and other incumbents might choose to oppose such policies in an effort to protect the value of their assets. Every hour generated by renewables is one less hour generated by thermal capacity, harming profitability of the latter.

The same effect could lead SOEs (and other incumbent firms) to pursue different strategies internationally than in their home market. For example, if an SOE has significant thermal generating assets in its home country, it may be disinclined to pursue renewables investments at home, due to concerns over “cannibalising” its own market and reducing operating hours and profitability of its thermal plants. At the same time, such a company may pursue a “green” strategy by pursuing profitable renewables projects in overseas markets where there is strong electricity demand growth. However, renewables and thermal power investment strategies are not mutually exclusive; even within the same market, firms may still pursue both, even if their strategic priority lies in one particular direction.

Whether SOEs are more or less likely than other incumbents to oppose renewable energy due to this effect is likely to depend on a range of factors. These factors include the governance of the firm (at board and management level), how willing the firm is to branch out into new technologies and financing models, and the preferences and policies of SOEs' government owners. Government preferences are often a balance of priorities spanning political and economic factors, including maintaining security of the

⁴ The pecking order theory of finance holds that companies prefer to finance M&A deals using retained earnings and cash over debt and equity, in light of lower transaction costs. Accordingly, the higher proportion of debt and equity used relative to cash, the higher the implication of tighter capital constraints. Systematic differences in financing patterns between SOEs and privately-owned firms might thus be an indication of financial or other privileges stemming from proximity of SOEs to their government (Lehmann and Lehmann-Tavares, 2014). There are however other reasons that might also impact the choice of financing instruments including the cost of capital of the acquirer, confidence of the acquirer in the performance of the target and the synergies between target and acquirer, as well as the general competitiveness of the markets of the acquirer and target.

⁵ To analyse whether financing techniques differed systematically between state-owned acquirer and privately-owned acquirers, we defined the ownership status of the acquirers and constructed a set of financing variables using Dealogic. A oneway ANOVA and post-hoc test difference of means of groups with equal variance was used to detect systematic differences in financing techniques of M&A deals.

electricity supply, maintaining employment in state-owned thermal power generation, and potentially a willingness to finance premature retirement of fossil fuel plants if environmental concerns are prioritised.

More generally, competitive advantages that accrue from SOEs' proximity to the government could be compounded by advantages resulting from incumbency effects. As SOEs in the electricity sector tend also to be large firms, they are perhaps more likely to enjoy both state and incumbency advantages. While closely intertwined, ownership and incumbency effects need to be analysed and treated separately. This is done in the empirical analysis described below.

3. EMPIRICAL ANALYSIS OF STATE-OWNED ENTERPRISES AND INVESTMENTS IN RENEWABLE ELECTRICITY

Section 2 showed that energy-sector SOEs remain key players in global electricity markets and that they invest heavily in both fossil fuel and renewable electricity generation. Given the prevalence of SOEs in the electricity sector, this chapter aims to explore empirically what is the current and potential role of SOEs for the low-carbon transition in general, and for investments in renewable electricity generation specifically, in OECD and G20 countries. Section 3.1 gives a short description of the main hypothesis, Section 3.2 discusses the general link between state-ownership, market regulation, market dynamics and investments in renewables, while Section 3.3 presents descriptive data. Section 3.4 interprets the results of the econometric model. For a detailed description of the econometric model and econometric methodology as well as the full results table, see Annex A.1.4.

3.1 Hypothesis on energy policy through state ownership

Governments with SOE holdings can pursue firm-level energy policies through mandating state-owned energy enterprises to invest in specific electricity generation technologies. Experience from Switzerland and Sweden shows how local, state-level, and federal governments have used firm-level mandates to advance decarbonisation of the energy sector (see Box 3). As these European examples show, governments can influence the action of state-owned companies, it can be expected that environmental mandates for SOEs would be aligned with a government's environmental and energy policy agenda.

State ownership could also have an impact on the level of investment (as measured in million USD) in new renewables if state-owned enterprises benefit from preferential treatment or preferential financing due to their proximity to the government (and not just due to their position as large incumbents) and thus discourage the participation of potential competitors in the field of renewables (as discussed in Section 2.2.3). The state might have a strong vested interest for preferential treatment if it relies on revenue from the SOE for the state budget. Moreover, governments might encourage SOEs to invest more in renewables for financial reasons as they can generate more stable revenues under long-term power purchase agreements than electricity wholesale markets to which conventional power plants are usually exposed, and which often have been volatile in recent years, which in turn might translate into higher investments in capital-intensive renewable electricity generation.

Due to these factors, we hypothesise that in the electricity market SOE ownership is conducive to investments in renewable electricity, if other factors including market concentration and country characteristics are accounted for. Given their often large size and experience in large-scale electricity generation, we assume that energy SOEs tend to invest in utility-size renewable electricity generation rather than in distributed generation. Thus, we expect the effect of state ownership on investment in renewable electricity to be positive, despite a common perception that SOEs are sluggish incumbents not

ready or willing to accept or spearhead market changes (Capobianco and Christiansen, 2011; Goldeng et al., 2008) and despite the possibility that they might constitute an obstacle to investments in renewables by market entrants if they benefit from preferential treatment (OECD, 2016d). Hence, the regression analysis tests the effect of SOE ownership on renewables investments to find evidence for the hypothesis of a positive relationship between SOE involvement and renewables investments.

3.2 Disentangling State Ownership and Electricity Market Structure

In addition to state-ownership, aspects of market concentration and design of electricity markets are also likely to influence how SOEs, and other incumbent firms, invest in renewables. This section puts SOE ownership and its possible effects in the context of electricity market structure.

While levels of state-ownership, market power and market design are often closely related, the three are distinct, which is why their effects need to be analysed separately. In the context of electricity investments, an effect of country-level SOE ownership has to be separated from the effect of market concentration. Due to the prevalence of SOEs in the electricity sector as monopolies or incumbents with considerable market power in a recently liberalised market, a relationship between SOE activity and renewables investments might otherwise be explained by the market power of SOEs. Therefore, the effects of state-ownership on renewable investments hypothesised above have to be separated from possible effects of market concentration and market design in the regression. To account for such effects on investments in renewable electricity generation, the analysis includes three specific variables on market structure: the intensity of competition in electricity generation; the extent of vertical separation; and the degree of third party access to the electricity grid. These three variables are expected to exhibit the following effects:

- more concentrated market leads to lower investments in renewables; All other things being equal, the more concentrated, or the more monopolistic a market is, the lower overall supply (i.e. electricity generation capacity) will be as firms with market power can drive up prices by withholding capacity. Moreover, firms with market power might engage in other strategic behaviour (such as temporary predatory pricing) to discourage market entrants, which in turn also reduces overall supply in the long term (see Knieps, 2008; Erdmann and Zweifel, 2008), and which might discourage the market entry of innovative new suppliers of renewable electricity.
- a higher degree of vertical separation of the electricity market value chain attracts more investments in renewables. All other things being equal, vertical separation of the electricity market value chain allows for competition and for entry by new market participants, which might increase overall supply (from monopolistic to competitive levels) and which might be more innovative than incumbents in offering renewable electricity. Moreover, in electricity markets with higher levels of separation, concerns for security of supply might weigh less heavily as in vertically-integrated markets as the responsibility for electricity of supply is delegated to a single, often not very powerful entity (mostly TSOs) whereas the powerful monopolist was responsible for security of supply in vertically-integrated systems.
- better third party access to the electricity network, for example by independent power producers, attracts more renewables investments. All else equal, third party access allows for competition and for entry by new market participants, which might increase overall supply (from monopolistic to competitive levels) and which might be more innovative than incumbents in offering renewable electricity.

The regression model builds on the model of Ang et al. (2017) to also account for other relevant factors of investments in renewable electricity in OECD and G20 countries.⁶ The investment values serving as the dependent variable in this analysis are estimations based on observed BNEF (2016) investment deal values in million USD for new built renewable electricity plants⁷ as well as observed capacity sizes of plants.⁸ The factors driving renewable investments which are analysed in Ang et al. include: climate mitigation policies (such as feed-in tariffs, renewable certificates, tenders and carbon prices); the quality of the investment environment (e.g. ease of doing business, corruption perception, licensing procedures, trading across border, access to credit) and other relevant factors to be controlled for, such as the size of the country, the countries' volume of electricity generation, etc. To isolate the effect of state-ownership on investments in renewable electricity generation, state-ownership has to be differentiated from other means by which governments have an impact on electricity generation. Governments design and regulate their electricity markets – whether a whole-sale market or a traditional vertically-integrated sector – as well as formulating regulation, taxation or other incentive schemes that are applied either at a sector-level or economy-wide. Examples include feed-in tariffs to incentivise investments in new renewable electricity generation, carbon pricing regimes, or energy taxation schemes. While Ang et al. (2017) rely on SOE variables for the whole economy to capture possible SOE effects, the analysis adds four variables specifically on the market structure in the electricity sector: *capacity share of SOE ownership*, *market concentration*, *degree of vertical separation* and *third party access*. These variables are presented in the following section, including checks on the possible collinearity of capacity share of SOE ownership and market concentration.

Box 2 - Decarbonisation mandates for SOEs: the cases of Vattenfall and Repower

The international importance of government-mandates for energy SOEs can be illustrated by the cases of the electricity utilities Vattenfall from Sweden and Repower from Switzerland.

