Does Decentralization matter for Renewable Energy Sources?

The impact of governmental decentralization
on the renewable energy transition.

Thesis
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Presented by:
Tobias Albrecht. *Universitat de Barcelona, School of Economics*

Thesis Advisor:
Professor Enrique López-Bazo. *Universitat de Barcelona, School of Economics*

Abstract
The human impact on the environment and climate is growing at an alarming speed, as about half of the cumulative anthropogenic CO_2 emissions have occurred since the 1970's. International efforts to limit the rise in global temperature to 1.5°C above pre-industrial levels are undertaken and the reduction of emissions in the energy sector plays a crucial role in this process. Based on the decentralized character of most clean technologies and the policy-based property of the energy transition, this study investigates the impact of (governmental) decentralization and its interdependency with institutional quality on the renewable energy development. For this purpose, a panel data sample, containing 63 developed and developing countries over the time-period of 1990 to 2015 is deployed and econometrically evaluated. The results indeed verify a promoting effect of decentralization and its crucial relationship with institutional quality, although, emphasizing its conditional robustness to alternative outcome variable and model specifications. Furthermore, the findings suggest a significantly heterogenous impact of decentralization depending on the level of development and the associated level of institutional quality. The results imply the importance of a simultaneous strengthening of the institutional quality in combination with decentralization to sustain an enhancing impact on the renewable energy deployment.

Keywords:
Renewable Energy Transition, Renewable Energy Deployment, Decentralization, Institutional Quality, Panel Data

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1. Introduction

Over the last decades, the human impact on the environment and climate is growing at an alarming speed. The anthropogenic greenhouse gas (GHG) emissions, mostly driven by economic development and population growth, have increased since the pre-industrial era and reached levels unprecedented in the last 800,000 years (IPCC, 2014, p.44).[1] The rise in carbon dioxide is up to 10 times faster than any sustained rise in CO_2 during the mentioned time period and its concentration was similar for the last time 3.3 to 3.0 million years ago (IPCC, 2018, p.54).[2] The pace of this trend is impressively shown by the fact that about half of the cumulative anthropogenic CO_2 emissions have occurred since the 1970's and CO_2 emissions from fossil fuel combustion, cement production and flaring have tripled since then (IPCC, 2014, p.45). The increased concentration of anthropogenetic CO_2 in the atmosphere is the largest contributor to radiative forcing and henceforth main driver of *global warming*. This rise in the average global temperature is estimated to be approximately 1.0°C compared to pre-industrial levels and already resulted in stark alterations of natural systems, causing increased occurrences of floods and droughts, but also a rise in sea level and a general loss of biodiversity (IPCC, 2018, p.53). This development, concentrated since the mid-20th century, led many scientists to assess and debate the beginning of a new geological epoch – the so-called *Anthropocene* – underlining the human impact on the global climate (IPCC, 2018, p.54).[3] Some scientists even refer to the *Capitalocene*, emphasizing the impact of the specific social structure, rather than the species-wide influence on the climate (Malm & Hornborg, 2014, p.67).

Regardless of the exact designation of the current time period, the extent of the anthropogenic impact on the environment and climate becomes apparent and emphasizes the necessity of global actions against the recent developments. Starting with the foundation of the *Clube of Rome* in 1968 and its report *The Limits to Growth* in 1972, first concerns regarding the relationship of economic growth and the finiteness of the earth's resources were proclaimed. In the 1990's, with the formation of the *United Nations Framework Convention on Climate Change* (UNFCCC) and the signed *Kyoto Protocol* – the first international agreement on climate actions – introductory negotiations and agreements were undertaken with the intention to limit global warming and prevent an even more severe global climate crisis. These international efforts were followed by the *Paris Agreement*, which defines the goal to limit global warming to 1.5°C above pre-industrial levels (United Nations, 2015, p.3). Key measure to achieve this goal is the reduction in GHG emissions. With the energy sector, including electricity and heat production, being one of the largest emitting economic sectors – emitting about 35% of the total global GHG emissions (IPCC, 2014, p.46)[4] – it is not only crucial to ultimately mitigate emissions in the sector by deploying energy from renewable sources (RES), but also pivotal to know and understand the determinants of the underlying renewable energy (RE) transition.

Based on the decentralizing and policy-driven character of this RE transition, the crucial role of the institutional framework becomes apparent. On the one hand, an equally decentral organized state could be potentially advantageous for the transition due to three identified and discussed

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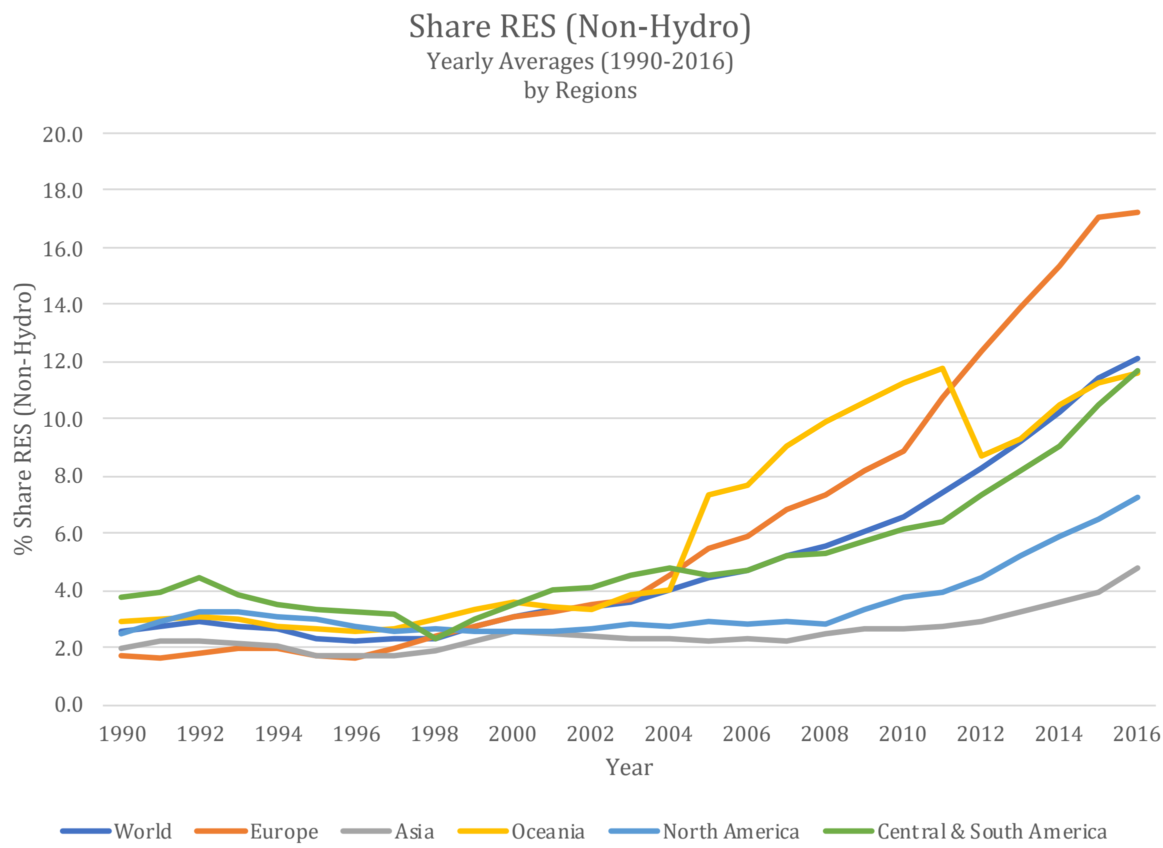
[1] Anthropogenic Greenhouse Gases (GHG) refer to carbon dioxide (CO_2), methane (CH_4) and nitrous oxide (N_2O) generated by human activities.
[2] During the geological epoch of the Pliocene.
[3] The official "current" geological epoch of the Holocene, adopted in 1855 by the geological science community, is characterized by relatively warm and stable climate conditions, starting about 11,700 years ago (Waters et al., 2016).
[4] In 2010.

channels: i) The *Efficiency Channel*; ii) The *Democratization Channel*; and iii) The *Regional Policy Channel*. On the other hand, the dependency of the transition on public policies and the connected institutions emphasizes the relevance of the institutional quality for the transition. Therefore, the main hypothesis of the study is that *(governmental) decentralization*, in combination with *institutional quality*, has a promoting effect on the RE deployment – and subsequent RE transition.

Figure 1 *Share of RES –Evolution by Region over time.*



Share RES(Non-Hydro) denotes the share of electricity generated from RES, excluding hydro-power. (Source: Own Calculations)

The literature on the link between (governmental) decentralization and RE deployment is still in its infancy and consequently scarce. It consists of only recent contributions which are limited to investigations of the link on a small(er) scale – either analyzing a single country, such as Elheddad et al. (2020) in case of China, or a small group of (homogenous) countries, such as Su et al. (2021), including seven OECD countries. Additionally, the previous literature is purely focused on measures of *fiscal* decentralization, ignoring instances like the Chinese-style decentralization – with large financial (re)distributions to sub-central government tiers and simultaneously highly restricted regional *political autonomy*. This study, on the other hand, employs a panel data set containing of 63 developing and developed countries over the time-period between 1990 and 2015, not only significantly increasing the scale of research, but also additionally deploying a more comprehensive and holistic measure of (governmental) decentralization. This measure, the *Regional Authority Index* (RAI), not only incorporates the fiscal dimension of decentralization, but also the political and administrative – equally important for RE transition. The RAI provides data on the level of decentralization for an extensive number of regions and countries, including measures for countries from broader Europe, Asia, Oceania and the Americas, allowing to significantly increase the number of included countries. It nevertheless has one drawback, as it does not include African countries – an issue which has to be addressed in future research. To verify the promoting effect of decentralization on the RE deployment, this study compiles a comprehensive panel data set with a wide range of additional controls. The discussed broader scale of the investigation allows for a subsequent analysis of potential heterogenous effects – depending on the level of development – of (governmental) decentralization, as the level of institutional quality may crucially depend on the level of development (Bardhan, 2002). Generally, this supplementary investigation of the combined influence and the interconnection between decentralization and institutional quality constitutes an equally important contribution to the existing literature – not treated to this extent by the previous literature.

The empirical findings seem to verify the previously discussed enhancing effect of (governmental) decentralization on the RE development and, additionally, highlight the crucial interconnection with the dimension of institutional quality – as the promoting effect starts to unfold from above average levels of institutional quality. This result is supported by the finding that the positive impact of decentralization is driven by developed rather than developing countries – where the latter are showing significant differences in the level of institutional quality. Nevertheless, the findings are limitedly robust to alternative measures of the RE deployment and the additional inclusion of RE policies as explanatory variables. Therefore, the findings on the link between decentralization and RE development have to be taken with caution and previous findings of the literature, confirming strong and unconditional significant impacts may be overstated due to more homogenously chosen countries and empirical settings. Yet, the findings in general seem to indicate a promoting effect and the implications from it are mainly twofold; 1) To enhance the decentralizing transformation of the energy and electricity sector and the connected establishment of new forms of energy governance, decisionmakers should seek for higher levels of regional authority, and 2) this decentralization process has to be accompanied by a strengthening of the institutional quality to ensure a promoting rather than a distorting effect of increased levels of (governmental) decentralization – an implication particularly significant for developing countries with still below average levels of IQ.

The remaining parts of the thesis are organized as follows. *Section 2* offers background information on the RE transition, formulates the theoretical argumentation and presents the findings of the previous literature. *Section 3* contains information on the sample, its variables, the data used and preliminary descriptive insights, and furthermore explains the employed methodology. *Section 4* displays the empirical findings, affiliated heterogenous and robustness analyses, and *Section 5* concludes this study by presents policy implications and a critical discussion.

