Measuring the Impact of Independent Regulatory Agencies on the Decarbonization of the EU Energy Mix

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Abstract: National Regulatory Agencies (NRAs) have a key role in the decarbonization of the European electric systems, as they may facilitate or constrain its transformation through the organization of wholesale electric markets. However, regulators face limitations in achieving this central objective set by the Union and its Member-States by the governance regime that was initially designed to in the aim of supporting the liberalization and the integration of the EU single market, in particular to benefit to (individual and professional) customers. NRAs original mandate is to support competition, guarantee market stability and set pricing mechanisms for efficient allocation of resources. NLP methods are relied upon to characterize the "regulatory governance regime" in each Member State, highlighting three main dimensions. Then, panel data analysis aims at measuring the impact of regulatory governance characteristics on the evolution of the share of renewable energy between 2013 and 2018 in EU member states. The results show that independence of the regulator is negatively correlated with the share of renewable energy, and transparency is negatively correlated with industrial tariffs. Results are then put in context to discuss the role of NRAs given the challenge of decarbonization or the EU energy mix by 2050.

Keywords: *networks: regulation, national regulatory agency, independent agency model, electricity, renewables energies, climate change policy, energy policy.*

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1. Introduction

This paper analyses the impact that the governance regimes from European National Regulatory Agencies (NRAs) in the electric sector have on the growth of the share of renewable energies. We are interested in the growth of renewable energies because European member states have committed to ambitious targets of decarbonization through European legislation. The most relevant being those resulting from the Paris Agreement and the European Climate Law that target the full decarbonization of the electric sector for 2050.

We focus on the governance regime of NRAs because most of the research previously conducted on regulatory impact had focused on the impact of policy output, -implementation of regulatory measures, changes in market design, etc- (Steiner, 2011; Asane-Otoo, 2016; da Silva & Cerqueira, 2017; Vona & Nicolli, 2019). In addition, -to the knowledge of the authors- there is little to no academic evidence on the impact of governance regimes on environmental or climate change objectives for the electric sector. Finally, NRAs governance regimes in Europe are converging to similar levels (Brousseau and Gonzalez-Regalado; 2021) which increases the importance of understanding their impact on European climate change commitments.

In Europe, NRAs in the electric sector were designed to support the *liberalization* reforms during the 1990s and formalized as a requirement for all member states by the European Commission (EC) in the Second Electric Directive (2003/54/EC). The *liberalization* had as its main objective the restructuration of the electric sector typically controlled by a vertically integrated monopoly, through regulatory reforms to develop a competitive market that would attract new investments (Joskow, 2008). European countries engaged with the *liberalization* process because competition increases sector performance, redistributing the gains derived from efficiency to the population through lower prices, and encouraging the integration of the EU economies by reducing the barriers of exchange between countries.

NRAs were created under a normative model of regulatory governance design to ensure that NRAs will not deviate from their mandate by the influence of politicians with short-term interests or private actors trying to abuse their market power. The model has been defined as the Independent Regulatory Agency (IRA) model. The model gives NRAs economic and legal independence from the government, but demands them to be transparent to market participants and stakeholders, and have a limited scope of action -i.e. a clear division between their roles as regulators, the private sector, and government-.

Considering the above, our thesis is that the adoption of the IRA model by NRAs will reduce the growth of renewable energies if there are trade-offs between increasing the share of renewable energies and their original mandates, such as increasing energy prices or affecting the returns of current market incumbents. We support our thesis with two arguments. First the greater the adoption of the IRA governance model, the more likely there is the ex-post threat of retaliation or loss of legitimacy from stakeholders (such as peers, congress or private sector) if NRAs deviate from their mandate. And second, the NRA mandate is to create stable markets to guarantee the return of investments and efficient allocation of resources through prices. Hence, NRA's will face a trade-off when decarbonizing the electric sector. On one hand, increasing the share of renewable energies with the current market design will affect negatively the consumer through higher prices, as the current market is designed for thermic and centralized plants (Henriot & Glachant, 2013; Blazquez et al., 2018). While on the other hand, changing the market design to allocate resources efficiently with a high share of renewable energies will impact negatively the returns of current investments.

To test our thesis, we performed an empirical analysis using panel data to measure the impact of regulatory governance on electric tariffs and renewable energy growth between 2013 and 2018 in EU member states. The IRAs' model adoption measure was built using text analysis on the OECD "Governance of Regulators" surveys. Our results show that during 2013 and 2018 the indicators of the IRA model adoptions are positively correlated with a reduction in electricity tariffs, while negatively correlated with the growth in the share of energy from renewable energies sources (RES). Considering that climate change commitments are made by the governments and that NRAs are independent, we use our results to develop new questions regarding the tension resulting from the technological change, and the process of institutional and market design in the electric sector.

The paper is divided into eight sections. Section 2 reviews the European legislation which sets a common political and normative ground amongst regulators in the EU. Section 3 presents the IRA model, particularly its three dimensions, independence, transparency, and scope of action (or regulatory tasks). Section 4 presents our theoretical framework. Section 5, describes the design of the empiric analysis. Section 6 showcase the results and robustness checks. Section 7 discusses the implications of the results and finally Section 8 the conclusions of the research.

2. European legal framework: A single, liberalized, and green electric sector

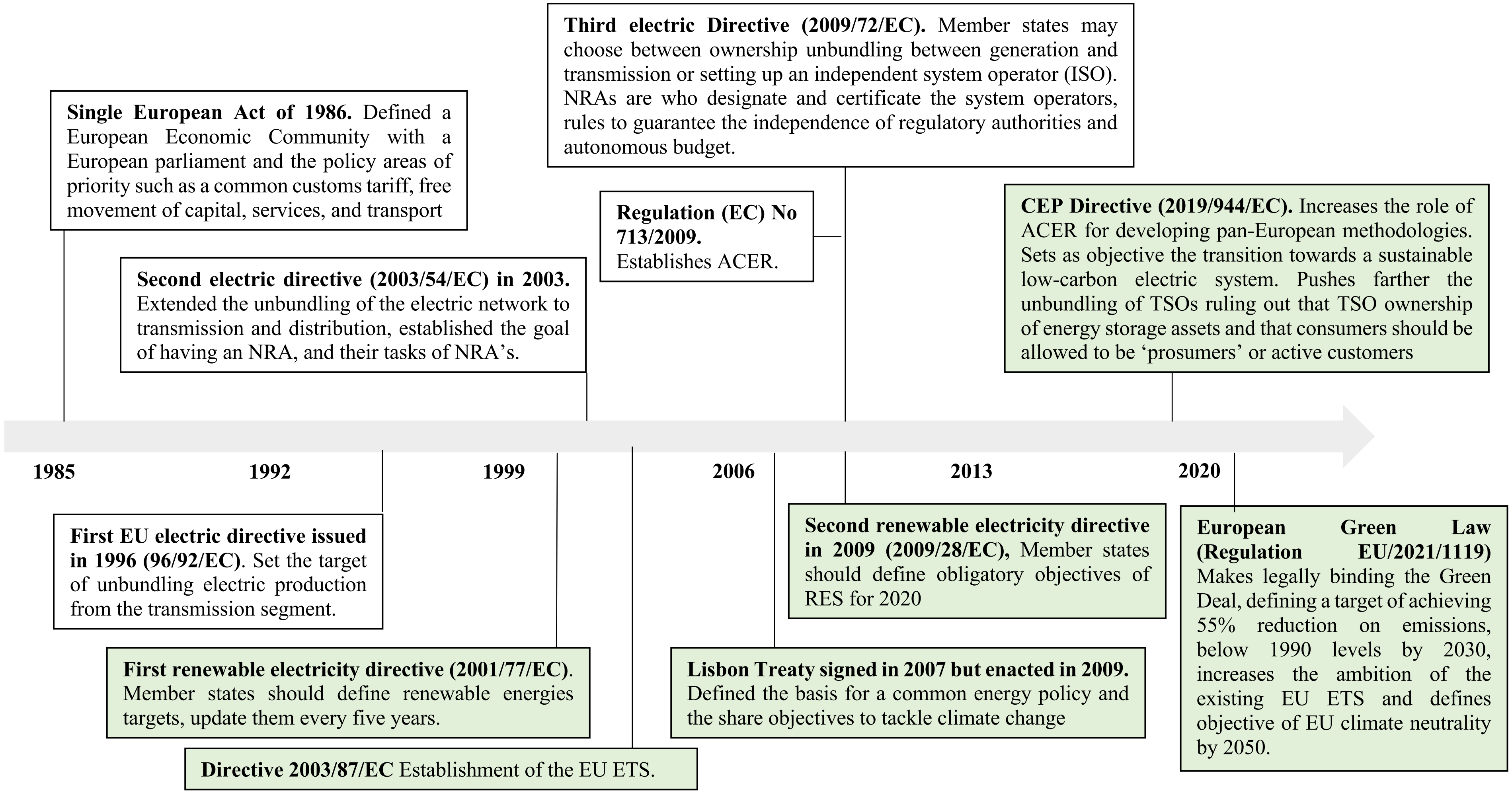
This section frames the context in which we will analyze our object of study, the European electric sector. EU member states are bundled in a common political process, in which a European framework has been transposed to member states using legislative acts. We divide this process into two sub-sections. First, we present the legal instruments enacted for the *liberalization* reform of the European electric sector. Then, we present the legal instruments used to increase the share of renewable energies production in Europe, mainly through the agreement of common climate change targets, and the promotion of renewable energies technologies.