Although fully owned by the Government of Sweden, Vattenfall has been active internationally since the 1990s, having acquired electricity generation assets in Finland, Denmark, Germany, Poland, and the Baltic countries, amongst others. Guidelines for Swedish SOEs mandate the firms to develop strategic targets not only for safeguarding financial interest but also pertaining to the firms being role models in environment, human rights, working conditions, anti-corruption, business ethics, gender equality, and diversity (see Regeringskansliet, 2015). To this end, in 2010 Vattenfall's board adopted sustainability targets which included the ambition to reduce CO₂ emissions by more than 30% by 2020 (Vattenfall, 2012). As part of efforts to meet the targets, in 2014 Vattenfall's management decided to divest its lignite mines and associated power plants in eastern Germany. After a controversial political debate, the divestiture was finally sanctioned by the Swedish government in July 2016 as it was deemed to be in line with the company's strategic long-term targets (see Vattenfall, 2016). By this time, market conditions had increased the liability of the assets and the final deal reportedly involved a cash transfer of EUR 1.7 billion to the buyer, Czech firm EPH (OECD, 2017a).

Amongst others, the Swedish Green Party criticised the sale (Bloomberg, 2016; Mundus, 2016). To render the assets profitable, the Czech buyer EPH is expected to maximise their life and utilisation rates, which may lead to higher overall CO₂ emissions than if they had been subject to a managed closure (Schwarzkoop, 2016 and Agora-Energiewende, 2016). The case is interesting for a number of reasons. Firstly, it highlights clearly that the

6 Note that even though the set of OECD member countries and the Group of Twenty includes 49 countries when including all single EU countries, this analysis considers only 46 countries. Argentina, Indonesia and Saudi Arabia are excluded due to missing data on independent variables, among others on vertical separation.

7 This analysis focusses on grid-scale projects due to the lack of available BNEF data for small-scale renewables projects. BNEF by design reports deals financing projects with a capacity larger than 1 MW. Additionally, BNEF does not track large hydro-power flows, so the analysis had to exclude large hydro power. The study also had to exclude nuclear power from the analysis due to lack of available BNEF asset finance data on nuclear power.

8 Measuring renewable investments in financial terms gives a clear representation of the magnitude of the investments relative to those made in other sectors. An alternative approach would be to measure new capacity in MW installed (or even MWh generated) instead of USD investment.

environmental impact of divestment strategies depends strongly on the future intentions of the buyer. Secondly, from an SOE perspective, the case raises questions about how decisions by SOE boards about operations overseas may affect policy outcomes in the host country; in this case the Swedish government's approval of the divestment might have an adverse effect on German CO₂-emissions in the medium term.

The case of coal-power divestments of Swiss utility Repower provides another example of decarbonisation mandates by SOE owners. Repower had to divest from coal power assets in Italy after two successful popular referenda in the Canton of Graubünden. Repower was majority owned by 58.3% by the Canton of Graubünden until summer 2016 when a capital increase reduced its share to roughly 22% (Repower 2015 and 2016). In September 2013, the people of Graubünden voted on a popular initiative, obliging Repower to divest from all companies that hold coal-power assets and passed it by a very narrow margin. Taking into account the results of the referendum, the cantonal government enacted new government objectives from Repower, which explicitly demanded the divestment from its holdings in the construction of coal-power plant in Calabria in Southern Italy (Government of the Canton of Graubünden, 2013).

3.3 Descriptive statistics of state-ownership and market structure variables

Figure 9 shows the fraction of SOE ownership of total generating capacity in a country's electricity market for OECD and G20 countries in 2014, i.e. data for the variable *capacity share of SOE ownership*. This share is constructed using newly gathered ownership data of electricity generation enterprises and proprietary capacity data of electricity generating enterprises as provided by UDI (2016). Due to large overall numbers of SOEs in the electricity sector, the collected SOE ownership data covers only a sub-sample of all SOEs in the electricity market. The construction of the *capacity share of SOE ownership* based on additional information of countries' electricity market structures and a careful choice of firms for which SOE ownership data is collected results in reasonably representative values for SOE ownership. For details of the construction of *capacity share of SOE ownership* for OECD and G20 countries in between 2000 and 2014 please see Annex A.1.1.

Three different versions of this variable are constructed, each using a different ownership threshold to cover the spectrum of SOE ownership described in Section 2.1.1: a loose definition which includes *any* ownership called *minority ownership* definition; a definition covering only SOE ownership of 50% and above; and a strong definition covering only 100% SOE ownership called *full ownership* definition. To also cover foreign investments by SOEs described in Section 2.1.3, all definitions include ownership by foreign SOEs as well. Data shown in Figure 9 use the loose definition. Figure 11 uses the 50% ownership threshold to reflect a minimum threshold of formal control. Regression results test for the robustness of using this definition by replacing the 50%-threshold ownership share values with the minority ownership and the full ownership definition.

As Figure 9 shows, the spectrum of possible ownership shares in 2014 is filled roughly equally with different levels of ownership shares within countries, ranging from full state ownership to almost none. As the newly gathered ownership data includes a time series of state-ownership for all years between 2000 and 2014, this analysis takes changing levels of state-ownership into account. The average SOE ownership of capacity in the electricity sector decreased steadily in the time span between 2000 and 2014 (not shown), from 52 percent to 45 percent.⁹

⁹ While some companies have been fully divested from their home government during the period, such as the Portuguese EDP (which is now partially owned by the Chinese "China Three Gorges" SOE), others have been partially privatised such as the Danish Dong Energy or French EDF. A third group of enterprises has been partially privatised with a minority of shares being retained by the government such as Italian Enel and French Engie. In rare cases, energy companies were nationalised or renationalised. Cases include Russian Gazprom and Japanese Tepco, for which state ownership levels increased from 38% to 52% and from 3% to 55%, respectively, between 2000 and 2014.

Figure 9. Cross-country comparison in capacity share of SOE ownership across OECD and G20 countries

Source: Authors' calculations based on in-house data gathering and UDI (2016); see Annex A.1.1 for details.

Figure 10 shows the overall market concentration in the electricity sector as measured by market shares of installed capacity in OECD and G20 countries in 2014, i.e. the variable **market concentration**. Since market data on revenue or generated electricity shares are not available, we rely on the definition of market power in the electricity sector of Benatia and Koźluk (2016), who construct the Herfindahl-Hirschman Index (HHI) of market power based on cumulative historic electricity generation capacity additions in a country collected in UDI's World Electric Power Plant Database. The HHI is constructed based on updated data from UDI (2016) and the calculations and estimations of Benatia and Koźluk (2016), including the estimation of capacity removal, i.e. exit of plants from the market.

As Figure 10 shows, the countries studied cover the full spectrum of market concentration. Countries with vertically integrated utilities, such as South Africa, naturally show high levels of concentration. Even where liberalisation has occurred, concentration can still be high, such as in France where formerly fully-vertically integrated EDF still owns more than 80% of French electricity generation capacity (Agora Energiewende, 2015). While the geographically large countries United States, China and India appear as competitive markets in Figure 10, further analysis of local or regional market power might be warranted herewith. Of the 49 countries shown in Figure 10, 23 country markets can be called highly concentrated, 9 moderately concentrated and 17 not concentrated markets. Similar to the data on share of ownership, the average market concentration for OECD and G20 countries also decreased from 45 units to 35 units in the HHI index between 2000 and 2014.

Figure 10. Cross-country comparison in market concentration across OECD and G20 countries

Source: Authors' calculations based on methodology from Benatia and Koźluk (2016) and data from UDI (2016).

The scatterplot of Figure 11 shows the close statistical relationship between market concentration and the share of ownership variables for 2014 data. It also reveals the greater divergence between the two, if values are roughly below 60 percent and below 60 units, respectively. This shows that while there is a tendency to have concentrated markets in situations with high state ownership, below a threshold a certain SOE ownership share does not necessitate a certain market concentration or vice versa. While some less concentrated markets show high levels of state-ownership, all of the more concentrated markets analysed show high levels of state-ownership.

As the apparent divergence of SOE ownership and market concentration in Figure 11 shows, there is clearly scope for independent effects between market concentration and SOE ownership share. In this context, we hypothesise that a more concentrated market leads to lower investments in renewables, independent of capacity share of SOE ownership. This hypothesis is consistent with a view that high market concentration is associated with a lack of competition and difficulty for market entry or exit, and also with our broader hypothesis that SOE ownership is conducive to renewable energy investment.

Figure 11. Scatterplot and best-fit line of capacity share of SOE ownership and market concentration for OECD and G20 countries

Source: Authors' calculations based on in-house data gathering and UDI (2016).

To control for the effect of changing market design on competition beyond a measure of market concentration, the analysis takes into account two electricity market specific variables in the econometric model: Firstly, the degree of unbundling, i.e. the degree to which formerly vertically-integrated, usually state-owned utilities have been broken up into separate (and potentially privatised) entities. And secondly, third party access, i.e. the degree to which non-incumbents get access to the electricity grid.

The unbundling variable measures steps towards vertical separation, i.e. unbundling of ownership of elements of electricity production, transmission and distribution, in OECD and G20 countries between 2000 and 2014 (excluding Argentina and Saudi Arabia for which data was not available). The variable takes into account the regulation of unbundling of the electricity supply chain. If the law demands full ownership unbundling between competitive segments of the electricity industry and segments that form a natural monopoly, a value of 4 is recorded. If the minimum level of separation consists in the legal separation of competitive and monopolistic segments, a value of 3 is recorded if it applies to the entire industry whereas a value of 2 is recorded if it only applies to large market players, which is often the case. A mere separation of accounts of competitive and monopolistic segments within the same firm is recorded as 1. If the law does not demand any vertical separation at all a value of 0 is recorded. See Appendix A.1 for a more detailed description.