2. Background

2.1 The Renewable Energy Transition

As discussed in the introduction, the reduction of emissions in the energy sector constitutes a crucial role in the ongoing actions against the consequences of climate change. As the most successful clean energy technologies are based on the generation of electricity, i.e. solar, wind or hydropower, electricity generation from renewable sources and the employed technologies occupy a pivotal role in the current (renewable) energy transition. Additionally, to the decarbonization of the energy sector itself, the increasing electrification of economic processes plays a key role (Blazquez et al, 2020, p.1).

Policymakers are promoting the substitution of previously or currently fossil fuel powered economic activities, such as raw material processing, transportation or heating, with power sources based on RES. One prominent and currently discussed example is the production of steel, highly dependent on large amounts of coal and consequently fossil fuel based energy. Efforts are undertaken to switch the energy source to "*green hydrogen*" – amongst other things produced from surplus wind or solar electricity. But also, examples such as battery-electric cars, busses and trucks show the transformation or rather electrification of the total energy composition. All in all, decarbonized electricity generation technologies occupy a prominent role in the renewable energy transition.

When broadly conceptualizing the most prevalent clean electricity technologies, a first key characteristic of the underlying energy transition can be directly derived. The technologies, such as photovoltaic (PV) and wind turbines, but also biogas and geothermal system, range from micro and small-scale applications to medium and large-scale plants. This creates, on the one hand, *electricity prosumers*, who use rooftop PV systems or, in case of farmers, wind turbines and biogas facilities, to meet the individual household's electricity needs. Whereas, medium-scale plants can create local or regional electricity-to-demand systems with potentially new stakeholders, such as energy cooperatives, municipalities or citizens' alliances. On the other hand, large-scale plants, such as large onshore and offshore wind parks, are even capable of achieving generation capacities such as conventional power plants. Although not strictly applicable, due to the described range of technologies and systems, we can generally observe a *more decentralizing* characteristic of the renewable energy transition. The energy and electricity generation transforms systems from centrally planned systems, such as conventional fossil fuel power plants, to the demonstrated more decentralized and diversified energy generation systems (Acatech et al., 2020, pp.16-23).

A second key characteristic of the ongoing energy transition is its policy driven character. Compared to previous transitions, the current must advance at an unprecedented fast rate, as it was illustrated in the introduction. Additionally, the transition is not exclusively driven by economic forces, but rather under the main goal of reducing CO_2 emissions in the energy sector – only one out of many properties of energy systems. International agreements such as the Kyoto Protocol and the subsequent Paris Agreement further underline the reliance of the transition on public interventions and policies. Policymakers have at their disposal a variety of different policy tools, such as feed-in tariffs or premiums, tax credits, certificates or renewable portfolio standards, to compensate an earlier cost-ineffectiveness of clean technologies, but also to immediately stimulate the RE deployment and henceforth imposing a positive supply shock on renewable energy. On the other hand, tools, such as carbon taxes or cap-and-trade systems, are designed to simultaneously impose a negative supply shock on fossil fuel based energy, as these mechanisms increase electricity prices from carbon-intensive energy sources. Next to the discussed supply-side influencing mechanisms and regulations, the financing of the imposed policies and the consequences of carbon-pricing mechanisms are leading to a negative demand shock for electricity and energy in general – caused by increasing taxes and increasing prices of carbon intensive energy, products and services (Blazquez et al, 2020, p.2-3).

2.2 Decentralization

Decentralization, generally, describes the transfer of governance dimensions from the national to subnational government tiers. The *Organisation for Economic Co-operation and Development* (OECD) therefore defines decentralization as follows (OECD, 2019, p.30):

> *"Decentralisation consists in the transfer of a range of powers, responsibilities and resources from central government to subnational governments, defined as legal entities elected by universal suffrage and having some degree of autonomy."*

Consequently, subnational governments consist of their own politically legitimized executive bodies and their own administration and assets. Next to a particular decision-making power, sub-central tiers additionally feature autonomy regarding revenue spending, taxes and financial budgets. Furthermore, the concept of decentralization is about reorganizing and reallocating relationships between different tiers of governance to ultimately induce more coordination and cooperation among them. The caused reciprocal dependence on their part presupposes structural and cultural changes within the central government level itself (OECD, 2019, p.30).

The motivations behind decentralization aspirations are manifold. Factors such as the political transition in Eastern Europe, globalization and citizens' dissatisfaction with the government and their pursuit for, among other things, accountable governance systems can be seen as contributing drivers. But also, the information revolution and divisive politics may play an important part in the ongoing decentralization trends over the last decades (Ivanyna & Shah, 2012, p. 2).

The process of decentralization, as discussed above, is from a multidimensional character and consists of three main dimensions; fiscal, political and administrative decentralization. All three facets are interlinked, mostly depend on each other and rarely occur as independent phenomena. *Political Decentralization,* in this context, lays out the legal basis, implying a new distribution of political powers to sub-national or sub-central tiers of government. The objectives behind such delegation of power can be various, as, for example, the strengthening of democracy by redefining the selection procedure of subnational administrators – i.e. through regional elections instead of appointments by the central government.

Administrative Decentralization, on the other hand, involves the reorganization and reassignment of administrative tasks and functions – such as planning, financing and management decisions – among different levels of governance. The main objectives behind such administrational reorganization are driven by considerations regarding increased efficiency, effectiveness and transparency of a nation's government system – initiated by research of Oates with his 1972's seminal paper regarding the efficiency of fiscal decentralization.

Finally, *Fiscal Decentralization* depicts the (re)assignment of fiscal responsibilities between central and sub-central levels of government, such as taxing and spending autonomies. In this context, higher levels of fiscal decentralization imply increased amounts of financial resources for lower government tiers, but also greater autonomy in financial management decisions – i.e. tax base, rate or spending decisions (OECD, 2019, p.31).

2.3 RE Transition, Decentralization & the Institutional Framework

Based on the previously discussed characteristics of the renewable energy transition, i.e. the decentralizing effect and its policy focus, the central role of the institutional framework becomes apparent. The increasingly decentralized character of the energy sector, resulting from the rising share of small and medium-sized energy and electricity projects, raises the question if a similarly decentral organized state or government system is advantageous – compared to a more centrally organized one. At the same time, the dependency of the transition on public institutions and policies emphasizes the significance of the quality of the institutions itself. Consequently, the main hypothesis of the here presented work is that governmental decentralization has an enhancing effect on the RE development, i.e. the renewable energy transition. This hypothesis is based on several mechanisms through which governmental decentralization is potentially positively influencing the RE deployment, which are discussed in detail below. Additionally, the crucial and contemporaneous role of the institutional quality itself is accounted for by additionally making the hypothesis that institutional quality, too, has a promoting impact on the RE development. Here, the focus lies on its general relationship and interactions with governmental decentralization, as a decentral organized state itself not necessarily implies or rather generates a promoting effect on the RE deployment.

2.3.1 Governmental Decentralization

There are three key mechanisms through which (governmental) decentralization is potentially promoting the RE deployment, which are based on considerations regarding efficiency, democratization and regional policies.

The *Efficiency Channel* directly rests on the so-called "Decentralization Theorem" from Wallace E. Oates (1972) which constitutes that "in the absence of cost-savings from the centralized provision of a good and of inter-jurisdictional externalities, the level of welfare will always be at least as high (and typically higher) if Pareto-efficient levels of consumption are provided in each jurisdiction than if any single uniform level of consumption is maintained across all jurisdictions" (Oates, 1972, p. 54). Due to the heterogeneity of preferences among sub-national or local territories, the government structure should be decentralized to achieve a higher sensitivity and efficiency regarding the specific needs and environments of the individual regions (Oates, 1999, p.1122). This general mechanism of higher efficiency in delivering public services can be directly applied to the specific topic of RES, due to the earlier discussed characteristic. Especially, compared to the spatial bureaucratic requirements of fewer and centralized energy facilities, which can potentially be easily condensed and accomplished by central authorities, the large, rapidly growing and geographically distributed number of RES plants and facilities can be potentially better processed by regional and local authorities with more political and fiscal autonomy – as these authorities are better informed and more efficient in the approval processes. Poggi et al. (2018) emphasize the complex and demanding balancing act of the implementation of RES plants, between land use and protection of the environment and stress the link of the implementation of RES and the local decision-making process for an efficient, balanced and sustainable zoning in rural areas. Indications that more decentralized governments are potentially better adjusted for the requirements of increasing RE deployment.

The *Democratization Channel* is considered to be an essential part of political decentralization, as the vertical division of power is enhancing communication tools and the involvement in formulating policies and is thereby promoting active participation and engagement of local citizens (Moisiu, 2014, pp.460-461). This mechanism is shown in the increasing importance of so-called citizen-owned or community energy projects – local energy investments which are installed and managed individually or by local communities and initiatives (van der Schoor & Scholtens, 2019). Next to '*grassroots*' energy projects of citizens, also the significance of local or municipal utility corporations is increasing in the transition process. So, for example, in Germany, where over the last two decades several earlier privatized local utility companies were remunicipalized – in some cases after the active involvement of citizens through referendums. In just seven years over 72 new local power companies were founded which depict a key facilitator of the German energy transition, as many municipalities set ambitious targets to achieve 100% renewable energy or zero-impact communities. As the overall objective of remunicipalization is directly linked to the constitutional right of municipal self-government and implies autonomously developing local infrastructure, the central role of decentralization for this process has to be emphasized (Wagner & Berlo, 2017, p.398).

The *Regional Policy Channel*, the third mechanism through which decentralization is potentially enhancing RE deployment, is based on heterogenous regional interests and the resulting RE policies. As emphasized by Poggi et al. (2018), the energy transition is providing substantial potentials for rural and peripheric areas. Due to low population densities and available land for the implementation of RES facilities, like solar parks or wind farms, these areas can benefit from the increasing extension of RES. But also on a larger regional level the opportunities for structurally weak regions are large, as multiple studies have shown the positive impact of RES on regional economic performances (for an overview see Jenniches, 2018). Sub-national authorities, when equipped with sufficient political and fiscal power, can define their own RES strategies and policies, independent from the central government line, as shown by the German Federal States (Ohlhorst, 2013, pp.52-54). Additionally, Melica et al. (2018) stress the vital role of regions and provinces in supporting local and municipal participation in the energy transition process, due to motivating and coordinating potentials.

2.3.2 Institutional Quality

Institutional Quality, generally, represents a collective term for the goodness or efficiency of different dimensions of a country's institutional framework, ranging from levels of corruption or democratization to the administration's bureaucratic quality or efficiency. The previously discussed *energy democratization* process, potentially enhanced by political decentralization, is fundamentally political and exhibits strong political tensions. The high complexity of the development demands strong coordination and participation of the public sector (Burke & Stephens, 2018). Next to this, also the previously discussed *policy-driven* character of the RE transition emphasizes the relevance of the institutional framework's quality. The new and locally organized licensing processes, with the discussed novel forms and increasing amounts of entrepreneurs and stakeholders, but also the connected substantial flows of funds – in form of subsidies – can potentially give rise to criminal activities and corruption, leading to the exploitation of the public policy structures (Gennaioli & Tavoni, 2016). This emphasizes the supplementary importance of the institutions' quality, next to the impact of governmental decentralization for the RE transition. Accordingly, Uzar (2020) derives different channels through which an increasing institutional quality potentially positively affects the RE development.