The European framework in both sections has been mostly built using four main legal instruments: Treaties, Directives, Regulations, and Common market rules -such as network codes and guidelines- (Meeus, 2020). The first major legislative acts that constituted the first European framework were the Treaty of Rome (1957), and the Single European Act (1986). They defined a European parliament with the objectives of establishing common customs tariffs, free movement of capital, services, and transport. The objective of the European parliament was the creation of a single European Economic Community with a single electricity market.

After the Treaties, the first type of legal act enacted were Directives, which set common goals for all EU countries within a defined time frame without constraining the legal acts that they are required to implement at a national level. Then came Regulations, as they required a higher political agency of the EU across member states. Contrary to Directives, Regulations are immediately applicable to all member states overruling national legislation. Finally, the most detailed type of instruments are the European Common Rules, which are detailed technical processes that regulate the technical operation of electric systems to guarantee the efficient integration of electric networks in the EU.

Figure 1, summarizes the timeline of the implementation of the main legal acts affecting the regulation of the electric sectors across European member states. In green, have been colored those legislative acts that are related to the decarbonization of the electric sector.

Figure 1: Timeline of implemented legislation in the EU for the electric sector



a. The *liberalization* of the EU electric sector

Liberalization as defined by Joskow (2008) is the restructuration of a sector through regulatory reforms to develop a competitive market. The objective of liberalization for the electric sector is to ensure that prices reflect *"the efficient economic cost of supplying electricity and service quality attributes that reflect consumer valuations"* (Joskow, 2008).

In short, for the European Union (EU) the restructuration of the electric industry consisted of two main actions. First, the privatization and vertical separation of state-owned national monopolies, that controlled the totality of electric assets, being responsible for their construction and operation in the generation, transport, and distribution segments. And second, the development of a common regulatory framework to integrate the electric systems in a single market.

The rationale behind these two main actions was that competitive markets will encourage innovation in power supply technologies, provide incentives for network operators to deliver appropriate levels of service quality, and shift the risks of investment away from consumers, between others (Joskow, 2008). In addition, the liberalization facilitates the integration of the electric systems in the EU as firms from different nationalities have incentives to invest in transmission lines for exchanging electricity amongst countries, which contributes to better reliability of the system, and takes advantage of different industrial policies and natural resources.

The first EU electric directive issued in 1996 (96/92/EC), set the target of unbundling electric production from the transmission segment. Until this Directive only Norway, Sweden, and the UK did not have vertical integrated electric systems managed by national companies. The second electric directive (2003/54/EC) in 2003, extended the unbundling of the electric network to transmission and distribution, legally separating Transmission System Operators (TSOs) from Distribution System Operators (DSOs), it also established the goal of having an NRA in all member states to guarantee non-discriminatory access to the network[2].

The second directive was implemented in parallel with Regulation (EC) No 1228/2003, which defined that transmission rights should have a market-based allocation for all cross-border exchanges in electricity. However, it did not specify which market-based allocation should be used. Because of this, between 2003 and 2015 different approaches were used until common rules were defined.

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[2] Art. 23 of this Directive defines the tasks of NRA's.

The third electric Directive (2009/72/EC) gave choice to member states between defining ownership unbundling between generation and transmission or setting up an independent system operator (ISO). The directive also defined that NRAs are who designate and certificate the system operators. The directive also (Art. 35) laid out the rules to guarantee the independence of regulatory authorities and autonomous budget.

Regulation (EC) No 713/2009. Established an Agency for the Cooperation of Energy Regulators (ACER). ACER's objective is to promote the EU's internal energy market through economic regulation and solve cross-border disputes between NRAs. In addition to ACER, the European network of TSOs (ENTSO-EU) was created to support the coordination across TSOs and elaborate common European network codes and operational tools. The regulation also implemented a framework for financing European common infrastructure that contributes to EU market integration, for example, cross-border transmission lines.

Since the third electric Directive, common rules for the EU started to be designed and enacted to coordinate the exchange of electricity and the already existing national markets. The first generation of network codes and guidelines were developed by European institutions, ENTSO-EU and ACER. Its objective was to create a common temporal division of energy products and a coordination mechanism to enable transactions.

The last electric Directive approved until today is the CEP Directive (2019/944/EC). The directive brought significant changes to the definition of network codes and guidelines (Meeus, 2020). Particularly it reduced the relevance of ENTSO-EU in drafting common rules and increased the role of ACER as it now decides the methodologies with a pan-European scale (Regulation EC/2019/942). CEP pushes farther the unbundling of TSOs ruling out TSO ownership of energy storage assets. For common rules at the distribution level, the fourth Directive supports the establishment of EU DSO (Regulation EC/2019/943) developing a framework for an independent aggregator to operate next to retailers.

A major difference between the CEP and previous directives is that it sets as objective the transition towards a sustainable low-carbon electric system. CEP pushes farther the unbundling of TSOs ruling out that TSO ownership of energy storage assets (possible derogated under specific circumstances) and consumers should be allowed to be *'prosumers'* or active customers, phase-out of net metering, and the obligation to enable a regulatory framework for DSOs to procure flexibility services and develop multi-annual investment plans that consider flexibility as an alternative to network expansion.

b. The *decarbonization* of the EU electric sector

Directives to promote RES were initiated in 2001 under the Kyoto Protocol, which agreed in a binding target for the EU to reduce their emission levels by 5% to respect their 1990s for 2012. The first renewable electricity directive (2001/77/EC) ruled that member states should define renewable energies targets, update them every five years, and encourage member states to use national economic mechanisms until the EU defines a common framework. Its update in 2009 (2009/28/EC), enforces that member states should define obligatory objectives of RES for 2020, and its last version in 2018 (2018/2001/EU) set a binding target for collectively ensuring that the share of energy from RES is at least 32% in 2030.