Most unbundling efforts have the goal to make electricity markets more accessible and competitive. Hence we hypothesise that with a higher value in unbundling, a country should attract more renewables investments.

The third party access (TPA) variable captures the degree to which independent power producers have a right to access the electricity grid. For ease of entry into the market, new entrants have to be allowed to connect to the grid and not be charged excessive connection charges by the grid operator. For this variable a value is recorded as 0 if there are no TPA stipulations. If the law foresees TPA, but does not provide any rules for how network operators have to grant it, a value of 1 is recorded (negotiated TPA). If the law foresees TPA and stipulates rules for how it has to be granted, e.g. with relation to the tariffs the network operator can demand, a value of 2 is recorded (regulated TPA). For a more detailed description of the variable see Appendix A.1.

As the aim of increased third party access is to increase competition, access for newcomers and therefore likely the kind of enterprises which introduce renewable energy technology to the market should be increased. Hence we hypothesise that higher values for third party access should lead to more investments.

A regression model tests the effect of the following four independent market structure variables on investments in the renewables sector in OECD and G20 countries:

- *capacity share of SOE ownership* (in percent),
- the capacity-based *market concentration* (as HHI, an index),
- the indicator of *third party access* to the electricity grid (as rank), and
- the *degree of vertical separation* between production, transmission and distribution (as levels).

The regression model also includes variables of the four categories **Climate Policies**, **Investment Environment**, **Innovation Environment** and **Control Variables**, drawn from the model in Ang et al. (2017). Variables in these categories are not considered variables of interest in this study. Therefore results on these variables are not interpreted unless they are part of an analysed interaction. For a detailed explanation and interpretation of variables in these four categories see Ang et al. (2017).

Seven variations of this regression model are presented in the results section to also test for interactions effects, check robustness of results against removing China and India from the sample and check robustness of results for a change in definition of SOE ownership. For details of the choice of regression model specification, the selection of variables, the full list of variables included in the model and the full results table with all included variables from Ang et al. (2017) see Annex A.1.

3.4 Results and discussion of regression analysis

This section presents results for market structure variables of the analysed regression models for investments in the renewable sector in 2000-2014 in OECD and G20 countries. All effects are interpreted as separate from each other. Other than table A.1.2 in Annex A.1.4, the Key Results Table 3 shows the change in investments as a reaction to a change in the interpreted variable as sign-changes. Only coefficients that are statistically significant are listed with signs. Those estimated effects can be expected at acceptable levels of certainty to exist as shown. Only these statistically significant effects are interpreted herewith.

To test for the robustness of results on the *capacity share of SOE ownership* and other variables, variations of the basic model are tested. Beyond the basic investment model the results also include interpretations on:

- a model with interactions including market structure variables to test possible effects of combinations of variables,
- three models excluding the large countries China and India (one model each excluding China and excluding India, and a third model excluding both) for robustness checks on the representativeness of results without data on these two countries, given the possibility that data from China and India might bias results for OECD and G20 countries, and
- two models with alternative formulations of the SOE capacity share variable as a robustness check of the applied definition of state-ownership.

Table 3 reproduces key results of the regression analysis for only the market structure variables as an overview. Compared to Ang et al. (2017), only few results differ in a meaningful way. The noteworthy striking differences are the lack of significance for renewable energy certificates in any of the models and the consistently positive and significant results on fossil fuel support for power generation, which only appears in one sub-sample model in Ang et. al (2017). Even though these are noteworthy differences, the interpretation and policy recommendations of Ang et al. (2017) apply equally for these two factors. For renewable energy certificates levels were probably too low to show an impact, which is also reflected in various models in Ang et al. (2017). For fossil fuel support the message from Ang et al. (2017) to reduce them is not changed herewith, despite counter-intuitive results in both analyses showing a positive effect of fossil fuel support on renewables investments. The counter-intuitive results in both cases could be a possible cross-subsidisation of renewable energy projects or an indication of overcompensation by other factors not captured well by the rest of the model.

Table 3. Impact of market structure variables on investment in renewable electricity projects in OECD and G20 countries for the years 2000-2014

Models:	Basic Investment	Interactions terms	Full sample excluding China	Full sample excluding India	Full sample excluding China and India	Investment (only full ownership)	Investment (including minority ownership)
Capacity share of SOE ownership (50%)	+	+	+	+	+	n/a	n/a
Market Concentration (HHI)	-	-	-	-	-	-	-
Third party access	not significant	-	not significant	not significant	not significant	not significant	not significant
Degree of vertical separation	not significant	not significant	not significant	not significant	not significant	not significant	not significant
Market Concentration (HHI) # Public tender (MW)	n/a	-	n/a	n/a	n/a	n/a	n/a
Third party access # Market Concentration (HHI)	n/a	+	n/a	n/a	n/a	n/a	n/a
Capacity share of SOE-ownership (100%)	n/a	n/a	n/a	n/a	n/a	Not significant	n/a
Capacity share of SOE-ownership	n/a	n/a	n/a	n/a	n/a	n/a	+

Notes: A "+" Indicates that the corresponding variable had a statistically significant and positive effect on investment in the given regression; "-" Indicates that the corresponding variable had a statistically significant and negative effect on investment in the given regression; "not significant" indicates that the variable was not statistically significant; "n/a" indicates that the variable was not included in a given regression, so the result for this specific variable and specific regression is not applicable. For a table with full results including all variables in the model, see Table A.1.2 in Annex A.1.4.

Note that the model does not include the possible confounder of retail choice or lack thereof in OECD and G20 countries. Retail market choice might lead to a demand-induced change in market concentration as consumers might demand renewable electricity and firms might be under pressure to follow demand despite their positions as market leaders. Further, for the calculation of the HHI and the capacity share of ownership, all capacity is treated as equal with no regard to the different capacity factors of technologies. Future data gathering and construction could usefully include retail choice and allow for differing capacity factors.

3.4.1 Results from the basic investment model

This section presents results from the basic and interaction model for the effect of state-ownership and electricity market structure on renewables investments in OECD and G20 countries. For the basic model, the effect of all variables on investment is interpreted as independent from each other. Interaction effects in the interaction model are interpreted as the effect of one variable on the effectiveness of the other variable of the interaction.

The result on *capacity share of SOE ownership* shows a positive effect on investment in the renewable sector in OECD and G20 countries¹⁰. This supports the main hypothesis that SOE ownership has a positive impact on renewables investments and could give rise to at least two possible explanations on the role of SOEs. In part this result could be due to the use of SOEs by the state to further a "green" agenda and use the SOE as an instrument to directly increase deployment of zero or low carbon electricity generation. A second and possibly parallel explanation of this result could be that it is easier for SOEs to find financing for renewable electricity projects. It is well documented that financial risks and the long-term nature of projects are a frequent barrier to financing (OECD, 2015a; OECD, 2017). The credit rating of an SOE and the credit rating of the state owning at least parts of the SOE will in many cases reduce the risk to debt providers (see the discussion on ratings in Section 2.1). Additionally, SOE status might provide

¹⁰

Note that this variable also captures the addition of capacity to the total capacity held by the SOE from the year of the current observation. Though this could theoretically be endogenous with investment values of the current year, it is unlikely that investments yield functioning capacity additions in the same year the investments are made.

opportunities for preferential financing through state-backed guarantees or other state-supported means as pointed out in Section 2.2.3. Although this is a potential explanation for the observed effect of SOE ownership on renewables investments, preferential financing should not be seen as a preferred policy option due to its potentially detrimental effect on competition and efficiency.

Though effects of SOE ownership could be reliant on effects of political economy, robustness checks with variables capturing political economy effects showed no noteworthy change in the SOE ownership result (not shown). The proxies tested in the robustness checks are the unemployment rate of a country (World Bank, 2015b) and an electricity price index (IEA, 2015a). The unemployment rate might capture a political need to influence SOEs to boost employment and in turn gain political goodwill; electricity prices might capture a need to influence production volume or prices themselves to gain political goodwill from consumers. Future research could usefully test interactions with proxies for green agendas and preferential financial treatment, if available.

The basic *Investment* model shows results on the ***market concentration*** supporting the hypothesis that a higher market concentration hampers investments in the renewable sector. This result can be interpreted independently of enterprises' state-ownership share. Therefore it could either mean that incumbent or simply large utilities use their market power to keep or drive out competitors of the electricity generation market in general or that they have the ability in their country's setting to hamper development of a renewable electricity market by relying on possibly more attractive fossil fuel-based production methods.

Both ***third party access*** and ***degree of vertical separation*** are not significant in the basic model and therefore the model regression results of the basic model show no evidence to suggest an effect of these variables.

Additionally the model with *Interactions* shows the effect of two statistically significant interactions, showing that parts of the market structure in the electricity sector also have indirect effects. The interaction between ***market concentration*** and ***public tenders*** shows that beyond their separate effects, they have a combined negative effect. This could be a sign that tenders even amplify the dominance of market leaders in highly concentrated markets. Among other possible explanations, market leaders might have better insights into a market by virtue of controlling large parts of it, might be the only available bidders in tenders, possibly because they are the only possible bidders with enough capacity to carry out projects of the tendered size, or might simply be able to wield undue influence and therefore drive competition out of the market or even deter competition from entering the tender. A clear case of this special position of SOEs in tenders is the tender programme in South Africa. In past tenders 50% of the tendered capacity was reserved for the South African SOE Eskom, preventing competition for this section of the market altogether (OECD, 2015b). More research on the role of SOEs and incumbent utilities in renewables tenders would be needed to further understand this result.