Corruption is one of the most significant dimensions of institutional quality. High levels of corruption hereby negatively influence the level of RE investment by either affecting the response of politicians to the citizens' environmental preferences, as officials are prone to maximize their own interests, or, additionally, through the mechanism that high levels of corruption potentially favor the influence of lobby groups, especially lobbies of traditional (conventional) energy companies (Uzar, 2020, p.593). Regarding this mechanism the empirical literature finds, for example, that high levels of corruption and political instability cause a loosening of environmental policies (Frederiksson & Svensson, 2003). These weakened environmental regulations, on the other hand, can impair RE investments.

Democracy is another crucial component of the institutional quality. Institutional transparency, freedom of information and speech, but also citizens' democratic participation in general facilitate people to find out about environmental issues, express their demands freely and put pressure on governments to improve the quality of their environment (Payne, 1995). Opposingly, in autocratic societies, elections and environmental regulations can be strongly influenced by lobby or interest groups, as the citizens' rights to vote and be elected are restricted and universal and free debates on basic topics, but also the environment are missing and repressed (Sequeira & Santos, 2018).

From an impartiality perspective, the *Bureaucratic Quality* constitutes a pivotal role. Generally, the quality of the bureaucratic system and its agents is from central importance for the planning, implementation and supervision of environmental policies, especially relevant regarding the policy-driven renewable energy transition (Ringquist, 1993). Furthermore, increases in bureaucratic quality are hereby implying improved decision making autonomy of bureaucrats and therefore constitute their resilience in the face of political power and pressure (Law et al., 2015). This issue is from crucial significance and enables the possibility that for the society not beneficial policies, initiated by the influence of interest groups, can be prevented or redesigned (Acemoglu et al., 2001).

Finally, institutional quality, more precisely *Law and Order,* is likely to have a RE deployment promoting effect, as "RE projects, like other types of investment projects, benefit from general political stability, sound regulatory frameworks, effective governance and secure property rights" (Brunnschweiler, 2010, p.251). Guaranteeing judiciary independence, the rule of law, property rights and enforcing contracts in general are economic activity and investment promoting factors, crucial for high-cost investments such as in RES (Acemoglu & Johnson, 2005). Having these basic legal conditions not fulfilled generates an environment of uncertainty, a key inhibiting condition for investors, reducing or stopping new (RE) investments (Uzar, 2020). Additionally, the institutional quality in general could provide information about and be linked with the financial sector development in particular which is from crucial relevance due to the described high-cost investments of RE projects (Brunnschweiler, 2010, p.251).

2.4 Other Determinants of RE Deployment

Next to key hypotheses of this work, the promoting effect of governmental decentralization and its interaction with institutional quality on the RE deployment, other RES determinants of the empirical literature are examined – to ultimately empirically control for additional influences. Following Bourcet (2020), the remaining empirical determinants, next to the previously discussed political dimension, can be divided into five categories, dominated by the category of *economic variables*. Here, income, mostly taken as GDP per capita, is the most commonly used variable. It is argued that increases in income potentially lead to a higher energy consumption, including the consumption from RES (Bourcet, 2020, p.7). Furthermore, some authors argue that higher income could increase the financial means and resources for investments into the capital intensive medium and large-scale RE plants and projects (Pfeiffer & Mulder, 2013). Some authors even directly include variables connected to the development of the financial or banking sector, based on the same intuition and expected influence. Additionally, higher levels of income could more efficiently fund regulatory incentives supporting RE deployment. All argumentations state a positive expected impact on the RE development, with an important relativization, as from a certain income threshold the impact could be indeed negative, due to a lacking ability of RES to immediately meet increases in the energy demand (Cadoret & Padovano, 2016). Another included variable is the price of fossil fuel energy, emphasizing that fossil and renewable energy sources are potential substitutes. This implies that increasing fossil fuel prices are expected to lead to decreasing fossil fuel consumption and henceforth to increasing RE deployment – a so-called *substitution effect* (Sadorsky, 2009b). Nevertheless, there is no clear consensus about this relationship in the literature. The same applies for the influence of general energy or electricity prices on the RE deployment, another determinant used in the empirical literature (Bourcet, 2020, p.7). Regarding a technological dimension, some authors include controls for the size of international flows, such as trade openness or foreign direct investments (FDI), to depict technology and knowledge transfers. A more open economy is expected to have a positive influence on the RE deployment, although the impact might crucially depend on otherwise connected determinants, like the general level of human capital or environmental regulations (Pfeiffer & Mulder, 2013).

Environmental variables depict another category of determinants. These variables are mostly related to GHG or CO_2 emissions and are used as substitutes for environmental concerns and degradation, leading to the expectation that increasing emissions positively affect the RE deployment. Opposingly, Marques & Fuinhas (2011b) argue that a negative impact of increasing emissions on RES could be explained by the indifference of societies regarding environmental issues, upholding the engagement with conventional and fossil fuel energy forms. According to Valdés Lucas et al. (2016) the effect of strong fossil fuel lobby groups balances out the environmental friendly sentiments and policies in the society.

Furthermore, *energy variables* are included in empirical analyses, controlling for country specific characteristics of the energy sector. One frequently included variable is the total energy (electricity) consumption with a rather unclear expected effect on RE deployment, as increases in the consumption could be met with both energy sources (Bourcet, 2020, pp.7). Another variable, the weight of other sources in the energy and electricity mix, is expected to have a negative impact, based on the idea of a strong lobby effect of the existing conventional fossil fuel based energy technologies and their past and present dominance in terms of investment or employment (Marques et al., 2010). But also the low carbon intensity of nuclear and hydro power implies that an extensive deployment of such has an expected negative effect on the RE development (Pfeiffer

& Mulder, 2013). The issue of energy security, represented by variables such as energy import dependency or electricity imports, has an expected positive effect on the RE development, in the sense that decreasing energy imports, in order to achieve energy self-sufficiency, have an enhancing effect on the deployment of RES (Marques et al., 2010).

As analyzed before, the renewable energy transition is characterized to be policy driven. Based on this consensus in the literature, also *regulatory variables*, next to the discussed political dimension, are expected to have a positive effect on the RE deployment. These regulatory variables are mostly linked to RE support policies which are expected to generally have a supporting impact on the RE development. In the literature this relationship is either investigated by including diverse categories of support policies, on the aggregate or rather country wide level, or by analyzing individual support measures on the disaggregate level (Bourcet, 2020, p.8).

Finally, *demographic variables* are used as determinants, even though to a lesser extent, to control for population size or growth, whereas the expected sign is rather unclear. Increases in population indeed increase the energy demand, although, if the population growth is too high, conventional energy sources might be preferred, discouraging RE deployment (Aguirre & Ibikunle, 2014).

2.5 Findings of the Literature

Following Bourcet (2020), *Table 1* shows an overview of the empirical findings on the traditional determinants of RE deployment in the literature. Concerning only a few determinants consensus emerges in the literature. First, a positive influence of RE support policies, Kyoto Protocol ratifying countries and population size, and, second, a negative impact of lobby effects from conventional (fossil fuel) energy sources. Regarding the remaining determinants, deviating results are found, depending on the individual research settings and scopes. Additionally, due to the usage of a variety of measures for RE deployment as the dependent variable – ranging from per capita levels, through shares of energy supply and energy consumption, to installed capacities – the results are further divergent, as the determinants' influences can vary significantly, depending on the exploited measure (Bourcet, 2020).

Bourcet (2020), based on the conducted systematic literature review, concludes that, overall, the inclusion of *institutional quality* variables suggests a positive relationship to RE deployment. Similarly, Mehrara et al. (2015) find that *political stability* positively affects the RE consumption, retrieved from an empirical analysis of traditional and institutional drivers in Economic Cooperation Organization (ECO) countries from 1992 to 2012.[5] In case of the European Union, Cadoret & Padovano (2016) analyze the political factors affecting RE deployment, additionally comparing their explanatory power to economic and environmental determinants. They find that *lobbying* negatively, whereas measures of *government quality* and left-wing parties positively affect RE deployment. Gatzert & Kosub (2017), on the other hand, study policy and regulatory risks determinants of RES investments, suggesting that both risk dimensions are important for investments in RES. Regarding the relationship between *democracy* and RES, Sequeira & Santos

[5] The ECO, established as Regional Cooperation for Development (RCD) in 1964 by Iran, Pakistan and Turkey, is an intergovernmental regional organization encompassing countries from Europe, Caucuses and Central Asia, Middle East and South Asia, connecting Russia to the Persian Gulf and China to Europe. The overall objective of the Organization is the sustainable economic development of its Member States and the Region as a whole. Today it consists of ten countries, additionally including Afghanistan, Azerbaijan, Kazakhstan, the Kyrgyz Republic, Tajikistan, Turkmenistan and Uzbekistan (ECO, 2021).

(2018) conduct a literature review and a subsequent empirical application of more than 100 countries and find that democracy positively affects RE consumption. Finally, Uzar (2020) is examining the influence of institutional quality on RE consumption in case of 38 developing and developed countries from 1990 to 2015 and shows that institutional quality enhances RE consumption. And Mahjabeen et al. (2020) find that a *powerful institutional framework* is a crucial requirement to transform the economy towards more RES and improved environmental conditions.

Table 1 *Empirical Findings for main independent Variables by types of samples of Countries.*

Independent Variables	Global	Developing	Developed(European)	Developed (Global)
Socio-Economic Variables				
Income	NC	+	-	NC
Fossil Fuel Prices	NC	NC	NC	NC
Local Financial Sector	NC	(NC)		
Energy/Electricity Prices	(NC)	(-)	(NC)	(NC)
International Flows	NC	(NC)		
Population Size	(+)	(+)	(-)	
Environmental Variable				
CO_2 Emissions	NC	NC	-	NC
Energy Variables				
Energy/Electricity Consumption	NC	(NC)	(+)	NC
Other Sources in the Mix	-	(NC)	-	(NC)
Energy Security	NC		-	(NC)
Fossil Fuel Production	(NC)	(NC)		(NC)
Regulatory Variables				
RE Support Policies	NC	(+)	(+)	NC
Kyoto Protocol	(NC)	(+)	(NC)	(NC)
Political Variable				
Institutional Quality	(NC)	(NC)	(+)	

Amended from Bourcet (2020). "NC" stands for *Not Clear*, implying that no clear relationship was found in the analyzed papers. "+" and "–" represent a positive and negative impact of the variable, respectively. Results in parentheses relate to less than 5 papers with the independent variable of interest.

Most of the empirical literature regarding *(governmental) decentralization* is focused on its impact on various environmental quality or policy indicators rather than the direct influence on RE deployment. For example, Zhang et al. (2017) use panel data on 29 Chinese provinces to analyze the impact of fiscal decentralization on environmental policies – in order to investigate the '*green paradox*'. The authors find that policies alone can promote reductions in emissions, but that the Chinese fiscal decentralization is opposingly promoting higher emissions – the just described green paradox (Zhang et al., 2017). The impact of fiscal decentralization on CO_2 emissions, also for China, is investigated by Cheng et al. (2021). The authors find that technological innovation, fiscal decentralization and globalization negatively affect CO_2 emissions, evidence against the previously discussed green paradox and in favor for a positive impact of decentralization on environmental parameters (Cheng et al., 2021).

A more systematic approach is contributed to the literature by Brown et al. (2015). This paper from the *Renewable Energy and Decentralisation* (READ) project establishes the common foundations of the linkage between decentralization and RES and emphasizes the crucial role of local and decentralized energy governance (Brown et al., 2015). On an applied level the literature is marked by a couple of case studies. One investigates different municipal energy planning strategies in Denmark, concluding that both spheres, centralization and decentralization, are needed to perform a synthesis between the central and municipal energy planning strategies (Sperling et al., 2011). The other case study investigates the relationship and complex interdependencies of both aspects, applying the topic on Kenya and Malawi – as both countries are facing a decentralization process. The authors conclude that the effect of decentralization is rather mixed and crucially depends on the individual political environments (Zalengera et al., 2020).