Directive 2003/87/EC of the European Parliament and of the Council of 13 October 2003 established a system for greenhouse gas emission allowance trading within the Union, also known as the EU ETS. It has been structured in four stages. The first two stages finished in 2013, and mostly considered flexible allocation of allowances. From 2013 until 2020 stage 3 of implementation reduced the number of allowances available by the EU ETS by 1.74% per year. This allows companies to slowly adjust to meeting the increasingly ambitious overall target for emissions reductions.

European Green Law (Regulation EU/2021/1119) is the most recent commitment from the EU to climate change targets. It makes legally binding the Green Deal, defining a target of achieving 55% reduction on emissions, below 1990 levels by 2030, increasing the ambition of the existing EU ETS and the ambitious objective of EU climate neutrality by 2050.

3. The Independent Regulatory Agency (IRA) model

This section presents the theoretical concepts from which we will build our theoretical framework. Mostly, it treats the conception and transformation of the regulatory model used in the EU. The model was first born in the USA and later promoted by international institutions such as the Organization for Economic Cooperation and Development (OECD), and the World Bank as a model to improve the efficiency of utility industries. Then member states in the EU started to transpose it to their national legislation. However, the EU model for the NRA was formally established on the 2nd and 3rd electric directives. The name given by academic literature to the regulatory model is the IRA model.

a. Background

Gilardi and Magetti (2011), define IRAs as institutions "*separated*" from the government bureaucracy and elected politicians. The governance model grant NRAs with legitimacy, public authority, and discretional power to execute a given mandate. Their objective is to support political stability, give a signal that market rules will be respected, and encourage competition.

The model first appeared in the US in the mid-19th century, as independent commissions were created with the mandate to reduce information asymmetries between the government and monopolistic firms in the rail industry. However, the model of independent commissions quickly expanded its scope of action, as local and federal governments delegated to independent commissions the role of regulators. These regulators were given the mandate to review the calculation of prices, assess market-entry procedures, barriers for competition, and the efficiency of the firms. After the rail industry, the IRA model expanded to other sectors such as telephone, telegraph, gas, and electric utilities.

The IRA model is seen as the most effective mechanism to insulate regulatory rulemaking from the influence of private operators (Stigler, 1971), governments, and politicians that due to short-term electoral incentives could change the market rules of network utilities (Majone, 1996). Consequently, it was the selected governance model to support the market coupling during European utilities' “liberalization” waves in the early 1990s (Stern, 1997).

b. Dimensions of IRA: Independence, transparency, and scope of action

Governments are willing to “step back” from regulatory activities in exchange for new investments, increase in trade, and efficiency. The delegation of regulatory tasks to independent regulators solves the government’s political opportunism risk (credible commitment problem). Separation from the government is an important signal for investors because, the government could influence the regulator to deviate from their mandate of encouraging competition and market stability (Egert, 2009).

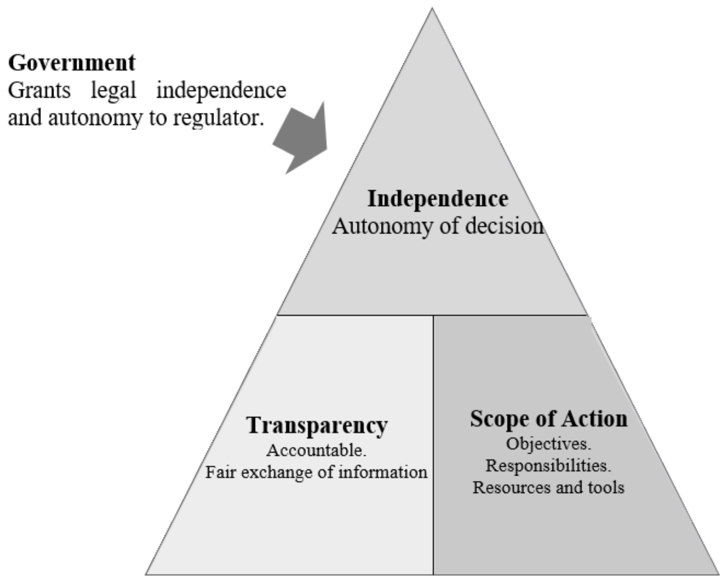
However, even if IRAs are independent, they are not democratically elected. Hence, they are required to be transparent and have institutional arrangements to make them accountable, limiting their discretion. The arrangements allow the government, the legislative, industry, and civil society to closely monitor the agency regulatory performance accommodating the regulator to act as an “*unbiased*” information intermediary, who sets market rules and resolves conflicts.

Transparency is a key part of the IRA model, for three reasons. First, decreases the likelihood of arbitrary decision-making and abuse of authority. Second, efficient, and open procedures decrease the principal’s costs of monitoring (Spiller and Tommasi, 2008). Third, under strict reporting provisions, the regulator’s expectations of severe scrutiny increase the prudence and precision of their assessments and decisions (Hanretty and Koop, 2018).

In addition to transparency, the government limits the discretionary power of the regulator by defining the limits of its responsibilities and available resources. The combination of the responsibilities, tools, and resources has been referred to as the "Scope of action" by the OECD (Kose et. al, 2016).

Figure 2 illustrates the dynamic within the IRA model as a pyramid structure. At the top of the pyramid is independence, which is granted by the government. However, this independence is given because transparency is required, and a clear scope of action is defined.

Figure 2: Dimensions of the IRA model (authors).



4. Theoretical framework

This section presents the framework in which we build our hypothesis and predictions. The question that we want to answer, is how does the implementation of the IRA model affect the growth of renewable energy in EU member states?

We divided our framework into three sub-sections. The first part presents the threats that NRA's following the IRA model have for deviating from their mandate, and the evolution in the "scope of action" of NRA's in Europe. The second part presents the tradeoffs that NRA faces to change the technological paradigm, from central thermic plants to renewable energies in liberalized markets, and finally a summary of our hypothesis and predictions.

a. Threats of deviating from their mandate: IRA as a Principal-Agent framework

Our theoretical framework relies on the relationship of principal-agent proposed by Maggeti and Pappadopolus (2018) for the IRA model, where the government act as the principal, and the NRA as the agent. Under this framework, the objective of the government is not to guarantee that the NRA acts in the government interest, but instead to ensure that the NRA is unresponsive to the government interests (Miller, 2005). The objective of the government by giving independence to the regulator is in Gilardi's (2008) words *"to guarantee that the rules of the game do not change over time"*.