The interaction between ***market concentration*** and ***third party access*** is statistically significant and positive. This shows that improved entry conditions to the market in a context of high market concentration could lead to more investments. It shows that in countries with high market concentration, a change in market design to open up the market can indeed achieve the reform's goal of attracting new investors investing in renewable technologies. Even if the observed effect of the interaction does not stem from new investors entering the market, it would still show that incumbent enterprises adopt more forward-looking investments in renewable electricity, possibly out of pressure to compete with new entrants. This result would be a strong affirmation to increase third party access for markets with high market concentration to support investments in renewables. Introducing the interaction also turns ***third party access*** statistically significant and negative. Future research on market entry design and market concentration in the context of renewable electricity could shed light on this result.

3.4.2 Results from investment models without China and India

The regression estimation also tests the robustness of results on data for China and India, the biggest and two very active states in recent years in the electricity sector, and both countries with high levels of state ownership. Comparable to Ang et al. (2017), results for the sub-samples without either or both of these countries show differences in the effect of *public tenders*, *barriers to services*, *sovereign credit rating* and *credit to government and SOEs*, but do not show changes on market structure variables compared to the basic model (for a discussion of these changes, see Ang et al., 2017). Therefore, we can conclude that the results presented are robust to the exclusion of data from China and India and are therefore representative of more than just investments and policies in these two countries.

3.4.3 Results from investment models with different definitions of SOE ownership

The regression estimation also tests the robustness of results using different definitions of state-ownership. The basic model includes only the capacity of SOEs with at least 50 percent state-ownership in the *capacity share of SOE ownership*. The two additional investment models use definitions with *only full ownership* and *minority ownership* as robustness checks. The *capacity share* of SOE ownership used in the *only full ownership* model defines state ownership narrowly as an ownership by the state of 100 percent. The *minority ownership* model SOE ownership is defined as any ownership down to a state-owned stake of just 1%. See Annex A.1.1 for details of the variable construction.

This robustness check allows the conclusion that under a reasonable definition capturing relevant effects of state-ownership the results of the basic model on state-ownership are robust. The state-ownership definition using only full state-ownership is not statistically significant. This could suggest that the full state-ownership definition is inappropriate to measure the influence of state-ownership as it excludes relevant SOE ownership forms and therefore misses the influence of other major ownership stakes and their effect of investments. Contrarily, the state-ownership definition that includes minority state-ownership shows a statistically significant and positive result. The similarity of the minority ownership result with that of the basic model (using the middle definition of state ownership) could be caused by both variables capturing the major factors driving this effect. Also including minor state-ownership allows the state-ownership variable in the *minority ownership* model to capture smaller influence of the state as well.

The introduction of the SOE ownership variable following a full ownership definition has an indirect effect on the statistical significance of the financial sector variable *credit to government and SOEs*¹¹. Compared with the basic *investment* model, the *full ownership* model shows *credit to government and SOEs* statistically significant. As the full ownership definition does not capture SOEs completely, some of the effect of SOE influence might have been captured by *credit to government and SOEs*. This is unsurprising as one reason why SOEs might have a positive effect on investments might be preferential access to finance, i.e. a part of the influence of SOEs captured in *credit to government and SOEs*.

The introduction of the SOE ownership variable using a minority ownership definition has an indirect effect on the statistical significance of the financial sector variable *sovereign credit rating*¹². In comparison with the basic *investment* model the *minority ownership* model shows no statistically

¹¹ The *credit to government and SOEs* variable (data from World Bank, 2016b) measures loans to the state including state-owned enterprises in % of GDP. This variable captures the outcome of the facilitation of finance, rather than the framework as other variables used in the model do. As this variable might be an indication of financing availability of renewables projects, it is expected to show a positive effect on investment and innovation.

¹² The *sovereign credit rating* variable is based on data from Moody's (2015), and measures trust in the solvency of the state. The variable converts credit ratings to a scale between 1 and 9 and is expected to have a positive impact on investment flows.

significant impact of *sovereign credit rating*. This could mean that in the context of renewables investments the creditworthiness of the state is captured by SOE ownership and therefore taken up by the SOE ownership variable capturing the complete SOE spectrum.

4. RESULTS, CONCLUSIONS AND FURTHER WORK

4.1 Results and conclusions

SOEs are important actors in the context of the low carbon transition. Through SOEs and other forms of ownership, governments still constitute the main owners of fossil fuel production assets globally. SOEs remain particularly important in the electricity sector, including in several OECD countries. SOEs accounted for 62% of total global capacity installed in 2016 and for roughly 52 % of power plants that are currently in different stages of planning or construction. A closer analysis shows that SOEs are both important investors in coal and renewable electricity generation. While SOEs have increased their market share of new renewables capacity additions from 9% in 2000 to 23% in 2014, they still account for roughly 56% of ownership of current coal power plants and 52% of the coal plant pipeline. Evidence suggests that, globally SOEs are on average investing in new coal plants at a higher rate than their non-state counterparts.

SOEs are unusual market participants. Firstly, state-owned companies may be strongly influenced by government mandates beyond general policy levers such as regulation and pricing. Secondly, SOEs may have performance objectives that go beyond maximising financial returns, such as social or environmental objectives. Thirdly, SOEs may benefit from preferential treatment from their government owners such as preferential financing or regulatory derogation. These issues can also extend beyond the home countries of SOEs, given that SOEs are increasingly active internationally. While concerns have been raised that potential preferential treatment can lead to market distortions and crowd out private investments, less attention has been paid to how government mandates and public policy objectives could be beneficial to major policy-led industry transitions, such as for the low-carbon transition. In some cases public policy objectives can act to limit SOEs' investment capability, such as obligations to deliver power to consumers at artificially low rates.

Results of the econometric analysis carried out for this study suggest that SOE ownership has a positive effect on investment in the renewable electricity generation sector in OECD and G20 countries. This effect could be due to a number of reasons, including SOEs being influenced by government mandates to advance their decarbonisation strategies or due to preferential financing terms potentially available to SOEs. Potential preferential financing as well as the existence of explicit and implicit state guarantees translate into lower costs of capital, which in turn would constitute a substantial competitive advantage in a sector that is dominated by high capital costs. Conclusive evidence on preferential treatment is difficult to find. Some indication of how markets perceive SOEs to benefit from their proximity to the government can be seen in the form of increased credit ratings and reduced cost of credit resulting from implicit or explicit state guarantees, but further work would be valuable in this area.

State ownership is only one factor influencing investment in electricity generation, including renewables. Effects of market concentration were also tested and results suggest that high market concentration in electricity generation is a hindrance to competition and indirectly also to investment in renewable electricity in OECD and G20 countries. This supports the notion that increased competition curbs market power and prevents abuse of market position to allow for entry of enterprises venturing into renewable electricity technologies. However, the econometric model shows no conclusive evidence to suggest an effect of other characteristics of market structure - such as third party access and the degree of vertical separation - on investments in renewable electricity generation.

These results point to an opportunity for governments with SOE holdings to make use of their shareholder influence to accelerate the low-carbon transition while retaining public service obligations (such as universal electricity provision) and financial return requirements. As a basis for this, governments can ensure that SOEs adhere to the OECD Guidelines on Corporate Governance of State-Owned Enterprises, which pursue three complementary goals: to professionalise the state as an owner of enterprises; to render SOEs as efficient, transparent and accountable as good practice in private enterprises and thirdly; and to ensure that competition between SOEs and private competitors is conducted on a level playing field (see OECD, 2015).

In countries with high levels of state ownership in the electricity sector, government influence over SOEs could be employed as a complementary policy lever to sector-wide or economy-wide energy and climate policies (given that SOEs might be less likely to respond to pecuniary incentives than their privately-owned peers). For example, in line with the OECD Guidelines, decarbonisation efforts could be explicitly and transparently included as public policy objectives in mandates for state-owned enterprises. In such cases, close co-ordination between general energy policy and SOE-specific objectives will be needed to maximise efficiency and limit spillover effects for competing non-SOEs (for example where SOEs are operating under emissions trading systems). Possible trade-offs with further SOE objectives such as specific return-on-equity expectations should be dealt with transparently. Moreover, it should be ensured that private players are able to compete on a level-playing field, for example by having access to the same sources of financing.

4.2 Future Work and Next Steps

This analysis has provided initial insights into ways that the prevalence of SOEs – and the market conditions in which they operate – are influencing some aspects of the low-carbon transition. Further research would be needed to understand the full picture. The empirical analysis presented looks only at effects of SOEs on renewable electricity investments, one important element of the low-carbon transition, but only one part. State-ownership is also likely to be important in other aspects. Beyond renewables, the role of SOEs in financing and building coal-fired power generation units warrants further exploration and is currently in preparation as part of the OECD Climate Change Mitigation Report 2018. This paper tracks coal investments being made by SOEs, but does not investigate empirically how policy could influence SOEs' investment strategies for coal versus renewables. SOEs can also be important influencers on GHGs beyond the energy sector itself – both as heavy energy users (e.g. steel and cement firms) and as financiers (state-owned banks).