The empirical literature on the direct link between decentralization and RES is sparse. Elheddad et al. (2020) analyze the impact of fiscal decentralization on the total energy consumption – measured as electricity consumption in million kWh – of 31 Chinese provinces between 2006 and 2015, concluding that fiscal decentralization shows a non-linear relationship with energy consumption (U-shape), first increasing and then decreasing the consumption. The most relevant study for the present work, on the other hand, is Su et al. (2021), incorporating both fiscal decentralization and political risk, a potential proxy for institutional quality, as new determinants of renewable and non-renewable energy consumption – measured as the percentage of the total energy consumption. The authors apply an time-series focused empirical model on seven OECD countries over the time period of 1990 to 2018 and the results show that fiscal decentralization, decreased political risk and eco-innovation promote RE consumption (Su et al., 2021). Generally, as the empirical literature review shows, the previous investigation of the link between (governmental) decentralization and RE deployment is limited to only individual or a small number of countries – more importantly developed countries –, is ignoring the potentially relevant interdependency between decentralization and institutional quality and is focusing on the fiscal dimension of decentralization only.

Consequently, this research contributes to the literature by, generally, extending the scarce literature on the relationship between decentralization and RE deployment, by extending the scope to a wider and more heterogenous range of selected countries. Additionally, in contrast to earlier research which focused on *fiscal decentralization*, a different measure for the level of decentralization is applied, better incorporating the different dimensions of (governmental) decentralization. Finally, the influence of institutional quality and its relationship with (governmental) decentralization is studied in more depth.

3. Methodology

In contrast to the discussed previous literature, which employed data on individual or small samples of countries and used panel data time-series approaches to investigate the impact of decentralization or institutional quality on the RE deployment, this study focuses on the inclusion of a wider and more heterogenous range of countries into the analysis. In this regard, if the number of panels and the heterogeneity of such increases, time-series oriented approaches seem to pose difficulties to be adequately applied. The study deploys a data sample containing of 63 developed and developing countries from five regions of the world, namely broader Europe, Asia, Oceania and the Americas. *Table 5* of the *Appendix* contains a detailed overview on the included countries. The choice of countries is mainly influenced by data availability issues. As the measures for decentralization and institutional quality depict the main variables of the investigation, the countries are included depending on the data availability of the individual indicators. According to the aim of the study and the discussed characteristics of the sample, a panel data sample with five-year spans is build which is strongly balanced, whereas the period of investigation stretches from 1990 to 2015.

3.1 Variables & Data Sources

3.1.1 Outcome Variables

The empirical literature on the determinants of RES utilizes a variety of measures as dependent variables – i.e. the RE deployment. The main dependent variable of this study is the *Share of RES* which denotes the share of electricity generated from renewable energy sources – in relation to the total electricity generation. This specification operates as the benchmark in the later applied robustness check, as the measure best incorporates the underlying electricity mix characteristics. It is from relative nature and takes into account all dimensions of potential determinants of the electricity demand; the population, the energy consumption and the composition of the energy sector. In the case of this measure as the dependent variable, changes in such can interpreted in the most consistent manner. Additionally, to the above discussed dependent variable *Share of RES* for the main empirical investigation, two further measures are considered in the analysis as a robustness check. On the one hand, the *RES Generation* in absolute terms and, on the other hand, the RES Generation *per Capita*. The former is measured in *billion kWh* and the latter in *kWh per inhabitant* – derived by the division of the absolute generation by the population. Generally, all discussed measures do not include electricity generated from hydro-power facilities, such as dams or pumping power plants. There are two main reasons for the exclusion of these energy sources. First, compared to the earlier discussed other clean electricity technologies, hydro-power constitutes a rather old technology, already employed for a long time period. The focus of this study though, lies on the development and determinants of the recently employed technologies, such as solar PV or wind turbines. And, second, unlike these technologies – which are theoretically unboundedly installable – the technology of hydro power shows limitations regarding this matter due to space and geographical dimensions. All electricity data is retrieved from the *U.S. Energy Information Administration* (EIA). The principal agency of the U.S. federal statistical system collects and analyzes independent and impartial energy information to support policymakers and markets and to promote public understanding of energy, especially its interactions with the environment and economy. The administration has detailed data on electricity, energy, emissions, fuels, demographics and economics for the USA, but also for 230 current (and former) jurisdictions worldwide on monthly and annual basis (U.S. EIA, 2021).[6]

3.1.2 Regional Authority Index

Governmental Decentralization, the main determinant of this study, is proxied by the *Regional Authority Index* (RAI), based on Hooghe et al. (2016) which (now) covers 96 countries from 1950 through 2018 on an annual basis. This index measures the authority in different types of ruling exercised by regional governments within their countries. Regional authority is hereby composed by two types of ruling, which are the *self-rule* and the *shared-rule.* The former indicates the authority exercised by a sub-national or rather regional government

[6] For example, data on the former *Soviet Union* or the *German Democratic Republic* (East Germany) is available.

over those who live in the region and the latter depicts the authority exercised by a region or its representatives in the country as a whole. Both dimensions are each disaggregated in additional sub-dimensions, consisting of indicators related to political, fiscal and administrative dimensions, such as the political or fiscal autonomy or control, respectively. The main advantage of using the RAI as a measure of the level of decentralization is the just described multidimensional characteristic of the index. As indicated in the literature review, all empirical studies related to the influence of decentralization on magnitudes of environmental issues, such as emissions or the RE deployment, have used measures for fiscal dimensions only. But, examples like the Chinese-style Decentralization, with its larger distribution of financial means to sub-central units and simultaneously highly restricted regional political autonomy (Zhang, 2006), emphasize the utilization of a more holistic measure of governmental decentralization. The index is composed by the addition of the individual sub-dimensions and ultimately the dimensions of *self-rule* and the *shared-rule* and ranges between 0 and 30, whereas increasing values indicate higher levels of decentralization.

3.1.3 Institutional Quality

Institutional Quality, as a potentially important determinant of RES and, additionally, from suspected importance in relationship with (governmental) decentralization, is introduced into the model as a variable, constructed from the International Country Risk Guide (ICRG) rating by the PRS Group. The PRS Group provides ratings for 140 countries on a monthly basis, and for an additional 26 countries on an annual basis – for the time period from 1984 until now. The rating comprises 22 variables in three subcategories of risk; political, financial, and economic. The subcategory of Political Risk includes 12 weighted variables covering both political and social attributes from which the *Institutional Quality Index* (IQ) is artificially constructed. The choice of dimensions follows Buzar (2020) and Law et al. (2015), which include; Government Stability, Corruption, Law and Order, Democratic Accountability and Bureaucratic Quality. These measures are rescaled from their original range to newly range between 0 and 10 and then added up to the IQ index, which consequently ranges between 0 and 50 – where higher values indicate increased institutional quality.

3.1.4 Control Variables

The previous literature section of the study derived several groups of potential determinants of RE deployment. My study includes at least one variable for each of the discussed groups. First, socio-economic determinants. Here, as in the majority of empirical studies, *Gross Domestic Product* (GDP), in constant 2010 US$, is included in *per capita* terms. Additionally, the net inflow of *Foreign Direct Investment* (FDI) – in percentage terms of GDP – is deployed. The demographic dimension is covered by the inclusion of the country's *Population*. Next to these socio-economic variables, a measure regarding the environmental dimension is included, namely the amount *CO_2 emissions* in tons and, again, in *per capita* terms. To represent energy sector characteristics, three parameters are introduced; the share of electricity generated from *fossil fuel energy sources* – as the percentage of the total electricity generation – the share of *electricity imports* – as the percentage of the total electricity consumption – and the *electricity* *consumption* – in billion kWh. Data on *Population*, *GDP per capita*, *CO_2 Emissions*, *Foreign Direct* and *Investment* (FDI) are retrieved from the World Bank Database (World Bank, 2021).

Additionally, to control for regulatory characteristics, two dummy variables are included in the analysis. First, a variable for the implementation of a *Feed-in Tariff* (FIT) Policy and, second, a variable depicting the implementation of a *Renewable Portfolio Standard* (RPS) Policy. Both policies are designed to reduce investors' risk by artificially creating long-term markets, although they try to achieve this goal by different means. The FIT policy provides RES electricity producers with preferential prices per unit of generation (kWh) over a previously established time period – e.g. 10 to 15 years. This allows investors to securely recover their investments over time and, additionally, reduces the competitional disadvantage of RES technologies, if such exhibit too large investment costs. The RPS policies, on the other hand, establish a "quota systems" or mandates rather than financial incentives. If such policy is ratified, it requires that electricity utilities generate a previously specified percentage of their total generation or sales from RES. Most commonly, such percentual requirements start with small targets in the early years, but then raise these targets to higher values until the terminal year. The annual RPS benchmarks are then translated into individual generation levels that must be reached. Both variables take the value 1, if either of the policies is implemented in a given country, in a given year. The data regarding RE policies is based on two sources. The data is primarily based on Carley et al. (2016) which analyze the effects of different determinants on the RE development, inter alia the effect of feed-in tariffs and renewable portfolio standards. For this purpose, the authors conduct a comprehensive source and literature review in order to determine (if existing) the implementation year and application period of the two policies for a wide range of countries. An overview is presented in the paper and depicts the main source of information. As the authors conduct the review on the time-period between 1990 and 2010, this information is complemented by information from the *International Energy Agency* (IEA) for the years between 2010 and 2016, more precisely from the *Policies and Measures Database* (IEA, 2021). The detailed information can be found in *Table 18* of the *Online Supplementary Material*.

Finally, the variable *Annex B* is introduced in the analysis, not as an additional control variable but rather as a proxy for a country's commitment to fight climate change. This proxy is introduced when analyzing the effect of the above discussed policies on the RE deployment. The variable takes the value 1 from 1998, if a country is part of the Annex B of the Kyoto Protocol – only including countries which ratified the protocol together with binding emission reduction targets. The year 1998 hereby depicts the ratification year of the Kyoto Protocol. The list of countries ratifying the *Kyoto Protocol* with binding emission reduction targets can be found in the *Annex B* of the agreement (United Nations, 1998).

3.2 Descriptive Statistics

Figure 1 presents the development of the *Share of RES* over the investigated time period. For this purpose, the yearly averages of the global sample, but also of the regional sub-samples are shown. It is clearly visible that during the first years, about 1990 to 1995, there is almost no clear increasing trend. This characteristic can be explained by the rather late introduction of new RES technologies for the broader market during the 1990's. Even the Kyoto Protocol, as the first international agreement, dates back to 1998. Pioneer in the promotion of new RES technologies was Germany which ratified the worldwide first FIT policy in 1990 (Klein et al., 2007). From 1995, though, a clear increasing trend can be seen in the data. The share of RES of the global sample increased from about 3% to about 12%, which is outdone only from Europe, increasing the share to about 17%.

Table 2 presents the summary statistics of the main variables of interest, that are the alternative measures of RE deployment, the RAI, the IQ Index and GDP per capita as an indicator for the income-level heterogeneity of the sample. The results show that the overall mean share of the total sample is 5% and that the share ranges quite a lot between 0% and about 70%. The RAI also shows a large overall variation of about 10 index points, ranging from 0 to 37 – which is actually outside the range of the RAI. These values can be reached though, as the example of Germany shows, which has a mean of 36 index points – qualified by the higher number of sub-national tiers and the with it associated higher potential scoring (Hooghe et al., 2016).