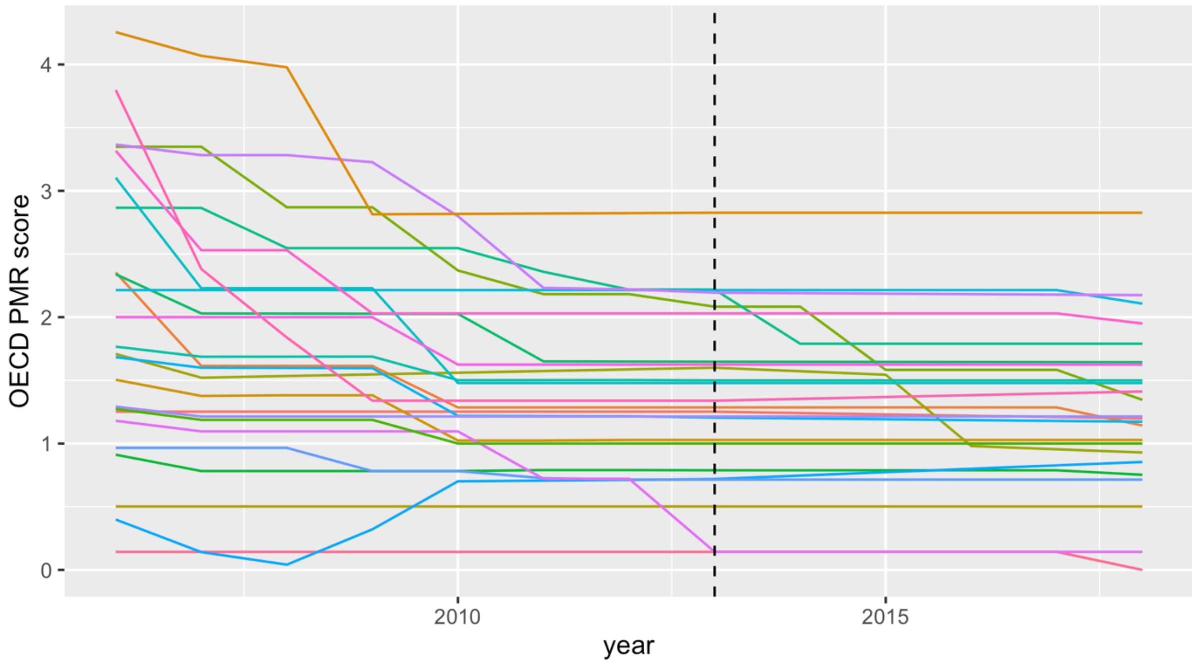
As seen in section 3, the IRA model gives independence to ensure investors that market rules will be respected, but to guarantee that regulators will fulfill their mandate demands transparency and gives the IRA a defined "scope of action". Hence, by design, the IRA model restrains the agent of deviating from their mandate. If NRA's deviates they may have a cost from ex-post threat, as transparency and a defined "scope of action" reduces the cost of monitoring the agent's performance, creating the threat of exercise sanctions to the agent if they deviate from their mandate. The threats may come from different sources, such as the loss of legitimacy from civil society and their peers, or citations to congressional hearings and investigations.

Regulatory convergence and increase of regulatory oversight

NRAs were mandated obligatory in Europe to support the liberalization reform, through the implementation of European legislative acts. After the implementation of the 2nd Energy Directive (2003), European reforms have been less focused on market *liberalization* and more focused on electricity market integration and related cross-border issues. The reason behind this change in focus is because the main objectives of *liberalization*, such as the decrease of market barriers and unbundling of generation and transmission, were reached in most European countries (Pollit & Jamasb; 2005). For example, in 2014, 96 of approximately 100 transmission system operators in Europe were certified as compliant with the Third energy package's unbundling models (EC, 2014).

To illustrate the previous point, Figure 3 shows the evolution of the Partnership for Market Regulation (PMR) indicators, developed by the OECD which measures the regulatory barriers to firm entry and competition for the electric sector, one of the main objectives of the liberalization process. The Figure shows that even if regulatory barriers differ significantly across European countries, there has been a process of stabilization in barriers of entry after 2013.

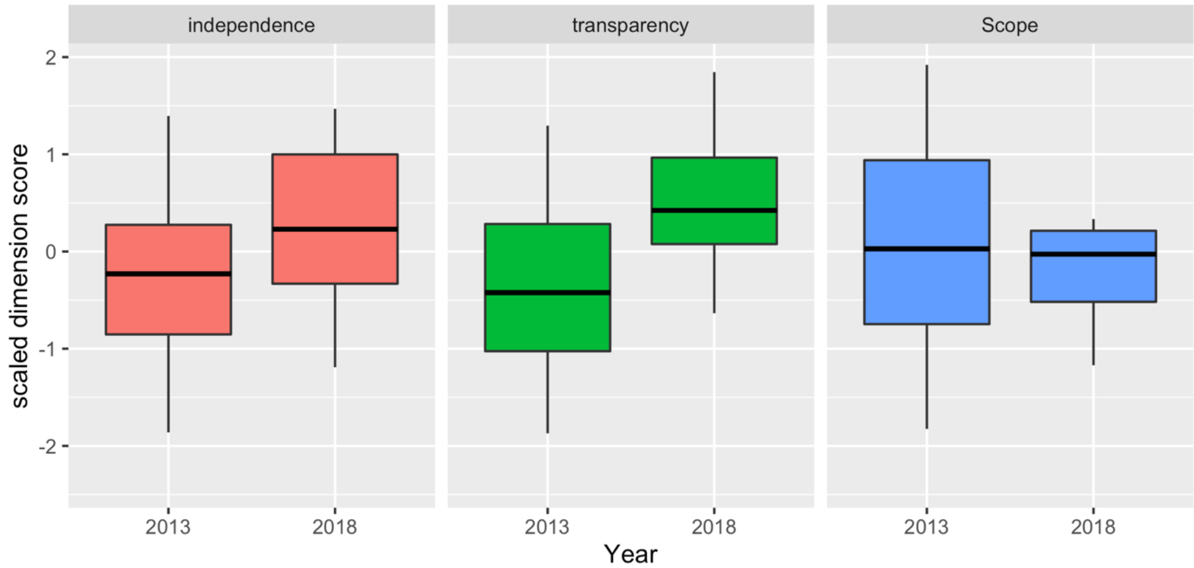
Figure 3: Evolution of Regulatory Barriers to Firm in Europe Electric Sector



Brousseau and Gonzalez (2021) identified more evidence regarding the convergence in regulation and market reforms across NRAs in Europe by analyzing the OECD surveys of Regulatory Governance using text analysis. Figure 4 shows the distribution of the NRA governance regimes in the EU according to their score on the three dimensions of the IRA model. Particularly in the third column, the median of the dimension "scope of action" (market) has not changed between 2013 and 2018, and even more, has reduced its variance. While independence and transparency have increased during the same period and show convergence to a governance regime closer to the IRA model.

The change from liberalization to market integration, requires European legislation of greater detail, as network codes and guidelines become more relevant to design the integration of markets and operate common networks. In addition, market integration has come with an increase in regulatory oversight to ensure market integrity and avoid market abuses through the application of the rules laid down in the 2011 REMIT Regulation, which establishes a clear obligation on transparency and data sharing (EC, 2014).

Figure 4: Evolution of the IRA dimensions in Europe between 2013 and 2018 (Brousseau and Gonzales, 2021)



b. Tradeoffs from changing the technological paradigm: Current and new market designs

The current technological paradigm in the electric sector consists of an energy mix mostly composed of central dispatchable thermic or large-hydroelectric generation plants. However, to accomplish the objectives of decarbonization of the electric grid, a change in the technological paradigm is required by increasing the share of intermittent renewable sources. In this sub-section, we present the tradeoffs identified in the academic literature from the change in technological paradigm, which we divide in tradeoffs from current market design, and changes in market design.

Tradeoffs from current market design

Increasing the share of renewable energies with the current market design will affect negatively the consumer through higher prices, as the current market is designed for thermic and centralized plants. Tradeoffs occur because the current market design is based on a spot electric market using a marginalist approach. Generators declare their marginal costs for electricity generation. Then generation plants are dispatched based in order by their marginal costs; dispatching first those technologies that have lower marginal costs. Finally; the market is cleared with prices equal to the marginal cost of the most expensive technology being dispatched.