Greater penetration of renewable electricity requires modern transmission and distribution infrastructure, in particular where renewable resources may be far from demand centres. SOEs are likely to play an important role in investing in transmission and distribution assets, and this would be one area for further work. Conversely, the action of SOEs as electricity transmission and distribution operators may have positive or negative effects on the profitability of investments made by competitors at the generation end of the electricity chain. Although the unbundling and third-party-access variables did not show significant results in the current analysis, this is another area warranting further research.

Finally, the market concentration and market structure variables explored suggest that even where markets are open to competition, highly concentrated markets have often remained in place and have not been conducive to renewables investments. However, information technology combined with ever-falling renewables costs are leading to potentially fundamental changes in electricity markets. Incumbent utility firms, regardless of whether they are state-owned, are increasingly finding their business models under pressure, whether due to low wholesale power prices depressing profitability of thermal plants (in part due to increased zero marginal cost renewables), or due to the increasing digitalisation of the sector allowing commercial opportunities for smaller firms new to the market. How this change of business model will affect both the stability of the electricity sector and its rate of decarbonisation is an important area for future research, beyond the question of state ownership.

ANNEX A.1 DATA, MODELING AND DETAILED RESULTS

This annex details the construction of the three variables *capacity share of SOE ownership* (A.1.1), *vertical separation* (A.1.2) and *third party access* (A.1.3) as well as the modelling approach taken for the econometric analysis of section 3 (A.1.4). For the construction of the fourth market structure variable used in the regression analysis, the *HHI*, see Benatia and Koźluk (2016). Table A.1.1 shows descriptive statistics of all variables used in the lasso approach in Table A.1.

Table A.1.1. Descriptive statistics

Variable	Unit	Observations	Mean	Standard Deviation	Minimum	Maximum	Source
Capacity share of state ownership (50%; incl. foreign)	Percent (0-1)	4410	0.46	0.31	0.0	1	Based on UDI (2016) and in-house data gathering
Capacity share of state ownership (100%; incl. foreign)	Percent (0-1)	4410	0.37	0.35	0.0	1	Based on UDI (2016) and in-house data gathering
Capacity share of state ownership (incl. foreign)	Percent (0-1)	4410	0.49	0.28	0.0	1	Based on UDI (2016) and in-house data gathering
Market Concentration	HHI	4410	39.59	30.25	2.1	100	Benatia and Koźluk (2016)
Third party access	Rank	4230	1.59	0.78	0.0	2	In-house data gathering
Degree of vertical separation	Level	4230	1.61	1.12	0.0	4	In-house data gathering
Feed-in tariff	USD/kWh, weighted with power purchasing agreement-duration	4410	0.82	1.99	0.0	15	Updated based on Haščič et al. (2015)
Renewable energy certificate	Percent	4404	1.03	3.04	0.0	21	Updated based on Haščič et al. (2015)
Public tender	MW	4410	6.85	86.19	0.0	3000	Own data gathering
Explicit carbon price	USD/tCO _{2e}	4404	3.98	6.80	0.0	72	Ecofys and World Bank (2015), OECD (2015e,f)
Energy taxation in the power sector	USD/MWh	4410	4.45	12.13	0.0	108	CESifo (2015), OECD (2015g)
Logarithm of fossil fuel support for power generation	Ln USD	4410	3.23	7.04	0.0	23	OECD (2015d), Oosterhuis (2013)
Significant changes in climate mitigation policies	Dummy; narrow	4410	0.01	0.09	0.0	1	Own data gathering
Public RD&D spending	USD million	4410	141.88	153.00	0.8	643	IEA (2015b), BNEF (2016), Harvard Belfer Center (2010)
Antitrust Exemption	Index	4230	0.48	0.75	0.0	3	Koske et al. (2015)
Implementation Basel III risk-based capital requirements	Dummy	4410	0.08	0.27	0.0	1	Own data gathering

Table A.1.1. Descriptive statistics (cont'd)

Variable	Unit	Observations	Mean	Standard Deviation	Minimum	Maximum	Source
Implementation Basel III leverage ratio	Dummy	4410	0.01	0.10	0.0	1	Own data gathering
Implementation Basel III liquidity coverage ratio	Dummy	4410	0.02	0.13	0.0	1	Own data gathering
Barriers to entry	Index	4230	1.20	0.73	0.0	4	Koske et al. (2015)
Barriers to FDI	Index	4230	0.74	0.75	0.0	4	Koske et al. (2015)
Barriers to network sectors	Index	4230	3.06	0.80	0.7	6	Koske et al. (2015)
Barriers to services	Index	4230	3.37	0.89	0.9	6	Koske et al. (2015)
Banking competitiveness	Boone indicator	4404	-0.04	0.25	-2.1	6	Koske et al. (2015)
Command and control	Index	4230	2.14	0.84	-0.0	4	Koske et al. (2015)
Carbon intensity of energy	Kton CO2/ktoe TPES	4410	9.25	43.90	0.0	588	Olivier et al. (2014), IEA (2015e)
Corruption perception index	Index	4410	6.07	2.15	1.7	10	Transparency International (2015)
Sovereign credit rating	Ranks	4410	7.28	1.60	1.0	9	Moody's (2015)
Direct control of the state over enterprises	Index	4140	1.41	0.93	-1.2	5	Koske et al. (2015)
Ease of acquiring construction permit	Index	4410	65.73	16.56	-5.9	92	World Bank (2015c)
Contract enforcement	Index	4410	66.53	12.36	25.8	86	World Bank (2015c)
Getting credit	Index	4410	63.18	22.02	-47.7	100	World Bank (2015c)
Ease of getting electricity	Index	4410	74.47	16.30	-18.0	100	World Bank (2015c)
Resolving insolvency	Index	4410	58.23	28.29	-32.2	107	World Bank (2015c)
Minority Investor Protection	Index	4410	58.38	14.07	-2.7	97	World Bank (2015c)
Registering property	Index	4410	69.97	15.68	-24.9	97	World Bank (2015c)
Ease of doing business	Index	4410	79.71	14.19	16.8	100	World Bank (2015c)
Paying taxes	Index	4410	71.56	16.11	7.3	99	World Bank (2015c)
Trading across borders	Index	4410	77.41	16.15	-54.9	94	World Bank (2015c)
Electricity consumption per capita	Terajoule per capita	4410	7.32	6.78	0.4	55	World Bank (2015c)
Electricity consumption	Terajoule	4410	3.19e+11	7.36e+11	1.7e+09	5.51e+12	World Bank (2015c)
Electricity generation	GWh	4410	343.81	778.57	0.4	5533	IEA (2015a)
FDI inflows	USD million	4338	25211.60	57119.30	-41305.3	705267	World Bank (2015b)
Local-content requirement attached to feed-in tariff	Percent	4410	1.13	8.44	0.0	100	OECD (2015a)
Treatment of foreign suppliers	Index	4230	1.00	0.83	0.0	5	Koske et al. (2015)
GDP per capita	USD	4356	24.43	18.52	0.6	86	World Bank (2015b)
Network involvement	Index	4230	3.37	1.20	0.1	6	Koske et al. (2015)
Governance of SOEs	Index	4140	3.79	1.38	0.5	6	Koske et al. (2015)
Strength of Intellectual Property Rights	Index	4410	4.91	1.05	1.8	8	Property Rights Alliance (2016)

Table A.1.1. Descriptive statistics (cont'd)

Variable	Unit	Observations	Mean	Standard Deviation	Minimum	Maximum	Source
Licenses and permit system	Index	4230	3.64	1.56	0.0	7	Koske et al. (2015)
Innovation spillover	Patent count	4410	58.38	171.54	0.0	2011	Haščič and Migotto (2015)
Perpetual inventory of renewable power-related patents	Patent count	4410	129.52	601.12	0.0	10343	Haščič and Migotto (2015)
Price Controls	Index	4230	1.92	1.09	0.1	6	Koske et al. (2015)
Domestic credit to private sector	Percent of GDP	4404	95.18	59.78	7.1	311	World Bank (2016b)
Domestic credit to private sector	Percent of GDP	4404	95.18	59.78	7.1	311	World Bank (2016b)
Regulatory capital to risk-weighted asset	Ratio	4410	13.52	4.43	-1.9	33	IMF (2016)
Communication and simplification	Index	4140	1.12	0.86	0.0	6	Koske et al. (2015)
Scope of state-owned enterprises	Index	4230	3.32	1.18	1.0	6	Koske et al. (2015)
Credit to government and SOEs	Percent of GDP	4404	13.81	11.17	0.0	73	World Bank (2016b)
Natural resource endowment	Various units	4400	0.01	0.91	-1.7	8	World Bank (2015b), IEA (2015e), World Resource Institute (2015), CIA (2015), SolarGIS (2013), Lu et al. (2009)
Tariff barriers	Percent	4230	0.51	1.06	0.0	6	Koske et al. (2015)
Tertiary education	Percent enrolment	4410	27.28	13.67	0.0	102	World Bank (2015b)
Electricity transmission loss	Percent of output	4410	8.45	4.66	-1.2	28	World Bank (2015b)
Number of universities	Count	4410	18.63	37.89	0.0	245	Webometrics (2016)
Contract Enforcement Time	Index	4410	534.96	268.50	210.0	1580	World Bank (2015b)
Business extent of disclosure	Index	4410	6.26	2.50	0.0	10	World Bank (2015b)
Time resolve insolvency	Days	4410	2.29	1.50	0.4	10	World Bank (2015b)
Time required starting business	Days	4410	27.17	29.30	0.5	168	World Bank (2015b)
Cost of business start-up	Index	4410	10.86	16.50	0.0	137	World Bank (2015b)
Procedures registering property	Count	4410	5.43	2.26	1.0	14	World Bank (2015b)
Time registering property	Days	4410	50.04	100.95	1.0	956	World Bank (2015b)
Procedures to build warehouse	Count	4410	14.66	6.91	6.0	51	World Bank (2015b)
Time to build warehouse	Days	4410	196.46	120.14	27.0	678	World Bank (2015a)
Time to get electricity	Days	4410	107.58	67.58	18.0	302	World Bank (2015a)
Procedures to enforce contracts	Index	4410	33.95	5.28	21.0	46	World Bank (2015a)
Control of corruption	Index	4410	0.89	0.98	-1.1	3	World Bank (2016c)
Quality and independence of government service	Index	4410	1.02	0.76	-0.8	2	World Bank (2016c)