Table 2 *Descriptive Statistics*

	(Share of RES)	(RES pc)	(Abs. RES)	(RAI)	(IQ)	(GDP pc)
Mean	0.054	344.122	8.972	11.672	33.277	20269.08
Median	0.018	53.618	0.905	9.812	32.153	10214.05
Maximum	0.693	15153.48	323.328	37.672	49.167	90029.36
Minimum	0	0	0	0	6.528	411.165
Std. Dev.	0.085	1179.785	29.759	10.249	9.138	19792.95
Obs.	378	378	378	378	378	378

Compared to the RAI, the IQ does not contain countries with 0 levels of institutional quality – whether starting from about 6.5 index points. The RAI, on the other hand, consists of countries indeed showing no level of decentralization at all – e.g. El Salvador and Jamaica. The statistics of GDP per capita impressively show that the here employed sample contains of a wide range of developing and developed countries – ranging from only $US 411 to about $US 90,000 per inhabitant. More detailed summary statistics are presented in *Table 7* of the *Appendix*.

Figure 2 Correlation between Variables of Interest and RE Deployment.

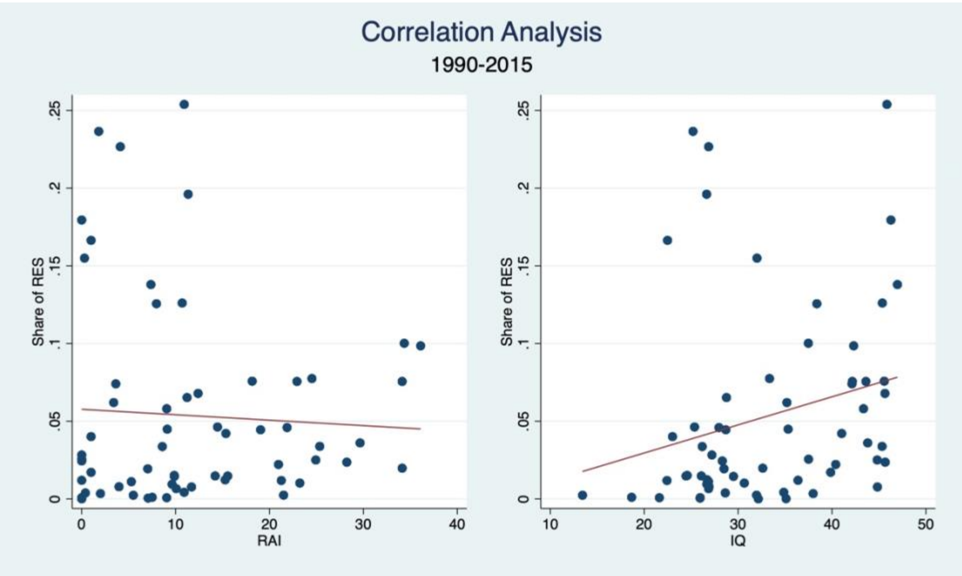


Figure 2 shows the preliminary correlation between decentralization and RE deployment, and institutional quality and the RE deployment, respectively. For this purpose, the individual panel average values of the variables are presented in a scatterplot. Regarding the level of decentralization and the connected share of RES, the relationship is rather indistinct. Although, a

potentially increasing pattern could be identified in the lower half of the graph, *outliers* – with low levels of decentralization and high levels of RE deployment – are biasing the overall relationship. Examples for such outliers could be centrally governed countries like Iceland or El Salvador, with simultaneously high levels of RE development. Consequently, the linear fit of the two variables even shows a negative slope or rather sign. The preliminary relationship between the institutional quality and RES, on the other hand, shows a more distinct distribution. A clear positive slope or rather relationship between IQ and RES can be seen, giving first indications of the relevance of the IQ for the RE transition. Some "outliers" such as Denmark with one of the highest levels of institutional quality even shows a disproportionately strong level of RE deployment – represented by the most upper and right data-point. Overall, the introductory descriptive analysis indicates a first potentially positive relationship between the two main variables of interest and the RE deployment, but simultaneously emphasize the heterogeneity of the employed sample and the connected issues regarding the isolation of a general impact.

3.3 Empirical Specification

The primary purpose of this study is to examine the promoting effect of (governmental) decentralization on the RE deployment. For this purpose the following model is specified:

$$lnRES_{it} = \beta_0 + \beta_1 lnRAI_{it} + \sum_{j=1}^{9} \beta_j Z_{it} + \mu_i + \tau_t + \varepsilon_{it} \quad (1)$$

, where $\ln RES_{it}$ represents the different measures for electricity generated from renewable sources in logarithmic form.[7] $lnRAI_{it}$ is the *Regional Authority Index*, the deployed measure of the level of decentralization, as well in logarithmic form. Z_{it} denotes the set of *Control Variables*, including controls regarding socio-economic, environmental, energy sector and policy characteristics of the individual countries. The included socio-economic variables are; the log of *GDP per capita* ($lnGDP_{it}$), the log of the ratio of *Foreign Direct Investment* over GDP ($lnFDI_{it}$) and the log of *Population* ($lnPOP_{it}$). Regarding environmental characteristics, *CO_2 per capita* ($lnCO2_{it}$) emissions are introduced into the model in logs. Finally, the log of the ratio of electricity generated from *Fossil Fuels* (FF_{it}), the log of the ratio of *Electricity Imports* ($lnEI_{it}$) and the log of the *Total Electricity Consumption* ($lnEC_{it}$) are employed to control for energy sector characteristics. In a following separate analysis the influence of RE Policies in connection with *Kyoto Protocol Annex B* countries is examined, namely the effect of *Renewable Portfolio Standards* (RPS_{it}) and *Feed-in Tariffs* (FIT_{it}), both incorporated as dummy variables. The subscripts i and t indicate the individual country and time-period, respectively, with $t = 1990, 1995, \dots, 2015$ measured in five-year intervals. The parameters μ_i and τ_t represent *Country Fixed Effects* and *Time Fixed Effects*, respectively, and ε_{it} is the error term. β_1 is the coefficient of interest, expected to be positive and henceforth verifying a positive effect of decentralization on the RE development.

Following the previous theoretical argumentation, the influence of *Institutional Quality* and, more importantly, its connection and interdependency with (governmental) decentralization is suspected to additionally play a significant role when investigating the impact of

[7] Excluding electricity generated from hydro-electric power generation facilities.

decentralization on the RE deployment. To incorporate this issue into the existing empirical strategy, the model is extended as follows:

$$lnRES_{it} = \beta_0 + \beta_1 lnRAI_{it} + \beta_2 lnIQ_{it} + \beta_3 lnRAI_{it} x lnIQ_{it} + \sum_{j=1}^{9} \beta_j Z_{it} + \mu_i + \tau_t + \varepsilon_{it} \qquad (2)$$

In this specification, the effect of the regional authority index on the RE deployment is given by:

$$\frac{\partial_{RES}}{\partial_{RAI}} = \beta_1 + \beta_3 * lnIQ_{it} \qquad (3)$$

Hence, the impact of RAI on the RES varies with the level of institutional quality positively as hypothesized in the study. The static model specifications of (1) and (2) are estimated by a *Fixed Effects* (FE) panel estimator, having the advantage of controlling for unobserved individual effects.

4. Empirical Findings

Section 4 presents the empirical findings of the study. First, the main results based on the previously derived equations (1) and (2) are shown and discussed. Following, a sub-section presents the results of a further investigation on the heterogenous impact of decentralization on the RE deployment, more specifically, analyzing the relationship of the effect of RAI with the level of development. Finally, estimation results of additional robustness analyses are presented, illuminating the effect of alternative outcome variables, as well as discussing the role of RE policies for the impact of RAI on RES. The main results are shown and discussed in the main text, whereas additional findings are reported in the *Appendix*.

4.1 Main Results

The results of the estimation of equations (1) and (2) are discussed in this section. *Table 3* presents the estimation results of the coefficients and significance levels of the parameters of interest – which are the impact of (governmental) decentralization, institutional quality and their interaction term. In case of equation (3), the *Average Marginal Effect* (AME) as well as the estimated effect at different points of the institutional quality distribution are also reported. The detailed results are presented in *Table 10* of the *Appendix*.

Column (1) depicts the results of the simplest model specification, not controlling for any type of potential influences. The estimated coefficient of RAI is expectedly counterintuitive, but significant at 5% significance level. Following, *Column (2)* controls for unobserved country heterogeneity by applying the *Fixed Effects* (FE) Estimator. Here, the coefficient of RAI remains significant at 5% and takes the value of 1.033, implying that a 1% increase in the level of decentralization would imply a 1.03 % increase in the share of RES. *Column (3)*, on the other hand, additionally controls for *Time Fixed Effects*. Note here, that the coefficient of RAI stays relatively stable at about 1.04 and significant at a 5% level. In turn, *Model (4)* introduces the first sub-set of control variables, more specifically, the socio-economic controls. They seem to capture some of the effect of the RAI, as its coefficient decreases to 0.805. In any case, the estimated impact of RAI is robust to the introduction socio-economic controls and unobserved country heterogeneity, as well as to time effects.

Table 3 *Estimation of the Effect of Decentralization.*

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
lnRAI	-0.205**	1.033**	1.044**	0.805*	0.979*	0.936**	0.982**	0.530
	(0.087)	(0.421)	(0.451)	(0.475)	(0.530)	(0.429)	(0.451)	(2.178)
lnIQ							-0.796	-0.988
							(1.119)	(1.361)
lnRAIxlnIQ								0.137
								(0.636)
AME								1.002**
								(0.462)
Marginal Effects at:								
IQ (10%)								0.959**
								(0.475)
IQ (25%)								0.978**
								(0.459)
IQ (50%)								1.004**
								(0.463)
IQ (75%)								1.040**
								(0.520)
IQ (90%)								1.051*
								(0.545)
Country FE		x	x	x	x	x	x	x
Time FE			x	x	x	x	x	x
Socio-Econ. Controls				x	x	x	x	x
Environm. Control					x	x	x	x
Energy Sctr Controls						x	x	x
N	378	378	378	378	378	378	378	378
Log-Likelihood	-837.909	-755.989	-753.382	-734.533	-725.172	-714.803	-714.085	-714.027
AIC	1679.817	1513.978	1518.765	1487.066	1470.344	1455.606	1456.169	1458.053
R^2 (within)	0.014	0.032	0.045	0.136	0.177	0.221	0.224	0.224

Dependent Variable *Share of RES*. Clustered (by country) standard errors are reported in parentheses. ***, **, and * show statistically significance at 1%, 5%, and 10% level, respectively. IQ (p%) denotes the value of the p-percentile of the distribution of IQ.

When additionally including CO_2 emissions into the estimation, as a control for the environmental conditions, the RAI coefficient is changing quite noticeable (back) to the previously established range of about 1, as can be observed in *Column (5)*. Finally, *Column (6)* additionally introduces control variables related to the energy sector. Still, a positive effect of decentralization on the RE development is confirmed even after the inclusion of a comprehensive list of controls and country unobserved heterogeneity.

So far, the specifications have not included the impact of IQ on RES. As indicated in *Section 2*, the quality of the institutional framework may have an impact on RE deployment and it can also moderate the effect that RAI has on RES. To explore this, *Column (7)* reports the results when IQ is added as an additional regressor whereas *Column (8)* shows the estimation of the specification that also adds the interaction between the two factors. As previously mentioned, in the latter case the AME is reported along the estimates of the coefficients. In addition, the effect of RAI for different levels of institutional quality are calculated and additionally presented in *Column (8)*. The AME is significant at 5% and takes the value of 1.002, verifying a significant and (similarly) strong impact (on average) of RAI on RES – such as in the previous specifications. The coefficient of RAI at the sample's 10% level of institutional quality is, compared to the previous coefficients, slightly lower – with about 0.959 – and significant. The coefficient at the sample's 25% level of institutional quality is increased to about 0.978. At the following levels of institutional quality the coefficients are increasing from 1.004 to 1.05 – values in range of the previously determined single effect of decentralization. Furthermore, all coefficients are significant at a 5% significance level. *Column (8)* depicts the preferred specification, as it is controlling for a comprehensive set of controls and potential influences, but also shows the highest explanatory power and corresponding lowest AIC. Overall, the results imply that there indeed exists a strong promoting effect of (governmental) decentralization on the RE development. Furthermore, the relationship and interdependency between the level of decentralization and institutional quality is shown. In other words, decentralization is also dependent on the quality of country institutions, as the promoting effect is increasing with higher levels of IQ.