Blazquez et al. (2018) claim that the marginal approach in combination with the specificities of renewable energies, such as zero marginal cost of generation, production variability, and low-predictability creates a renewable energy policy paradox. Where, the insertion of renewable energies decreases the revenue on the spot market, and increases its volatility (Blazquez et al., 2018). On one hand, conventional generators, which are required to cover the unavailability of renewable energies, have a harder time recovering their costs because they are dispatch later in the queue because of the entrance of renewables. While, on the other hand, more renewable energy reduces electricity prices, which at the same time reduces the attractiveness of investing in renewable energy (Gross et al.; 2015). As a consequence, the increase of renewable energies has relied on economic support schemes, such as feed-in tariffs which have become more expensive over time (Henriot & Glachant, 2013).

Tradeoffs from changing market design

Changing the market design, to efficiently allocate resources with a high share of renewable energies, for example using an Energy Only Market, will impact negatively current investments. NRAs require to adapt a market design conceived for thermic and controllable energy sources, to a market design with distributed, intermittent, and renewable sources. However, investments in energy infrastructure are capital intensive and typically have large periods of return, which requires stable and predictable regulatory conditions (EC, 2014). Consequently, any proposal of a new market design may impact the return of incumbents, and will go against their current mandate of market stability. In addition, technologies to store renewable energy, such as hydrogen or batteries are still expensive, hence creating a dependence on the current installed thermic capacity. Hence, until the storage of energy will not reduce their prices any foreseeable market reform may require considering a mechanism to incentivize thermic plants.

c. Hypothesis and predictions

We hypothesize that those NRAs that have adopted the IRA model, will follow their original mandate, which is that electric price reflects the economic efficiency of electricity production and to have a competitive and stable market to attract investment. Moreover, the increase in the details of regulation required to implement a single European electric market increases the oversight of NRA and consequently, the threats of deviating from their mandate, as the consequences of instability of market or distortion in energy prices will have the effects on other countries.

We postulate two predictions regarding the impact on performance in the adoption of the IRA model by the NRAs in Europe:

i. *Prediction 1:* Electric system will have a negative correlation with electric tariffs, as the redistribution of rents to customers is part of their main objectives coming from the NRA original *liberalization* mandate.

ii. *Prediction 2:* Electric systems will have a smaller growth in the share of renewable energies, as the current market design, creates strong tradeoffs from the adoption of renewable energies and changing the market design may affect incumbents' returns.

5. Design of Empiric Analysis

This section describes the strategy for the empiric analysis of the research question and the hypothesis developed in the previous section.

a. Overview and scope

The empiric analysis of adopting the IRA model is challenging. Mainly, because the degree and pace of the transposition depend on the market reform pace, the institutional context, social preferences and geography, which vary from country to country. Our panel data model attempts to isolate the effect of governance regime by controlling for unobserved time invariant country characteristics and other potential determinants of efficiency and grid decarbonization. More details are provided in the following subsections.

The scope of the empiric analysis is the European electric systems, between 2013 and 2018. Because of data availability, our econometric analysis relies on 24 countries for the decarbonization and efficiency analysis. Both analyses share 22 countries: Austria, Belgium, Czech Republic, Germany, Denmark, Estonia, Spain, Finland, France, Greece, Hungary, Ireland, Italy, Luxemburg, Lithuania, Latvia, the Netherlands, Poland, Portugal, Sweden, Slovenia, and Slovakia. Additionally, price analysis includes information from Great Britain, and Norway, while the renewable share analysis covers data from Bulgaria and Cyprus.

b. Data

Table 1**Erreur ! Source du renvoi introuvable.** shows a summary of the main variables in the study. To measure e fficiency, we use end-use consumer year-averaged prices (for industrial and household customers, excluded VAT). The data comes from the International Energy Agency (IEA) "Energy Prices and Taxes Statistics" database. While the share of electricity produced from renewable sources was extracted from the Statistical Office of the European Union (EUROSTAT) database. The share, in the numerator, includes hydropower, wind, solar, biomass, bioliquids, biogases, tide, wave, and ocean gross production. The denominator is the country's gross energy (electricity and fossil fuels) consumption in MWh. European Environmental agencies use this metric to track country performance. However, hydroelectric generation has been contested as a green friendly energy source because of its social and environmental costs. Thus, we created a second variable that captures solar and wind generation.

To capture de NRAs' governance regime, i.e., independence, transparency (accountability), and scope of action, we use the indicators described in Brousseau and Gonzalez-Regalado (2021). By Applying text analysis algorithms to surveys conducted by the OECD, the authors identify four relevant dimensions[3] and estimate scores for their influence in the overall governance regime. The scores range between 0 (no dimension influence) to 1 (full dimension influence) [4].

The sector liberalization and market reform are captured by two variables. First, we constructed a market reform text-analysis (TA) variable using the OECD Product Market Regulation (PMR) electricity sector surveys (details on the appendix). This metric captures terms associated to generators' access to the grid and consumer price de-regulation in the retail market (this dimension showed relevant in our analysis). Countries with higher scores support market access provisions (scores closer to 1), while countries with lower scores account for market barriers. Second, the OECD PMR index (Vitale et al., 2020) is used as an aggregate measure of market reform[5]. However, country data availability is limited. Therefore, we used a multiple imputation method to estimate the missing data on this variable[6]. The score ranges between 1 to 6. Lower values indicate high support to market competition, while greater values indicate market barriers.

Additionally, our dataset contains other control information. The technical characteristics, consumption, production, and capacity of the electric system comes from EUROSTAT (2021) and the IEA OECD Database. The GDP and population data from Penn World Tables version 10 (Feenstra, Robert C., Robert Inklaar, and Marcel P. Timmer, 2015). The institutional quality information is extracted from various sources. The Freedom House Political Rights Score (Freedom House, 2021) accounts for government freedom to carry their mandates. Other institutional characteristics are captured by the rule of law indicators from his-Market and the World Bank Governance Indicators (Kaufmann et al., 2010), and the Corruption Perception (CPI) Index from Transparency

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[3] By assessing sets of co-occurring terms, the authors identify four dimensions: Independence from the Government, Transparency, Scope of Market Monitoring and Discretion of the NRA. The methodology allows to compare the metrics between time periods (2013-2018). Our empirical analysis excludes *Discretion* to avoid multicollinearity issues. Topic modelling (LDA) identifies co-occurring terms as probabilities. In other words, the sum of each dimension score equals one for every country.

[4] The OECD estimates governance scores with the same survey (Casullo et al., 2019). However, the scores are not comparable between time periods because a significant change in their questionnaire.

[5] The OECD PMR index aggregates information on entry barriers, market structure, vertical integration and price controls. The information is available as a time-series starting from 1975 to 2018

[6] We carry the multiple imputation method for three countries. The method assumes a multivariate normal distribution and data missing at random. The latter means that the estimated metrics are derived from the observed data. The estimates are obtained averaging the scores of 10 simulation rounds using the R package Amelia. We use the imputed OECD PMR index as an alternative control for reform effect. However, it was not our preferred control because of the potential inference biases that the metric could introduce.

International. The social green preferences are extracted from the Comparative Political Data Set (Armingeon et al., 2021), and measured by the number of seats that green parties hold in the legislative.