Table A.1.1. Descriptive statistics (cont'd)

Variable	Unit	Observations	Mean	Standard Deviation	Minimum	Maximum	Source
Political stability	Index	4410	0.49	0.76	-2.1	2	World Bank (2016c)
Regulatory quality	Index	4410	0.99	0.68	-1.1	2	World Bank (2016c)
Rule of law	Index	4410	0.91	0.83	-1.1	2	World Bank (2016c)
Voice and accountability	Index	4410	0.87	0.74	-1.9	2	World Bank (2016c)
Stability of financial institutions	Score	4404	16.66	12.48	-7.9	74	World Bank (2016a)
Population	Count (thousand)	4410	89.91	245.32	0.3	1364	World Bank (2015b)
Logarithm of GDP	Ln USD	4356	26.33	1.65	22.5	30	World Bank (2015b)
Logarithm of sector-specific trade	Ln USD	4410	11.37	2.86	0.0	17	Comtrade (2015)
Average MFN tariff	Percent	4410	3.07	3.53	0.0	29	UNCTAD Trains (2016)
Logarithm of CO2 emissions	Ln kton CO2	4410	11.69	1.75	7.3	16	Olivier et al. (2014)

Source: Authors' calculations.

A.1.1 Construction of the capacity share of SOE ownership variable

This section outlines the details of the construction of a country-level variable as an indicator for the extent of state-ownership in the electricity sector. The variable construction identifies the top-ranked electricity capacity owners and infers the level of SOE ownership of remaining firms based on data for the identified top-ranked firms. Information on firm size is based on capacity addition data at the plant level from UDI (2016). The inference of countries' SOE ownership from available data is based on knowledge of the changes in market structure of the electricity sector. The main feature of this inference of SOE ownership data is the modelling of representative country values based on an unrepresentative data sample.

Finding information on the extent of ownership of companies in the electricity sector by the state is difficult and therefore imposes a limit on the feasibility of data search. While gathering data on the state share of ownership might be feasible for large companies, data is prohibitively hard to collect for the more than 10,000 electricity producers active in OECD and G20 countries from 2000 to 2014. This lack of available data is due to a range of factors, including the small size of firms, the status of firms as defunct, the lack of willingness of private firms to disclose ownership information, or the disclosure of information in a local language or another form that might impede research. Hence the data search for state-ownership values concentrates on the most important firms and as a second step infers country values from this information on the most important firms. To i) select relevant firms, ii) reduce the number considered per country and iii) standardise the search strategy, the variable construction only considers the top-ranked firms in terms capacity that hold *a cumulative 50% of a country's capacity in any year between 2000 and 2014*. 50% of cumulative capacity cover a large enough extent of the market to form a picture of ownership (though not necessarily equally representative for each country, which will be taken into account in the following variable construction) but keeps the number of firms for which to track ownership throughout years to a manageable level. In some countries this means that an SOE ownership is only observed for one firm holding 50% or more of a country's capacity throughout the years, while in others these are up to 18 firms. Overall for OECD and G20 countries this search strategy results in more than 2000 state-ownership values for the 138 relevant firms. That means that on average close to 3 firms per country hold 50% of capacity in any year between 2000 and 2014. Data gathering for SOE ownership information for those 138 firms relied on various resources, including annual reports of companies, reports in the public domain and companies' voluntary public disclosure.

To use SOE ownership data in a country-level panel regression, the year-by-year firm-level SOE ownership data has to be aggregated to the country-year level. Collecting and aggregating only information on the top-ranked firms holding 50% of capacity, however, could result in unrepresentative¹³ values of state ownership in a country's electricity market. If the sample is indeed unrepresentative, it could bias regression results on SOE ownership.

Given the historical change in SOE ownership in many recently liberalised electricity markets, it is more than likely that judging the extent of SOE ownership in a country only based on the largest players will overestimate the SOE ownership. For example, the largest electricity provider in France would be EDF, an incumbent firm. However, assuming that the level of state-ownership of EDF is representative for all French electricity producers would miss the fact that the state hardly owns any shares in electricity

¹³ While the most straight-forward way to use information of the top 50% capacity owners would be to demonstrate representativeness of the subsample, the variable construction has to forego this otherwise simple method and assumes as well as corrects non-representativeness. Though the UDI (2016) dataset contains detailed information on plants, it provides little information on the parent companies holding these plants (e.g. lacks data on revenue, customers, production or employment). Therefore a comparison between the full sample and the subsample of 138 companies for which SOE ownership data is available is impossible. Therefore the construction outlined in this annex relies on economic reasoning without the aid of statistical comparison to construct a country-level SOE ownership variable.

generation companies other than those in the EDF group. Generally, for some countries, say with only one state-controlled monopolist, the value for the top-ranked holders of 50% capacity will necessarily be an exact representation of the value for the whole market. For other countries, for example in a market with two state-owned incumbents and two privately-owned firms in the top-ranked 50%, it is questionable that the average state ownership of these four firms is representative for the bottom-ranked 50% of the capacity as well, as state-owned firms are often overrepresented in the top-ranked sample of firms in the market.

Despite knowing the ownership structure of only the top-ranked firms holding 50% of capacity, information on the composition and history of electricity markets can support formulating assumption on the composition of a market and help to correctly represent SOE ownership. From structural changes in the power market, most notably the wave of liberalisation in recent decades, it follows that newcomer firms are rarely if ever owned by governments (except when acquired by a large SOE). Accordingly we can formulate the following assumptions. If these assumptions hold, aggregate country values will be more representative.

- The small number of firms dominating even liberalised markets shows that rather than having a field of many competitors, liberalisation in almost all cases created a highly concentrated market (for a discussion of electricity market concentration see Benatia and Koźluk (2016)). In newly liberalised markets, incumbent firms often belong to the top-ranked firms and are also likely state-owned.
- This observation allows the assumption that for markets with an overall high share of state-owned firms in the top-ranked 50% it is more likely to have SOE ownership in those top firms than in the bottom firms. Hence in those markets the observed SOE ownership in the top-ranked 50% *overestimates* the SOE ownership in the complete market and this overestimation is related to market concentration. Therefore we can assume that **the higher the market concentration, as measured for example by the Herfindahl-Hirschman Index (HHI), the more likely the observed values would be an overestimation.** This is *assumption 1*.
- Further, knowledge of electricity markets and liberalisation history also allows the assumption that the more market share single SOEs have (i.e. the higher the contribution of single state-owned firms to the HHI), the more the average ownership value in the top 50% overestimates the average ownership in the whole market. This is because the larger SOEs are in the market, the less likely it is that SOEs with small capacity also exist. During liberalisation, it is unlikely that a state would split large state-owned utilities very unequally. Hence, **the higher a single SOE's market share of the top firms, the more the observed values would be an overestimation.** This is *assumption 2*.

Following the above assumptions means that the bias of the aggregate state-ownership value observed for a country relates to that country's market concentration, i.e. relates to the HHI. The higher the HHI in an oligopoly market, the more a correction has to reduce the average value since it overestimates¹⁴.

An equation for the SOE-ownership in the whole market inferred from the SOE-ownership of the top-ranked 50% would thus have to build on assumption 1 and assumption 2 outlined above and would have to be able to cope with the special cases of monopolies as well as competitive markets. The equation

¹⁴

The exception is an HHI beyond the tipping point of dominance, i.e. a situation with just 1 player which the calculation falsely equate with 1 player in the top-ranked 50%, a negligible flaw in our data collection. An enterprise owning more than 50% of capacity likely has enough market power to justify a categorization of the market as monopoly with a fringe, i.e. also a situation with very high market concentration.

outlined in the following paragraph captures these properties to infer the **representative SOE ownership of the bottom-ranked 50% firms**, $SOEown_{bottom50}$.

A naïve version to start with that does not take assumptions 1 and 2 into account would be $\frac{\sum_i^{I_{top50}} SOEown_i}{I_{top50}}$, with $SOEown_i$ as the observed value of SOE ownership by the state for firm i and I_{top50} as the number of firms in the top-ranked 50%. This naïve attempt to estimate SOE ownership in the unobserved half of firms would ignore the assumptions and instead assume that SOE ownership is equally distributed for the top-ranked and bottom-ranked 50% of firms. To correct for the overestimation due to the unequal distribution of SOEs between top-ranked and bottom-ranked firms as formulated in assumption 1, the naïve term is reduced by multiplying with the term $\left(1 - \sum_i^{I_{top50}} HHIcontr_i\right)$, relating to the overall distribution of market share. Specifically, here $HHIcontr_i = \frac{MarketShare_i^2}{\sum_i^{I_{top50}} MarketShare_i^2}$, the HHI contribution of firm i , with $MarketShare_i$ as the market share of firm i . Each single SOE ownership value, once again, is reduced by the term $1 - \frac{HHIcontr_i}{\sum_i^{I_{top50}} HHIcontr_i}$ capturing the relative position of firm i in the distribution of firms based on assumption 2.