The presented coefficients and the related significance levels of the included controls in *Table 10* of the *Appendix* show the high correlation and potential collinearity of the economic and environmental dimensions – in the form of highly significant, large and opposing coefficients of GDP and the share of fossil fuel electricity in the mix. This relationship was captured by CO_2 emissions in the model specification without energy sector variables. The positive sign for GDP and negative sign for the share of FDI are as expected from the literature review – although FDI not being significant – GDP, on the other hand, is highly significant. The coefficient related to the share of electricity imports has the expected and previously derived negative sign, but is not significant, as well. The coefficient related to the electricity consumption shows a negative sign which seems to be an indication for consumption variations over time too large to be solely driven by RES expansions.

4.2 Does the impact of Decentralization vary with Development?

After the initial validation of the promoting effect of decentralization on the RE deployment on a larger scale, a subsequent investigation and discussion regarding potential heterogeneous impacts of the parameters of interest seems appropriate. One important insight to be investigated is the influence of the level of development on the effect of decentralization. Here, in case of developing countries, the impact of decentralization and its mechanisms can potentially differ, compared to developed or rather higher-income countries. Although, the reasoning behind processes of decentralization might be the same as for developed countries, local accountability structures may not be as advanced and regional or municipal governments may be strongly dependent on "local power elites", in case of developing countries (Bardhan, 2002). These differences, inspired by the literature about the impact of decentralization on economic growth, could also potentially influence the effect of decentralization on the RE deployment, leading to deviating results. To investigate this potential heterogenous impact, in which the interdependency with institutional quality seems to occupy a central role, the countries of the sample are grouped according to the *income levels*, using the *World Bank taxonomy* – i.e.: high income, upper middle income, lower middle income and low income. The distribution of countries regarding this classifications is shown in detail in *Table 6* of the *Appendix*. Based on this classification, the countries are further clustered into *high income*, consisting of high and upper middle income economies, and *low income*, consisting of low and lower middle income countries.

Table 4 presents the estimation results of the high and low income groups. The first column depicts the previously derived preferred specification with both variables of interest and the interaction term, all control variables and the effect of RAI at different levels of institutional quality – estimated with the total (global) sample. The second column shows the results when estimating this preferred specification with high and upper middle income countries only. Compared to the estimated effects using the full sample, the effects of RAI are significant from the

10% percentile of IQ on. All in all, the variation of the estimated effects of RAI along the distribution of IQ in the sample of high income countries more or less reproduces the estimates of the whole sample, but shows decreasing rather than increasing coefficients of RAI along increasing levels of IQ.[8] This could imply that the impact of decentralization declines in the highest levels of institutional quality. Nevertheless, a significant and robust influence of decentralization and institutional quality is verified for the subset of developed countries.

Table 4 *Differences between High & Low Income Countries.*

	TOTAL SAMPLE	HIGH INCOME	LOW INCOME
lnRAI	0.530	1.402	-3.933
	(2.178)	(2.783)	(6.138)
lnIQ	-0.988	-2.074	0.597
	(1.361)	(1.319)	(5.787)
lnRAIxlnIQ	0.137	-0.130	1.223
	(0.636)	(0.758)	(1.907)
AME	1.002**	0.944*	-0.048
	(0.462)	(0.499)	(1.215)
Marginal Effects at:			
IQ (10%)	0.959**	0.985*	-0.632
	(0.475)	(0.579)	(1.494)
IQ (25%)	0.978**	0.968*	-0.128
	(0.459)	(0.536)	(1.217)
IQ (50%)	1.004**	0.937*	0.039
	(0.463)	(0.496)	(1.227)
IQ (75%)	1.040**	0.914*	0.167
	(0.520)	(0.508)	(1.271)
IQ (90%)	1.051*	0.906*	0.294
	(0.545)	(0.520)	(1.342)
Country FE	x	x	x
Time FE	x	x	x
Socio-Economic Controls	x	x	x
Environmental Control	x	x	x
Energy Sector Controls	x	x	x
N	378	306	72
Log-Likelihood	-714.027	-552.696	-142.011
AIC	1458.053	1135.392	306.023
R^2 (within)	0.224	0.107	0.437

Dependent Variable *Share of RES*. Clustered (by country) standard errors are reported in parentheses. ***, **, and * show statistically significance at 1%, 5%, and 10% level, respectively. IQ (p%) denotes the value of the p-percentile of the distribution of IQ.

The third column, in turn, shows the results for the preferred specification estimated on the sub-sample of developing countries. Interestingly, here the estimates of the effect of RAI are all far below the previously estimated parameters and insignificant. Even in case of the highest percentiles of institutional quality the coefficients are only between 0.06 and 0.08, implying almost no enhancing effect of decentralization on the RE development – provided the impact was significant. The results imply that the overall enhancing effect of decentralization appears to be rather driven by developed countries and seems to additionally support the conclusion of Bardhan (2002) on the deviating effect of decentralization in case of developing countries. As emphasized before, the interaction of decentralization with institutional quality is from crucial relevance when investigating the promoting effect of (governmental) decentralization on the RE deployment. The identified potential differences in *democratic accountability* and *corruption* – i.e. dependency on local elites – as causes for the deviating impact of decentralization in developing countries verify the importance of institutional quality for the mechanism, as both dimensions –

[8] In case of the sub-sample estimations related to different levels of development, the percentiles are in relation to the sub-samples' averages, not the global ones.

democratic accountability and corruption – are central components of the here deployed IQ index. Indeed, the figures reported in *Table 9* of the *Appendix* this conjecture appears to be verified. The level of decentralization is, on average, higher in developed than in developing countries, but, more importantly, also the level of institutional quality is substantially higher in developed countries. The results imply that the enhancing effect of (governmental) decentralization seems to unfolds from an above average level of IQ and emphasizes the discussed interaction of both dimensions.

4.3 Robustness Analysis

As discussed in the data section, the empirical literature on the determinants of RES utilizes different measures for the RE deployment. This allows for an additional robustness check by using different RES measures as dependent variables. *Table 11* of the *Appendix* presents the results of this robustness analysis. The first column shows the preferred model specification from the main empirical analysis, with the *Share of RES* as the dependent variable.

The following column presents the results of the preferred model specification with the *Absolute RES Generation* (in billion kWh) as dependent variable. Using RES generation as the dependent variable can be interpreted as analyzing the effect of decentralization on the general RE deployment, as the measure, generally, does not take into account other determining dimensions, as the before discussed variable of Share of RES. The results indeed seem to verify the previously presented outcome, as the effects of RAI at different levels of IQ are shown to be significant. The effect of decentralization appears to be robust when analyzing the effect on the absolute RE development.

Finally, the last column employs *RES per Capita* or rather RE electricity generation per inhabitant as the dependent variable. Although this measure indeed incorporates the country's population, it does not relate the derived per capita RES generation to the total electricity generation or the remaining energy sources in the electricity mix. Consequently, the measure is restrictively reliable as a measure of RE deployment and changes in the measure are conditionally meaningful. The results of the robustness check, too, seem to support this argumentation, as the marginal effects of decentralization are insignificant at all significance levels and all percentiles of institutional quality.

Additionally, the influence of RE policies on the deployment of RES is investigated. As previously discussed, the RE transition is characterized and largely dependent on public policies promoting the deployment of RES, justifying this separate and more detailed analysis. Therefore, the aim of this analysis is to check whether the main results are robust to the inclusion of specific RE policies, as it could be the case that such policies capture significant parts of the impact of RAI and IQ, due to a potentially strong collinearity – as "better" countries potentially also implement policies aiming to increase RE deployment.

The impacts of the two most commonly implemented policies, namely RPS and FIT policies, are shown in *Table 12* of the *Appendix*. *Column (8)*, as before, depicts the preferred specification. Subsequently, *Column (9)* additionally introduces both RE policies as explanatory variables. The coefficients are quite large, with 0.706 and 0.628 for renewable portfolio standards and feed-in tariffs, respectively, although with the coefficient of FIT not being significant at any significance level. The coefficient of RPS, on the other hand, is significant at a 10% level. These results imply a globally positive and significant, even though weakly significant, impact of the RPS policy on the RE deployment. And, indeed, the AME and the marginal effects of RAI at different levels of IQ show (slightly) lower coefficients and weaker significance – first indications of the discussed potential relationship. The subsequent *Column (10)* tries to capture the additional influence of a country's commitment on the effect of the RE policies and the deployment of RES in general. For this purpose *Annex B* is included in the specification, together with interaction terms of the individual RE policies with Annex B. As the variable of Annex B is identifying countries which committed to binding emission reduction targets in cause of the Kyoto Protocol, the variable is utilized as a proxy of "*commitment to the cause*". And, indeed, the single coefficient of Annex B is quite large and significant. More interestingly though, the marginal effect of the FIT policy in interaction with Annex B becomes significant, compared to an insignificant combined impact of the RPS policy and Annex B. *Tables 15 to 17* of the *Online Supplementary Material* show the distribution of Annex B countries and FIT and RPS policies by income. Analyzing these tables shows that the result might be caused by the fact that Annex B countries are almost exclusively developed or rather high income countries, based on the idea of the industrialized countries taking responsibility for their historic contribution to global emissions and henceforth global warming. FIT policies, too, are mainly implemented in higher income countries, potentially caused by the connected costs. These factors could cause the strong and significant effect of FIT policies, in combination with Annex B countries, on the RE deployment. The marginal effects of decentralization seem to verify this conclusion. The coefficients are substantially lower compared to the preferred specification and overall less significant. Furthermore, the coefficients decrease with increasing levels of IQ, potentially implying that the effects of RAI on RES at higher levels of IQ are partly (or better) captured by the newly introduced RE policies and their interaction with Annex B countries – as these countries potentially show higher levels of institutional quality. All in all, the combined effect of decentralization seems to be less robust to the inclusion of specific RE policies.

5. Conclusion

The human impact on the environment and climate is growing at an alarming speed. Anthropogenic greenhouse gas (GHG) emissions have increased since the pre-industrial era and reached unprecedented levels in recent history. The increased concentration of anthropogenetic CO_2 in the atmosphere is the main driver of *global warming,* causing increased occurrences of floods, rising sea levels and a general loss of biodiversity. International efforts to limit global warming to 1.5°C above pre-industrial levels are undertaken, with the key measure to reduce GHG emissions. The energy sector, including electricity and heat production, as one of the largest emitting economic sectors emphasizes the crucial relevance of the mitigation of emissions in the sector by deploying energy from renewable sources (RES) – shedding the focus on the determinants of the underlying renewable energy (RE) transition.

The decentralizing and policy-driven character of this RE transition stresses the relevance of the institutional framework for the development of RES, leading to the main hypothesis of the study that *(governmental) decentralization*, in combination with *institutional quality*, has a promoting effect on the RE deployment – mainly based on mechanisms concerning efficiency, democratization and regional policy. Compared to previous literature on the relationship between decentralization and RE deployment which investigated the link on a substantially smaller scale

– either analyzing a single country or a small (homogenous) group of countries – and purely focused on measures of fiscal decentralization, this study not only significantly increases the scale of research, but also deploys a more comprehensive and holistic measure of (governmental) decentralization – i.e. the Regional Authority Index. The study employs a panel data set containing of 63 developing and developed countries over the time-period between 1990 and 2015, including countries from broader Europe, Asia, Oceania and the Americas.