Table 1: Descriptive summary of variables used in the empiric analysis

Type	Variable name	Description (units)	Source	Min	Mean	Max	SD
Main dependent variables	Sh. renewables	Share of renewable energy (%)	EUROSTAT	3.499	20.12	54.65	12.38
	Ind. electric	Tariff charged for consumption of a KWh by hou. (log(EUR/KWh))		4.245	4.802	5.473	0.272
Secondary dependent variables	Sh. windgen	Share of renewable energy wind (%)	EUROSTAT	0.0208	9.496	45.78	10.75
	Sh. solar	Share of renewable energy solar (%)		0	2.145	7.820	2.194
	Hou. elecprice	Tariff charged for consumption of a KWh by households (log(EUR/KWh))		4.879	5.440	5.960	0.267
Governance and reform variables	Independence	Independence index (0 – 1)	Brousseau & Gonzalez, 2020)	0.185	0.304	0.372	0.0432
	Scope	Market coord. Gov. index (0 – 1)		0.216	0.269	0.321	0.0269
	Transparency	Transparency index (0 – 1)		0.167	0.254	0.349	0.0519
	OECD PMR	OECD PMR (1 - 6)	OECD-PMR	0.140	1.282	2.190	0.523
	TA mkt access	Market access index (0 - 1)	Constructed PMR survey	0.110	0.150	0.200	0.0231
Electricity supply, demand and security controls	Elec gen.	Total electricity supply (log GWh)	IEA OECD database	7.688	11.03	13.37	1.398
	Elec cons	Total electricity supply (log GWh)		15.27	17.29	19.55	1.211
	Trade balance	Elec. exports – imports (log GWh)		5.367	8.139	9.149	0.718
	GDP	GDP in const. (log 2017 million USD)	PWT ver10	24.30	26.63	28.99	1.318
	Income PC	GDP per capita (log USD/population)		10.05	10.58	11.44	0.363
Renewable's support controls	Years lawren	Policy time that supports renewable generation (log years)	Constructed, IEA policy database	2.485	4.186	5.659	0.773
	Green Party	Green party seat in the Legislative	Comparative Political Dataset	0	2.34	12.4	3.28
	1-IHH sshare	Diversification of elec. generation sources (0 – 1)	Constructed, IEA-OECD database	-0.441	0.472	0.722	0.248
	1-IHH sshare NR	Diversification of elec. generation nonrenewable sources (0 – 1)		0.0819	0.581	0.950	0.214
Institutions and government efficiency controls	FH civil law	Freedom House civil law scores (0-60)	Freedom in the World Report, 2021	44	55.88	60	3.471
	FH pol rights	Freedom House pol. rights scores (0-40)		28	38.06	40	2.290
	FH index	Freedom House total scores (0-100)		72	93.94	100	5.567
	IHS RL	HIS rule of law index (0-1)	IHS Markit	0.670	0.858	1	0.0917
	TI CPI	Transp. International corruption perception index (0-100)	Transparency International	43	67.39	91	14.07

Besides our list of controls, we construct two additional variables. The first accounts for the lobbying capacity of the dominant non-renewable energy mix structure. We followed (Pfeiffer and Mulder, 2013) and estimate the

Hirschman-Herfindahl (HH) index for non-renewable sources[7]. The shares are extracted from EUROSTAT. The second variable captures the government support to renewable generation and tracks the total number of years that a policy (or group of policies) has provided incentives or direct subsidies to renewable energy generation[8]. We use the IEA Policy Database to identify the policies, their type, their status, and duration period.

c. Econometric model

We use an econometric investigation to uncover the effects of adopting the IRA model in achieving market efficiency and grid decarbonization. We use a two-way fixed effects (FE) model to control for unobserved country and time effects[9].

Equation 1

$$(1)\quad ln\left(dependent\_variable_{i,t}\right) = \alpha + \beta_1 govern\_regime_{i,t} + \beta_2 liberalization_{i,t} + \beta_3 Controls_{i,t} + u_{i,t}$$

In Equation *1*, $ln\left(\text{dependent\_variable}_{i,t}\right)$ stands for our outcome variables, i.e., electricity price and share of renewable energy produced. We are interested in estimating the effects of the independence, transparency and scope of action ($govern\_regime_{i,t}$), which are captured in the term β_1. However, regulatory governance is strongly associated to the electricity market reforms and integration. This issue is partially solved by the individual fixed-effects component. The error term structure: $u_{i,t} = \delta_i + \gamma_{i,t} + \eta_{i,t}$ allows us to control for unobserved heterogeneity. The δ_i term captures time invariant individual characteristics (degree of market reform, long-lasting characteristics of geography, institutions, and/or local preferences). Figure 4 shows that governance regimes evolved significantly between periods, while market regulation remained stable (Figure 3). In other words, while most countries in our sample have not experienced significant reforms in their market regulation regimes, NRAs have converged to more independent and transparent administrations. Moreover, we added the $liberalization_{i,t}$ term to account for current changes in market reforms, which might impact our dependent variables. The $\eta_{i,t}$ captures unobserved time heterogeneity, and $\gamma_{i,t}$ term is an idiosyncratic individual error term.

In addition, we added a set of covariates ($Controls_{i,t}$) to account other determinants of prices and the energy mix such as demand (primary energy demand, income, energy security) and supply factors (persistence of current

[7] The variable is estimated as follows: $lobbying_{it} = 1 - \sum_{i=1}^{N} shareNR_i^2$

[8] We selected current active policies relevant for electricity generation at national level. Policies that support consumers were not included in the indicator. If a policy is active since 1976, in 2013 it was active for 37 years, while in 2018 it was active for 42 years.

[9] We checked for significant individual and time effects by testing if jointly, all individual and time intercepts are different from zero in an OLS regression. Our results suggest that the fixed-effects model should be selected.

generation mix structure, innovation and specialization effects), and institutional quality measures (government effectiveness).

6. Results and Robustness Checks

The section is divided in two sub-sections. First, we test whether regulators closer to the IRA model prioritize their market efficiency, by granting lower prices to consumers (Prediction 1). Later, we showcase our results regarding the effects of governance regimes on the shares of renewable energies (Prediction 2).

a. Electricity prices

Table 2 shows the coefficient estimates for the effects of the IRA model on final electricity prices for industrial consumers[10]. Specifications 1 to 3 measure the effect of each dimension on prices, while specification 4 checks the full regime influence.

Table 2: Fixed Effects estimation: Impact on electric tariffs from governance dimensions

	(1)		(2)		(3)		(4)	
Independence	-0.116	(0.291)					0.225	(0.438)
Transparency			-0.512^{*}	(0.298)			-0.767^{*}	(0.410)
Scope					0.387	(0.639)	0.727	(0.563)
Time effects	yes		yes		yes		yes	
Controls	0.828		0.845		0.830		0.851	
adj. R^2	-144.5		-149.5		-145.1		-149.8	
AIC	48		48		48		48	
Observations	27.87		32.10		32.96		28.66	

Robust standard errors in parentheses
$^{*}\ p < 0.1$, $^{**}\ p < 0.05$, $^{***}\ p < 0.01$

Models (1) and (3) suggest that *independence* and *scope of action* do not significantly affect market prices. Meanwhile, transparency is correlated to lower electricity prices for industrial consumers, as shown in model 2. This negative effect confirms Prediction 1. NRAs, under superior accountability/transparency arrangements, carry their mandate to redistribute industry rents towards consumers. Model 4 confirms our previous finding, after controlling for effects of the other dimensions. The effect of transparency increases between model 2 and model 4, but the statistical significance remains similar (10% significance level). Our outcomes are in line with other studies that link governance regimes with superior efficiency. In telecommunications, Edwards and Waverman (2006) finds that the IRA model mitigates high interconnection rates when government-owned firm operates in the market. Similarly, Gasmi et al. (2009) find regulatory governance is linked to lower consumer prices.

b. Growth of the renewable share in energy consumption

[10] We carried a similar analysis for electricity prices to household consumers. We reported the estimates in the appendix (**Table 7**). The effects of governance regimes were not significant.