An equation taking both assumptions into account and correcting for unknown SOE ownership in the bottom 50% of markets would therefore look like this:

$$SOEown_{bottom50} = \frac{\sum_i^{I_{top50}} SOEown_i \cdot \left(1 - \frac{HHIcontr_i}{\sum_i^{I_{top50}} HHIcontr_i}\right)}{I_{top50}} \cdot \left(1 - \sum_i^{I_{top50}} HHIcontr_i\right).$$

All values are calculated for each year and country; for the calculation of the HHI in terms of capacity-market shares based on Platts data see Benatia and Koźluk (2016).

This equation for $SOEown_{bottom50}$ also has the desirable property that it is equal to 0 when the top-ranked 50% of firms are not state-owned (a case that does not exist in the data collected for OECD and G20 countries) and also when a monopoly exists, i.e. situations in which state-ownership either cannot exist in the bottom-ranked 50% or is highly unlikely.

The last step of the variable construction is the aggregation to the country level and aggregation of observed data for top-ranked firms as well as observed and calculated data for bottom-ranked firms. To capture the impact of state-ownership in a regression model, the variable for state-ownership cannot ignore the absolute impact of a firm and the overall size of the market. Hence the country-level variable weighs SOE ownership with capacity owned by the SOE and relates it to total capacity in the market as a proxy for market impact. Accordingly the variable is:

$$Capacity\ share\ of\ SOE\ ownership = \frac{\sum_i^{I_{top50}} SOEown_i \cdot Capacity_i + \sum_j^{I_{bottom50}} SOEown_{bottom50} \cdot Capacity_j}{\sum_k^{N=I_{bottom50}+I_{top50}} Capacity_k}.$$

Note that ownership for $SOEown_i$ is defined as ownership shares of the state where the enterprise has its main operation base, but also includes values of foreign companies. That means that the variable captures the influence of foreign-owned SOEs on the domestic market but not the foreign influence within domestic SOEs. Further, the three variables eventually used in the regression model make a distinction between a full ownership, i.e. only $SOEown_i = 1$ are admissible, an ownership of at least 50%, i.e. $SOEown_i \geq 0.5$, and any type of ownership, i.e. $1 \geq SOEown_i \geq 0$. For the full ownership and ownership of at least 50% variables, all SOE ownership values that do not qualify are set to 0.

A.1.2 Construction of the vertical separation variable

The vertical separation variable takes into account the regulatory stipulations for the unbundling of the electricity supply chain, which pertains to the degree to which potentially competitive segments of the electricity sector (generation, trading, and supply) are separated from the natural monopolies of electricity transmission or distribution. The data used in this paper is based on the OECD indicators of regulation in non-manufacturing sectors (NMR), which measure regulation at the sector level in 35 OECD countries and in another set of non-OECD countries (see OECD Product Market Regulation Homepage and Koske et al., 2013). To complete the dataset, data on the nature of vertical separation in China, the US, India, Russia, Indonesia, Spain, and Norway between 1998 and 2003 was collected based on comprehensive literature review of the electricity market policies of the respective countries.

To measure the vertical separation of electricity distribution and transmission from the competitive segments of the industry, a value of 4 is accorded if the law demands full ownership unbundling. If the minimum level of separation consists in the legal separation of competitive and monopolistic segments, a value of 3 is accorded if it applies to the entire industry whereas a value of 2 is accorded if it only applies to large market players, which is often the case for electricity distribution. A mere separation of accounts of competitive and monopolistic segments within the same firm is valued at 1. If the law does not demand any vertical separation at all a value of 0 is accorded. In the end, the vertical separation values of electricity distribution and electricity transmission were added and averaged for every country for each point in time to come up with a single measure of vertical separation.

A.1.3 Construction of the third party access variable

The third party access (TPA) variable measures the degree to which independent power producers have a right to access the electricity transmission grid. The data used in this paper is based on the OECD indicators of regulation in non-manufacturing sectors (NMR), which measure regulation at the sector level in 35 OECD countries and in another set of non-OECD countries (see OECD Product Market Regulation Homepage and Koske et al., 2013). To complete the dataset, data on the nature of third party access in China, the US, India, Russia, Indonesia, Spain, Norway, and Malta between 1998 and 2003 was collected based on comprehensive literature review of the electricity market policies of the respective countries. If the law of a country does not include any stipulations for third party access to the network a value of 0 is accorded. If the law foresees TPA, but doesn't provide any rules for how network operators have to grant it, a value of 1 is accorded (negotiated TPA). If the law foresees TPA and stipulates rules for how it has to be granted (e.g. with relation to the tariffs the network operator can demand), a value of 2 is accorded (regulated TPA).

A.1.4 Methodology and full results table

The econometric strategy of the regression analysis is to estimate the effects of determinants on investments first in a *basic* regression model and then to test the robustness of this model by testing various iterations of subsamples and variable sets, such as samples containing particular countries. The following section describes the estimation strategy for the basic investment model, which is analogous to the models used for the robustness checks. It includes an abbreviated description of the *least absolute shrinkage and selection operator (lasso)* methodology used for variable selection.

The regression model analyses the impact of independent market structure, climate policy, investment environment, and control variables on the volume of investment in the renewable power sector. Using the basic investment model as basis, the methodology outlined is also used for additional models with sub-sample data and models testing the influence of interactions between market structure variables and climate mitigation policies.

The empirical specification for renewable power investments follows the working hypothesis that both climate mitigation policies and investment environment variables influence these investments. Accordingly data are fitted to a Poisson model with the following equation:

$$Investment_{ist} = \exp(\alpha + \beta'_1 \mathbf{Market\ Structure}_{ist} + \beta'_2 \mathbf{Climate\ Policies}_{ist} + \beta'_3 \mathbf{Investment\ Environment}_{ist} + \beta'_4 \mathbf{Innovation\ Environment}_{ist} + \beta'_5 \mathbf{Control}_{ist} + \gamma_i + \delta_s + \theta_t) + \varepsilon_{ist} \quad (1)$$

where $i = (1, \dots, I)$ indexes the country invested in, $s = (1, \dots, S)$ includes the six renewable-power sub-sectors biomass & waste, geothermal, marine, small hydro, solar as well as wind power and $t = (1, \dots, T)$ indexes the years of the investment flows.

Please note that even though the three vectors ***ClimatePolicies_{ist}***, ***InvestmentEnvironment_{ist}***, and ***InnovationEnvironment_{ist}*** are named and explained in detail in this section, they are considered vectors of control variables in this study given that their variables are not used in interactions. For a detailed explanation and interpretation of variables in these three vectors see Ang et al. (2017).

As described in detail in Ang et al. (2017), a large set of variables is considered for the five vectors of equation (1). To avoid redundancy, multicollinearity and additional noise, the *lasso* selects a subset of the considered variables for use in equation (1)'s five vectors. The following breakdown of the five vectors presents only those variables selected by the *lasso*. For a full list of variables considered by the *lasso*, please refer to Ang et al. (2017).

The vector ***Market Structure_{ist}*** is a vector of variables capturing the effect of the electricity market structure on renewables investments, described above in Section 3.3. The vector includes the *capacity share of SOE ownership* (in percent), the capacity-based *market concentration* (HHI, an index), an indicator of *third party access* to the electricity grid (rank) and the *degree of vertical separation* between production, transmission and distribution (level). Following the hypothesis on the effect of SOE ownership, capacity share of SOE ownership is expected to have a positive effect. Note that as opposed to the data used in Figure 9, the capacity share of SOE ownership used in the basic model is based on an SOE ownership definition of a state-ownership of at least 50%. *Market concentration* is expected to have a negative impact since market power of large players can be abused to deny access to market to newcomers (regardless of ownership), which renewable energy project developers are more likely to be on average. By contrast, *third party access* and *degree of vertical separation* could increase the access of newcomers and therefore both variables are expected to carry a positive sign.

The vector ***ClimatePolicies_{ist}*** is a vector of climate mitigation policy variables capturing public policies with a direct and targeted influence relevant for climate mitigation with a possible impact on renewables investments. Among the climate policy variables, the vector includes sector-specific *feed-in tariffs* (in USD per kWh, weighted with the power-purchasing agreement duration), *renewable energy certificates* (in percentage points) and sector-specific public renewable capacity tenders (*public tenders*, in MW) as proxies for three important direct policy support for renewable electricity. Data for FiTs, RECs and tenders are used as collected or updated for Ang et al. (2017), based on Haščič et al. (2015a). Further, the vector of climate mitigation policy variables includes a proxy for *explicit carbon prices* (in USD), *energy taxation in the power sector* (in USD/MWh), *public RD&D spending* (in million USD) and the amount of *fossil fuel support for power generation* in a country (in USD, as natural logarithm). Note that the data on RD&D spending is not country specific. Since many countries are missing data for many years the analysis cumulates data for all countries at the sector-year level to create *public RD&D spending* as proxy. Using the cumulated sector-year values rests on the assumption that the RD&D supported by this spending is disseminated quickly enough to have a global effect. With the exception of *fossil fuel support for power generation*, all variables in the ***ClimatePolicies_{ist}*** vector are expected to show a positive effect since they are either direct support policies of renewable power investments or cause a higher price on competing fossil fuel technologies. *Fossil fuel support for power generation* is expected to have a negative effect since it supports competing technologies to renewable power.