The empirical findings seem to verify the previously discussed enhancing effect of (governmental) decentralization on the RE development and, additionally, highlight the crucial interconnection with the dimension of institutional quality. The promoting effect seems to unfold from above average levels of institutional quality – identified by the analysis on the potential heterogeneity of the impact of RAI on RES. Developing countries, with lower levels of IQ – compared to developed countries – seem to not profit from decentralization. However, the general effect of decentralization seems to be conditionally robust to alternative specifications of the outcome variable and to the inclusion of the most common RE policies. Hence, previous empirical research on the promoting impact of (governmental) decentralization may potentially overstate the effect, due to smaller and more homogenous research settings. When allowing for more heterogeneity in the sample and, additionally, employing a more comprehensive measure of decentralization the estimated effect is still significant, but has to be taken with at least *some* precaution, due to conditionally robust findings. A result which strongly emphasizes further research on the relationship.

5.1 Policy Implications

The policy implications which can be derived from the findings are mainly twofold. On the one hand, as already indicated by earlier research and conditionally validated by the present investigation for a broader scale, the process of decentralization and the connected delegation of political, financial and administrative autonomy to sub-central tiers to enhance the participation and involvement of citizens, but also local und municipal authorities seem to enhance the RE deployment. Consequently, decisionmakers should promote the process of decentralization, either in a general application or specifically oriented to the energy and electricity sector, supporting the discussed new forms of decentralized energy systems and ownerships. The second, and potentially more significant, implication which can be derived from the here presented study is the importance of the institutional quality in connection with (governmental) decentralization. As shown, decentralization merely develops a promoting effect on the RE deployment, if it is accompanied by high(er) levels of institutional quality. Therefore, the process of decentralization needs to be supported by measures with the aim to increase IQ. This implication is from particular relevance for developing countries with substantially lower levels of IQ. In order to benefit from decentralization, policymakers are required to promote both dimensions – decentralization *and* institutional quality.

5.2 Discussion of some caveats of the Study

There is one significant drawback related to the data and several potential issues related to the econometric strategy which need to be discussed in more detail. First, as mentioned already in the data section, the Regional Authority Index is exhibiting a crucial drawback, as it is not covering any *African* country. Although, technically speaking, the African continent is continuously taking a minor role in the global economic activity, especially compared to Europe and North-America, but also compared to other emerging and developing regions like Asia or South-America, the continent is indeed facing sustained economic growth over the last decades. As pointed out in the introduction, economic development, but also population growth – particularly relevant for the African continent – are known to be the main driver of the rising GHG emission levels, which consequently emphasizes an increased interest also for Africa. Its part in the global climate crisis and its avoidance cannot be neglected, calling for a better understanding of the economic and RE conditions, respectively. Especially, from an energy point of view the continent exhibits interesting peculiarities and developments, such as the reliance on decentralized energy systems due to general energy accessibility issues and ongoing deficiencies of large-scale or rather centralized energy systems (Zalengera et al., 2020, p. 272). This is, on the other hand, one reason for the limited data availability and accuracy, as much of the energy demand is still produced locally and without sophisticated power grids – a major issue when trying to include African countries in such analyses. The lack of African countries due to the limited data availability of the RAI depicts a limitation of this study which will be addressed in my future research.

Regarding the econometric dimension, there are three main issues which potentially cause *endogeneity*; an omitted variable bias, a measurement error bias and a reverse causality bias. These concerns need to be addressed. To offset the first potential issue, the *omitted variable bias*, this study employs a comprehensive *set of controls*. As shown in the previous empirical analysis and theoretically derived in the literature part, control variables for all major RE determinant groups are introduced – i.e. socio-economic, environmental, energy sector and demographic determinants. But also, the relationship and interdependency of decentralization with other dimensions, particularly with income, need to be accounted for by the inclusion of corresponding controls to ultimately capture the pure impact of decentralization on the RE deployment (Bodman & Hodge, 2010). The relatively stable coefficients of RAI, depending on the employed set of controls, can be interpreted as a supporting indication that the individual effect of the impact of decentralization is captured by the specified model. Additionally, the country and time *fixed effects* control for other unobserved effects – specific to the individual country or as common international shocks –, allowing to neglect this potential bias with high confidence.

In terms of a bias arising from *measurement error,* several comments have to be made regarding the quality of the deployed *Regional Authority Index*. First, in my opinion with respect to previous research lies on the usage of different measures of *fiscal* decentralization, either in form of the share of sub-central revenues and expenditures or in form of the share of sub-central tax revenues. The already mentioned *Chinese-style decentralization*, with its highly decentralized fiscal, but rather centralized top-down governance system (Zhang, 2006), exemplary shows the shortcoming of only fiscally focused measures, as sub-national fiscal freedom is not necessarily accompanied by administrative or political freedom. As the main mechanisms through which governmental decentralization potentially influences the RE development are dependent on regional self-rule and political freedom, the deployment of the RAI seems more appropriate than solely fiscal oriented measures. Here, the RAI offers a more holistic approach, better capturing the different dimensions of (governmental) decentralization. Additionally, Harguindéguy et al. (2019) state in their literature review on the variety of decentralization indexes that the RAI is one of the few indexes which fulfill certain validity criteria.[9] More specifically, the RAI is verified regarding its convergent and content validity. The former compares the results of two (or more) instruments in order to verify if the results converge – despite their deviating methodologies. The latter, on the other hand, compares the way scholar define the same concept and, additionally, the way how to calculate it. Concluding, the authors unambiguously favor the RAI, providing "a clear definition of the concept of decentralization" (Harguindéguy et al., 2019, p.18). Both comments indicate a strong support for the usage of the RAI as an indicator of (governmental) decentralization and emphasize the quality, validity and accuracy of the index, limiting concerns regarding potential measurement error bias.

Additionally, next to the just described and discussed causes of endogeneity, *reverse causality* potentially imposes limitations to the conducted empirical investigation. I have addressed this issue by conducting additional regressions, in which the RE deployment is regressed on the lagged values of the parameters of interest, ensuring the one-directional estimation of the impact of decentralization on RES. The results are shown in *Table 13* of the *Appendix* which confirm the findings of the previous estimations, indicating a stable and robust effect of (governmental) decentralization on the RE development. Still, it can be argued that lagging the regressors will not solve the concerns of reverse causality, if they are strongly persistent. Hence, a potential solution to the problem is the usage of instruments in the course of an instrumental variable (IV) approach. This method is shown to be challenging in the case of (governmental) decentralization, as there do not exist simple and easily available instruments to employ. Discussed determinants of decentralization in the literature are mostly related to ethnical and geographical dimensions. The *Geographic Fragmentation Index* (GFI) from Canavire-Bacarreza et al. (2020), imposes advanced data requirements and demanding computations, hindering straightforward deployment of such in the course of this master's thesis. Nevertheless, I have conducted two attempts of the employment of instruments.

First, the just mentioned GFI and, second, an *Ethnic Fractionalization Index* (EFI). The GFI describes the weighted probability that two randomly taken individuals do not live in similar altitude zones, being the weight matrix specified as the average distance between altitudes. This index therefore captures the geographical diversity of a country which can be reflected on the pattern of population settlements potentially leading to different preferences in institutional designs (Canavire-Bacarreza et al., 2020). In the paper, the authors present the GFI for their sample for the year 2012 – containing all countries of the here conducted study. To use the GFI as an instrument, I have interacted the index with time dummies to create over-time variation.

The EFI depicts the probability that two randomly drawn individuals within a country do not belong to the same ethnic group (Drazanova, 2019) and the data is retrieved from the *Historical Index of Ethnic Fractionalization Dataset* (HIEF), available for 165 countries across all continents and covers the period between 1945 and 2013 on an annual basis. To be able to deploy the whole time period of the sample, the EFI values for 2015 are assumed to be the values of 2013 from the HIEF data set.[10]

[9] In this context, validity "refers to the degree to which an instrument of observation measures what it aims to measure" (Harguindéguy et al., 2019, p.17).

[10] Additionally, Bahamas, Brunei, Iceland, India, France, Malta, Papua New Guinea and Suriname are dropped as the EFI does not contain data on these countries.

The results are shown in *Table 14* of the *Appendix*. The first column represents the preferred specification of the study, the second column shows the results when applying an IV approach with the EFI and the third column with the GFI as the main instrument. Although, the IV estimation of the effect of RAI are quite similar to those reported in *Column (8) of Table 3*, the impact is not found to be significant for all the percentiles of IQ. The estimation of the effect when using the GFI as instrument, on the other hand, are shown to be highly significant at all levels of institutional quality, but exhibit rather large magnitudes – between 2.5 and 3.0. It is pivotal to note at this stage that both instruments are found to be invalid, implied by the clear rejection of the null hypotheses of Hansen J Test. This could explain the unrealistic and insignificant findings of the IV estimations and emphasizes the necessity of future research to address this issue and to find appropriate instruments.

Finally, the characteristics of the here employed dataset potentially allow for a more *time-series oriented* analysis of the relationship between decentralization and RE development – as applied in previous literature on this relationship. The here conducted analysis avoids issues related to time-series properties by exploiting five year intervals, but as the data is available on an annual basis, a more detailed analysis of the time-series attributes and the utilization of the accordingly appropriate estimation approaches is feasible. Preliminary results indeed indicate the existence of stationarity and, more importantly, cointegration in the panel – albeit heterogeneously located across the sample. This leaves room for subsequent research on the analysis of this particular dimension and its aspects and implications for the impact of decentralization on the RE development.

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Appendix

Table 5 Grouping by Region.

Europe				
Austria	Belgium	Cyprus	Denmark	Finland
France	Germany	Greece	Iceland	Ireland
Italy	Malta	Netherlands	Norway	Portugal
Spain	Sweden	Switzerland	Turkey	United Kingdom
Israel				
Asia				
Bangladesh	Brunei	China	India	Indonesia
Japan	Malaysia	Pakistan	Philippines	Singapore
South Korea	Sri Lanka	Thailand	Vietnam	
Oceania				
Australia	New Zealand	Papua New Guinea		
North America				
Canada	Mexico	United States		
Central & South America				
Argentina	Bahamas	Bolivia	Brazil	Chile
Colombia	Costa Rica	Dominican Republic	Ecuador	El Salvador
Guatemala	Guyana	Haiti	Honduras	Jamaica
Nicaragua	Panama	Paraguay	Peru	Suriname
Trinidad & Tobago	Uruguay			

Table 6 Grouping by Income Classification (World Bank).