Table *3* shows the parameter estimates for the effects of the governance regime in the share of renewable energies. models 1 to 3 test the individual effect of each dimension, while model 4 test the overall regime effect.

Table 3: Fixed Effects estimation: Impact of governance regimes in renewable energy shares

	(1)		**(2)**		**(3)**		**(4)**	
Independence	-0.817^{**}	(0.334)					-0.968^{*}	(0.531)
Transparency			-0.371	(0.496)			0.0984	(0.504)
Scope					0.167	(0.682)	0.530	(0.683)
TA mktacc	1.456^{**}	(0.616)	1.725^{*}	(0.902)	2.091^{**}	(0.787)	1.452^{**}	(0.583)
FH pol rights	0.0378^{***}	(0.0055)	0.0387^{***}	(0.00768)	0.0404^{***}	(0.00818)	0.0388^{***}	(0.00594)
1-IHH gen.	1.039^{***}	(0.312)	1.148^{***}	(0.358)	1.297^{***}	(0.371)	1.084^{***}	(0.312)
GDP	1.915^{**}	(0.873)	2.008^{*}	(0.996)	1.764^{*}	(0.935)	1.850^{**}	(0.870)
incomePC	-2.002^{**}	(0.933)	-2.147^{*}	(1.047)	-1.944^{*}	(0.994)	-1.924^{*}	(0.952)
trade balance	0.107	(0.105)	0.101	(0.113)	0.0940	(0.115)	0.104	(0.113)
y. proren. law	0.262^{***}	(0.0585)	0.274^{***}	(0.0920)	0.309^{***}	(0.0865)	0.255^{***}	(0.0731)
N. Patents	0.134^{**}	(0.0563)	0.125^{*}	(0.0665)	0.123^{*}	(0.0700)	0.127^{**}	(0.0526)
Time effects	yes		yes		yes		yes	
adj. R^2	0.870		0.846		0.841		0.868	
AIC	-141.5		-133.5		-131.8		-139.5	
Observations	48		48		48		48	
F-statistic	33.14		23.05		24.33		36.05	

Robust standard errors in parentheses
* $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$

Model 1 shows a negative relationship between independence and the share of renewable energy shares, which confirms Prediction 1. Our findings suggest that whenever tradeoffs between market efficiency and grid decarbonization arise, independent regulators face high tradeoffs (favor cost-efficient market designs, in line with their long-run mandates, as shown in the previous sub-section). This effect implies that some of the positive effects of market liberalization in green electricity generation, such as reducing entry barriers to clean producers (Nicolli and Vona, 2019), might be offset by the current governance regime structure. Besides, models 2 and 3 highlight no significant effects of transparency and scope of action. In model 4, independence remains statistically significant (at 10% level) among the rest of dimensions.

Next, we attempt to control for other factors that affect the share of renewable electricity across models in **Table *3***. First, we control for the effects of market liberalization (*TA mktacc*), which are positive and significant. The market reform has allowed the entry of new green electricity generators (Nicolli and Vona, 2019). Second, the effects of institutions (*FH pol rights*) and policies supporting renewable generation (*y. proren. law*) are positive and highly significant across models. Our estimates are in line with current literature, which highlights both factors as important determinants of green electricity production (Cadoret and Padovano, 2016; Nicollini and Tavoni, 2017 respectively).

Besides, we control for in industry characteristics (supply side), in particular we account for lobbying pressures to preserve the current generation technology (*1-IHH gen.*) and innovation/specialization effects (*N.Patents*). As expected, both variables contribute positively to predict the share of renewable energy. A low lobbying power allows the entry of new generators, including green ones. Similarly, countries that innovate and specialize in a clean technology(s) reduce future production and implementation costs, leading to higher clean generation shares.

Moreover, we included demand factors controls such as electricity consumption, income and energy security. Regarding electricity demand (GDP[11]), we find a positive and significant effect. Large energy consumption demands larger electricity generation capacity from all sources, including renewables. However, richer countries (income PC) show a negative significant coefficient, which is in line with the findings from Cadoret and Padovano (2016) for a European sample. They suggest that higher income results in a higher energy demand, which triggers the deployment of abundant (or cheaper) energy sources, harming the deployment of renewable energies. In addition, we controlled for the effects of energy security (trade balance). Our estimations show no significant association between countries with positive electricity trade balances (exports higher than imports) and higher renewable shares.

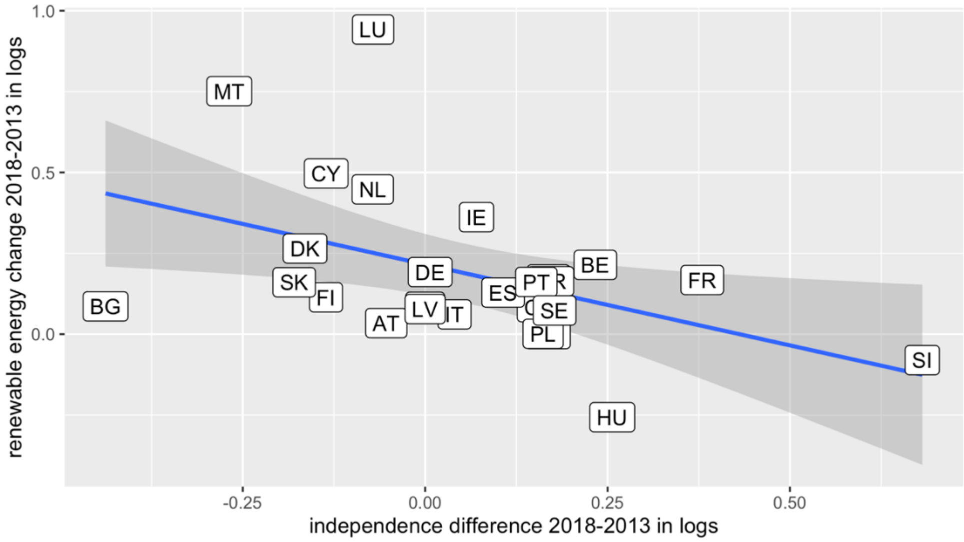
Our previous findings suggest that independent regulators between 2013 and 2018 consistently favor their mandates and objectives over "green" energy targets, because of the increasing renewable energy tradeoffs under current market design (prediction 2).

Robustness checks

Figure *5* shows the negative relationship between independence and the renewable share of electricity generation. In the vertical axis, we observe the change in the share of renewable energy (logs) from each country, while in the horizontal axis the change in the independence score (logs). The figure highlights the presence of potential outlier observations that might drive our regression estimations[12].