The ***InvestmentEnvironment_{ist}*** vector includes variables for the general investment environment possibly affecting investment in the renewables sector. Among investment environment variables the model includes *time required starting a business* (in days), *trading across borders* (index), *command and control* (index), *barriers to services* (index), *sovereign credit rating* (ranks), *credit to government and SOEs* (percent of GDP), *partial implementation Basel III-risked based capital requirement* (dummy), *partial implementation of Basel III-liquidity coverage ratio* (dummy) and *partial implementation of Basel III-leverage ratio* (dummy). With few exceptions, these variables are expected to have a positive sign in the regression either because they are expected to be conducive to renewable-power sector investments or the indices that capture the variables' effect are created so that larger values represent greater conduciveness. Exceptions are *time required starting a business*, *barriers to services*, and any *implementation of Basel III* regulation which are expected to have a negative effect on investments.

The ***InnovationEnvironment_{ist}*** vector includes variables specifically influencing the innovative capacity in a country. The vector includes the *perpetual inventory of renewable power-related patents* (patent count) as an indicator for a country's knowledge stock and *innovation spillover* (patent count) as an indicator the knowledge transfer from other countries. Both factors are expected to show a positive influence on investments in the regression analysis.

The ***Control_{ist}*** vector includes variables holding constant for factors that are neither climate mitigation policies, nor directly part of the investment or innovation environment, nor capture market structure. Though the effects of control variables might be of general interest, they mainly serve to enable unbiased results of the other variables in the regression. The control variables selected by the *lasso* for the basic investment model are: *natural resource endowment* (standardised unit), as proxy for natural conditions that each renewable energy source relies on, such as wind strength for wind energy or insolation for solar energy; *electricity generation* (GWh); and *electricity consumption* (terajoule). Even though these variables serve as controls, they are expected to have a conducive relationship with investments and therefore are expected to show a positive sign in the regression model.

Finally, γ_i controls for country fixed effects, δ_s controls for sector fixed effects and θ_t controls for year fixed effects. The remaining variation is captured by the residual ϵ_{ist} . All monetary values are in constant 2005 USD.

The estimation procedure applied to the above investment model has to account for sector-specific data which suffer from a so-called zero-inflation. The frequent occurrence of zeros in the dependent variable of the model is due to the lack of investments in some countries in some sectors in some years. While these observations could be irrelevant, disregarding all observations with a zero-investment would most likely exclude important information on the determinants of investments and would therefore likely lead to biased regression results. To counter this zero-inflation, we follow Santos-Silva and Tenreyro (2006) and use their Poisson pseudo-maximum likelihood (*ppml*) method for log-linearised models. *Ppml* is an appropriate choice since it counters the zero-inflation bias without requiring additional information on the cause of the zero-inflation. *Ppml* also has two distinct advantages over alternative 2-step approaches like a Tobit II (“Heckman”) model or a zero-inflated Poisson (*zip*) model. First, *ppml* does not have to rely on an exclusion restriction since the zero-inflation rather than selection bias is the issue. Second, the implementation of a Poisson *lasso* approach in statistical software is congruent with the *lasso* for *ppml*, whereas *lasso* for Tobit II and *zip* have not been implemented in standard software to our knowledge. As suggested in Santos-Silva and Tenreyro (2006) the regression analysis uses the Poisson Stata command with the *robust* option.

To reduce model complexity and increase interpretability, the investment model is based on a variable selection by the *least absolute shrinkage and selection operator* (*lasso*). It is not trivial to reduce the large number of possible determinants of investment in the renewable-power sector to a manageable set of relevant determinants. As Annex A.1 in Ang et al. (2017) shows, the model considers more than 70 determinants, i.e. 70 possible explanatory variables. Using all of these possible determinants in the same regression model would probably mean including redundant determinants, causing multicollinearity and creating unnecessary white noise. Since no detailed understanding of the impact and interdependence of all possible 70 measured factors exists, we rely on the *lasso*¹⁵ to select statistically relevant determinants for these vectors (Tibshirani, 1996; for an application to patents see Zachmann et al., 2015). It weighs the added model accuracy gained from including a variable in the model against the variable’s relevance for the predictive capability of the model. We restricted the *lasso* model, however, to always select market structure variables, climate mitigation variables and the fixed effects dummies. The market structure variables are variables of interest and therefore need to be included; for the climate mitigation policy variables, it is clear from previous research that they should be part of a renewable investment model. Lastly, the fixed effects are a modelling necessity for the employed panel model. Note that the application of the *lasso* to a variable set with added variables leads to a different selection of variables compared to Ang et al. (2017).

15 The *lasso* analysis was carried out using R version 2.15.3 with the “glmnet package 1.9-5”. The link for the *lasso* is Poisson, which covers *ppml* models.

Table A.1.2. Determinants of investment in renewable electricity in OECD and G20 countries from 2000-2014
(in the basic investment model, with interactions,
in sub-samples models and with alternative SOE ownership definitions)

	Explanatory variable (i.e. determinant)	Unit	Investment	Interactions	Full sample excluding China	Full sample excluding India	Full sample excluding China and India	Investment (only full ownership)	Investment (including minority ownership)
Market structure	Capacity share of 50%; incl. foreign state-ownership		2.732**	2.703**	2.177**	2.531**	1.895*		
	Market Concentration		-0.058***	-0.064***	-0.065***	-0.054***	-0.061***	-0.040***	-0.069***
	Third party access Rank		-0.232	-0.554*	-0.314	-0.225	-0.238	-0.302	-0.239
	Degree of vertical separation Level		-0.206	-0.173	-0.128	-0.186	-0.101	-0.159	-0.210
Climate mitigation policy	USD/kWh, weighted with power purchasing agreement-duration		0.082***	0.078***	0.097***	0.082***	0.099***	0.086***	0.079***
	Feed-in tariff energy Percent		0.049	0.046	0.051	0.042	0.046	0.045	0.051
	Renewable certificate								
	Public tender MW		0.289x10 ⁻³ **	0.001**	0.090 x10 ⁻³	0.278 x10 ⁻³ **	0.082 x10 ⁻³	0.296**	0.291 x10 ⁻³ **
	Explicit carbon price USD/tCO ₂ e		0.007	0.008	0.020	0.007	0.024	0.004	0.007
	Energy taxation in the power sector USD/MWh		-0.004	-0.003	-0.006	-0.004	-0.005	-0.002	-0.006
	Logarithm of fossil fuel support for power generation Ln USD		0.036**	0.036**	0.033**	0.035**	0.033**	0.032**	0.038**
	Public RD&D spending USD mln		-0.105 x10 ⁻³	-0.127 x10 ⁻³	-0.006 x10 ⁻³	-0.220 x10 ⁻³	-0.109 x10 ⁻³	-0.104 x10 ⁻³	-0.097 x10 ⁻³
Investment environment	Time required starting business Index		0.004	0.004	0.003	0.005	0.002	0.006	0.004
	Barriers to services Index		-0.460*	-0.591**	-0.363	-0.475*	-0.483	-0.501*	-0.451*
	Trading across borders Index		0.022***	0.021**	0.023***	0.019**	0.019**	0.021**	0.022***
	Command and control Index		0.377**	0.266	0.197	0.455**	0.309	0.193	0.425**
	Sovereign credit rating Ranks		0.164*	0.186*	0.282***	0.172	0.295***	0.201**	0.141
	Credit to government and SOEs Percent of GDP		0.024	0.022	0.036**	0.024	0.037**	0.027*	0.023
	Partial implementation Basel III risk-based capital requirements Dummy		0.634	0.666	0.940	0.725	1.174*	0.670	0.632
	Partial implementation Basel III leverage ratio Dummy		-0.735***	-0.707***	-0.801***	-0.807***	-0.909***	-0.732***	-0.739***
Innovation environment	Perpetual inventory of renewable power-related patents Patent count		0.214 x10 ⁻³ ***	0.215 x10 ⁻³ ***	0.049 x10 ⁻³ ***	0.214 x10 ⁻³ ***	0.238 x10 ⁻³ ***	0.219 x10 ⁻³ ***	0.211 x10 ⁻³ ***
	Innovation spillover Patent count		0.001*	0.001*	0.001**	0.001**	0.001**	0.001**	0.001*
Controls	Natural resource endowment Various units		0.212***	0.208***	0.218***	0.218***	0.217***	0.212***	0.212***
	Electricity generation GWh		0.001***	0.001***	0.002	0.001***	0.003	0.001***	0.001***
	Constant		-0.014	0.570	-0.886	-0.169	-1.238	0.410	-0.188
Interactions	Market Concentration HHI			-0.008 x10 ⁻³ **					
Robustness checks	# Public tender								
	Capacity share of 100%; incl. state-ownership foreign						0.414		
	Capacity share of Incl. foreign state-ownership								3.932***
	Observations		4202	4202	4113	4113	4024	4202	4202

Notes: The asterisk after the coefficient means that the coefficient of the variable is significant at the 10% significance level or lower, i.e. $p < 0.1$; The asterisks ** after the coefficient means that the coefficient of the variable is significant at the 5% significance level or lower, i.e. $p < 0.05$, The asterisks *** after the coefficient means that the coefficient of the variable is significant at the 1% significance level or lower, i.e. $p < 0.01$; source: based on authors' calculations.

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