High Income				
Australia	Austria	Bahamas	Belgium	Brunei
Canada	Chile	Cyprus	Denmark	Finland
France	Germany	Greece	Iceland	Ireland
Israel	Italy	Japan	Malta	Netherlands
New Zealand	Norway	Panama	Portugal	Singapore
South Korea	Spain	Sweden	Switzerland	United Kingdom
Trinidad and Tobago	United States	Uruguay		
Upper Middle Income				
Argentina	Brazil	China	Colombia	Costa Rica
Dominican Republic	Ecuador	Guatemala	Guyana	Indonesia
Jamaica	Malaysia	Mexico	Paraguay	Peru
Suriname	Thailand	Turkey		
Lower Middle Income				
Bangladesh	Bolivia	El Salvador	Honduras	India
Nicaragua	Pakistan	Papua New Guinea	Philippines	Sri Lanka
Vietnam				
Low Income				
Haiti				

Table 7: Detailed Summary Statistics (World Sample)

Variable			Mean	Std. Dev.	Min	Max
RAI	Regional Authority Index	overall	11.672	10.249	0	37.672
		between		10.075	0	36.125
		within		2.212	-4.788	20.469
IQ	Institutional Quality Index	overall	33.277	9.138	6.528	49.167
		between		8.443	13.426	46.968
		within		3.629	16.899	42.113
GDP pc	GDP per capita (constant 2010 US$)	overall	20269.080	19792.950	411.165	90029.360
		between		19483.610	632.802	79740.920
		within		4145.436	494.931	41612.670
FDI	Foreign Direct Investment (% of GDP)	overall	5.722	21.455	-19.773	339.788
		between		12.283	-5.577	84.151
		within		17.648	-77.251	261.359
POP	Population	overall	73,500,000	211,000,000	254,826	1,370,000,000
		between		211,000,000	291,514.8	1,270,000,000
		within		22,800,000	-151,000,000	286,000,000
CO2 pc	Carbon dioxide emissions per capita (in kilotons)	overall	0.002	0.001	0.000	0.010
		between		0.001	0.000	0.007
		within		0.000	-0.001	0.005
FF	Share of Fossil Fuel Electricity Generation (% Total Generation)	overall	56.919	32.555	0.002	100
		between		31.608	0.043	99.992
		within		8.604	14.701	91.948
EI	Share of Electricity Imports (% Total Consumption)	overall	5.113	10.014	0	66.658
		between		9.070	0	51.727
		within		4.370	-14.85531	46.772
EC	Annual Total Electricity Consumption (in billion kWh)	overall	5.448	15.829	0.009	136.051
		between		15.052	0.020	94.843
		within		5.195	-36.207	69.236
FIT	Dummy if Country has enacted a Feed-in Tariff policy	overall	0.241	0.428	0	1
		between		0.217	0	0.833
		within		0.370	-0.593	1.074
RPS	Dummy if Country has enacted a Renewable Portfolio Standard policy	overall	0.106	0.308	0	1
		between		0.210	0	0.667
		within		0.226	-0.561	0.939
Annex B	Dummy: 1 from 1998 onwards if country is part of Annex B	overall	0.233	0.423	0	1
		between		0.320	0	0.667
		within		0.279	-0.434	0.566

* With n = 63 and N = 378.

Table 8 Variables by Region, averages from 1990 to 2015.

Region	Share of RES	RAI	IQ
World	5.0	11.4	6.6
Europe	6.4	12.7	7.7
Asia	2.5	12.7	6.1
Oceania	6.2	14.7	7.4
North America	3.5	25.6	7.6
Central & South America	5.2	6.4	5.6

Table 9 Variables by Income Classification, averages from 1990 to 2015.

Income	Share of RES	RAI	IQ
High Income	5.7	13.0	39.8
Upper Middle Income	3.1	10.2	27.1
Lower Middle Income	6.7	10.6	25.6
Low Income	0.2	5.5	13.4

***Table 10** Detailed Results.*

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
lnRAI	-0.205**	1.033**	1.044**	0.805*	0.979*	0.936**	0.982**	0.530
	(0.087)	(0.421)	(0.451)	(0.475)	(0.530)	(0.429)	(0.451)	(2.178)
lnIQ							-0.796	-0.988
							(1.119)	(1.361)
lnRAIxlnIQ								0.137
								(0.636)
lnGDP				0.846	2.993**	3.611***	3.517***	3.481***
				(1.495)	(1.380)	(1.285)	(1.266)	(1.253)
lnFDI				-0.164	-0.169	-0.154	-0.134	-0.136
				(0.162)	(0.148)	(0.140)	(0.128)	(0.125)
lnPOP				-9.075***	-6.800***	-5.259*	-5.038	-5.064
				(2.416)	(2.556)	(3.143)	(3.091)	(3.067)
lnCO2					-2.527**	-0.661	-0.534	-0.521
					(0.953)	(1.040)	(1.067)	(1.070)
lnFF						-0.704***	-0.684***	-0.690***
						(0.229)	(0.231)	(0.241)
lnEI						-0.095	-0.093	-0.091
						(0.081)	(0.081)	(0.082)
lnEC						-2.211	-2.198	-2.187
						(1.391)	(1.362)	(1.351)
Country FE		x	x	x	x	x	x	x
Time FE			x	x	x	x	x	x
N	378	378	378	378	378	378	378	378
Log-Likelihood	-837.909	-755.989	-753.382	-734.533	-725.172	-714.803	-714.085	-714.027
AIC	1679.817	1513.978	1518.765	1487.066	1470.344	1455.606	1456.169	1458.053
R^2 (within)	0.014	0.032	0.045	0.136	0.177	0.221	0.224	0.224

Dependent Variable *Share of RES*. Clustered (by country) standard errors are reported in parentheses. ***, **, and * show statistically significance at 1%, 5%, and 10% level, respectively.

Table 11 *Robustness Check with alternative Dependent Variables.*

	Share	Generation (Absolut)	Generation (Per Capita)
lnRAI	0.530	-1.232	-0.126
	(2.178)	(1.810)	(1.351)
lnIQ	-0.988	-1.948	-1.088
	(1.361)	(1.276)	(0.784)
lnRAIxIQ	0.137	0.627	0.102
	(0.636)	(0.544)	(0.413)
AME	1.002**	0.938**	0.226
	(0.462)	(0.427)	(0.430)
Marginal Effect at:			
IQ (10%)	0.959**	0.741*	0.194
	(0.475)	(0.414)	(0.406)
IQ (25%)	0.978**	0.825**	0.208
	(0.459)	(0.411)	(0.411)
IQ (50%)	1.004**	0.945**	0.227
	(0.463)	(0.429)	(0.431)
IQ (75%)	1.040**	1.113**	0.255
	(0.520)	(0.491)	(0.480)
IQ (90%)	1.051*	1.161**	0.262
	(0.545)	(0.515)	(0.497)
Country FE	x	x	x
Time FE	x	x	x
Socio-Econ. Controls	x	x	x
Environm. Control	x	x	x
Energy Sctr Controls	x	x	x
N	378	378	378
Log-Likelihood	-714.027	-661.713	-539.067
AIC	1458.053	1353.426	1108.135
R^2 (within)	0.224	0.278	0.523

Dependent Variable *Share of RES*. Clustered (by country) standard errors are reported in parentheses. ***, **, and * show statistically significance at 1%, 5%, and 10% level, respectively. IQ (p%) denotes the value of the p-percentile of the distribution of IQ.

Table 12 *Impact of RE Policies.*

	(8)	(9)	(10)
lnRAI	0.530	0.642	1.000
	(2.178)	(2.139)	(2.145)
lnIQ	-0.988	-0.820	-0.454
	(1.361)	(1.314)	(1.334)
lnRAIxlnIQ	0.137	0.077	-0.051
	(0.636)	(0.618)	(0.619)
AME	1.002**	0.908**	0.822*
	(0.462)	(0.457)	(0.466)
Marginal Effect at:			
IQ (10%)	0.959**	0.883*	0.838*
	(0.475)	(0.478)	(0.486)
IQ (25%)	0.978**	0.894*	0.832*
	(0.459)	(0.459)	(0.468)
IQ (50%)	1.004**	0.908**	0.822*
	(0.463)	(0.458)	(0.467)
IQ (75%)	1.040**	0.929*	0.808
	(0.520)	(0.505)	(0.514)
IQ (90%)	1.051*	0.935*	0.804
	(0.545)	(0.527)	(0.536)
RPS		0.706*	1.192
		(.402)	(0.783)
FIT		0.628	0.510
		(0.430)	(0.667)
Annex B			0.928*
			(0.511)
RPSxAnnexB			-1.201
			(0.836)
FITxAnnexB			0.194
			(0.674)
Marginal Effect FITxAnnexB			0.704**
			(0.341)
Marginal Effect RPSxAnnexB			-0.009
			(0.270)
Country FE	x	x	x
Time FE	x	x	x
Socio-Economic Controls	x	x	x
Environmental Control	x	x	x
Energy Sector Controls	x	x	x
N	378	378	322
Log-Likelihood	-714.027	-710.046	-707.651
AIC	1458.053	1454.092	1455.303
R^2 (within)	0.224	0.241	0.250

Dependent Variable *Share of RES*. Clustered (by country) standard errors are reported in parentheses. ***, **, and * show statistically significance at 1%, 5%, and 10% level, respectively. IQ (p%) denotes the value of the p-percentile of the distribution of IQ.

Table 13 *Reverse Causality (RAI & IQ 5 year lagged).*

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
lnRAI	-0.067	0.989**	1.088**	0.857	0.961*	0.872*	0.983*	0.461
	(0.092)	(0.431)	(0.520)	(0.551)	(0.541)	(0.499)	(0.502)	(2.201)
lnIQ							-1.609	-1.823
							(0.948)	(1.359)
lnRAIxlnIQ								0.158
								(0.632)
AME								1.009**
								(0.511)
Marginal Effect at:								
IQ (10%)								0.959*
								(0.531)
IQ (25%)								0.980*
								(0.513)
IQ (50%)								1.011**
								(0.511)
IQ (75%)								1.053*
								(0.555)
IQ (90%)								1.065*
								(0.576)
Country FE		x	x	x	x	x	x	x
Time FE			x	x	x	x	x	x
Socio-Econ. Cntr.				x	x	x	x	x
Environm. Cntr.					x	x	x	x
Energy Sctr Cntr.						x	x	x
N	315	315	315	315	315	315	315	315
Log-Likelihood	-674.554	-601.609	-597.600	-587.440	-576.744	-571.979	-568.651	-568.570
AIC	1353.108	1205.219	1205.199	1190.880	1171.488	1167.957	1163.303	1165.140
R^2 (within)	0.002	0.035	0.059	0.118	0.176	0.201	0.217	0.218

Dependent Variable *Share of RES*. Clustered (by country) standard errors are reported in parentheses. ***, **, and * show statistically significance at 1%, 5%, and 10% level, respectively. IQ (p%) denotes the value of the p-percentile of the distribution of IQ.

Table 14 *Instrumental Variable (IV) Approach.*

	(8)	IV (EFI)	IV (GFI)
lnRAI	-3.216	-0.786	0.114
	(2.676)	(3.866)	(3.740)
lnIQ	-3.600*	-2.491	-3.163
	(1.947)	(2.340)	(2.211)
lnRAIxlnIQ	1.257	0.614	0.780
	(0.802)	(1.105)	(1.050)
IQ (10%)	0.779	1.146	2.568**
	(0.525)	(0.959)	(1.187)
IQ (25%)	0.880*	1.228	2.672**
	(0.520)	(0.927)	(1.165)
IQ (50%)	1.136**	1.345	2.821**
	(0.541)	(0.921)	(1.163)
IQ (75%)	1.484**	1.510	3.031**
	(0.640)	(0.992)	(1.218)
IQ (90%)	1.578**	1.557	3.091**
	(0.677)	(1.028)	(1.245)
Country FE	x	x	x
Time FE	x	x	x
Socio-Economic Controls	x	x	x
Environmental Control	x	x	x
Energy Sector Controls	x	x	x
N	322	284	322
Log-Likelihood	-610.313	-522.385	-623.287
AIC	1250.625	1184.769	1402.574
R^2 (within)	0.131	0.338	0.263
Hansen J Statistic	.	52.738***	47.389***

Dependent Variable *Share of RES*. Robust standard errors are reported in parentheses. ***, **, and * show statistically significance at 1%, 5%, and 10% level, respectively. IQ (p%) denotes the value of the p-percentile of the distribution of IQ.

Online Supplementary Material

Supplemental information used in the study can be retrieved from the following link:

https://drive.google.com/file/d/145G1363l9sfhQv-rvNrmD4nuzYAR_cOE/view?usp=sharing