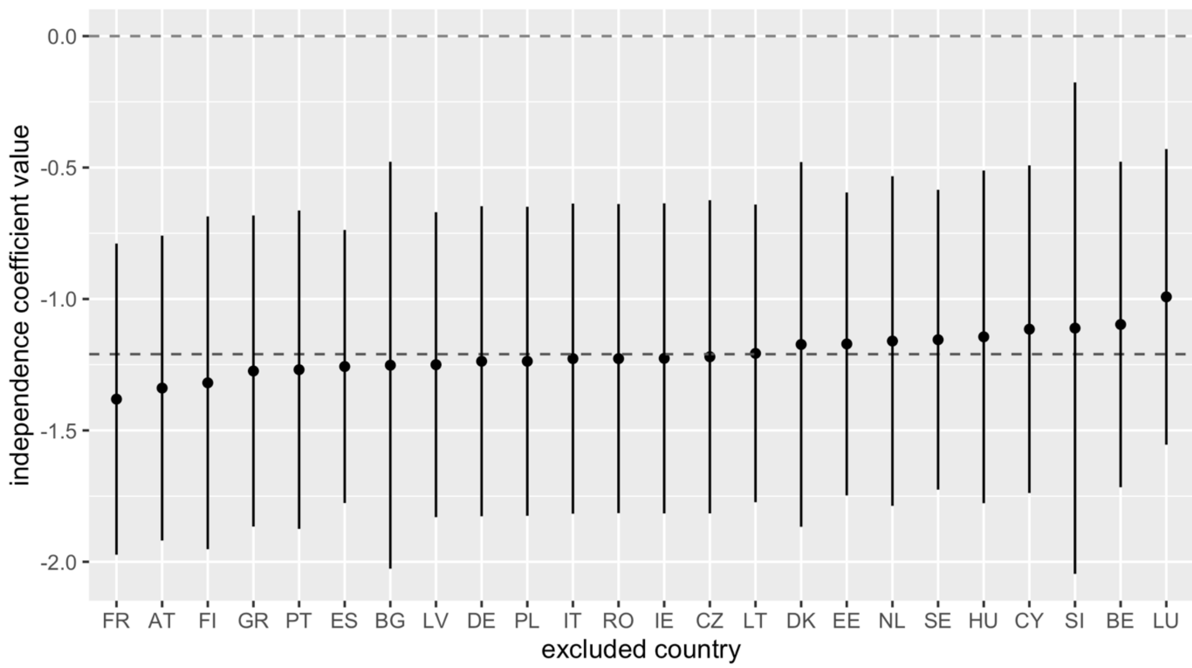
[11] We measure electricity consumption by using GDP instead of primary electricity consumption because of their high correlation (Pearson correlation coefficient = 0.98) and because of data availability.
[12] In addition to the leave-one country out regression, we test the potential effects of outliers graphically after a logarithmic transformation. Our analysis identified Slovenia (SI) as a potential outlier. Even after excluding Slovenia in the regression analysis, our estimates remained robust.

Figure 5: Correlation between the share of renewable energy and independent indicators



Consequently, we use the model 1 in Table 3 to re-estimate a new set of coefficients after excluding one country at a time. The results are presented in **Figure *6*** The y-axis displays the independence coefficient size, while the x-axis shows the excluded country. The solid line shows the coefficient confidence interval (95%). The estimates do not vary considerably between models and none of them include 0 in their confidence intervals. Thus, outliers don't seem to influence our results.

Figure 6: Effects in the impact of independence on renewable energy growth of rolling out countries



The institutional environment and its measures might impact our results our results as well. Differences in information sources and aggregation methods add uncertainty to our estimations. To check potential issues, **Erreur ! Source du renvoi introuvable. Table *4*** shows the estimation results with different institutional variables used in the literature of renewable share determinants (surveyed by Bourcet (2020))[13]. Model 1 displays coefficients of our baseline model. In model 2 we add an additional variable "Green Party" to capture environmental preferences beyond the government policies. The coefficient remains robust (at 10% level) and suggests that countries where green parties have more delegates, are associated to larger shares of renewable preferences. We did not include this variable in our main specification because it reduces estimation accuracy more than improving the model fitting, as pointed by the AIC[14]. In model 3, we use Transparency International Corruption Perception Index (CPI) as a proxy for government effectiveness. Lower corruption levels are translated into better functioning services offered by the government. The independence coefficient slightly varies, compared to model 1, yet the CPI coefficient is not statistically significant. In model 4, we use a measure of Rule of Law by the IHS-Market, which captures the extent to which individuals are equal to the law. The independence coefficient changes in magnitude, but the direction of the effects and statistical significance remain. However, the IHS-Market coefficient becomes negative and non-significant. Finally, in model 6 we use the OECD PMR index to track changes in the market reform. The independence coefficient varies slightly, but it becomes more significant. This significance improvement might come from not accounting the uncertainty introduced by the imputation method previously used. Although, the reform coefficient becomes insignificant at conventional levels. All the previous results let us conclude that our model is robust to changes in institutional measures.

Table 4: Fixed Effects estimation: Additional covariates in the renewable model

	(1) Base	**(3) Green**	**(4) Corrupt. Index**	**(5) IHS-RL**	**(6) OECD PMR**
Independence	-0.817**	-0.860*	-0.898**	-1.309*	-0.986***
	(0.334)	(0.423)	(0.363)	(0.649)	(0.318)
Green Party		0.0186**			
		(0.00709)			
N. Patents	0.134**	0.177***	0.117**	0.153**	0.138**
	(0.0563)	(0.0629)	(0.0536)	(0.0639)	(0.0618)
FH political rights	0.0378***	0.0344***			0.0362***
	(0.00552)	(0.00496)			(0.00524)
Corruption Index			0.0120		
			(0.00710)		
Rule Law				-0.693	
				(0.480)	
OECD PMR					0.0236
					(0.0615)
Time effects	yes	yes	yes	yes	yes
Controls	yes	yes	yes	yes	yes
adj. R^2	0.870	0.855	0.837	0.833	0.856
AIC	-141.5	-136.6	-130.8	-129.6	-136.6
Observations	48	48	48	48	48
F-statistic	33.14	43.16	11.96	16.27	25.93

[13] We carried a similar analysis for industrial consumer prices in **Table 6** in the appendix. Changes in institutional controls reduce the statistical significance of our estimates.
[14] In **Erreur ! Source du renvoi introuvable.**, a lower value of AIC indicates a robust model. In particular, model 1 has an AIC of -141.5 and model 2, -136.6

Robust standard errors in parentheses
$^{*}\ p < 0.1$, $^{**}\ p < 0.05$, $^{***}\ p < 0.01$

Finally, we measured the share of renewables using the olverlapping sample (22 countries) and only the share of solar and wind sources share in total production[15], which accounted for most of "green" electricity growth according to the IEA Global Energy Report (2020). Both coefficients of independence, in **Table 5** (in the appendix)- model 1 and 2, remain negative and significant. These parameter estimate suggests that the effect of the governance regime is present across the across different samples and renewable energy sources.

7. Discussion of results

The discussion aims to put our theoretical framework and results in context with current and future EU climate change targets. To frame our discussion, we suggest in our discussion that there is an ongoing tension between the government discretion in renewable energy growth and the NRA mandate of stable markets. The tension is driven by the tradeoffs arising from increasing the share of renewable energy and more autonomous NRAs.

We have divided the discussion into two sub-sections. The first sub-section discusses the discretion that governments have to achieve their renewable energy targets to which they have committed, even if regulators are independent. While the second section discusses some innovations in the NRAs governance regimes proposed in the literature to reduce the trade-offs to encourage the increase in the shares of renewable energies.

a. Government discretion in renewable energy growth

We also discuss why the discretion of governments may be reduce in the future and may become harder to achieve more stringent targets.

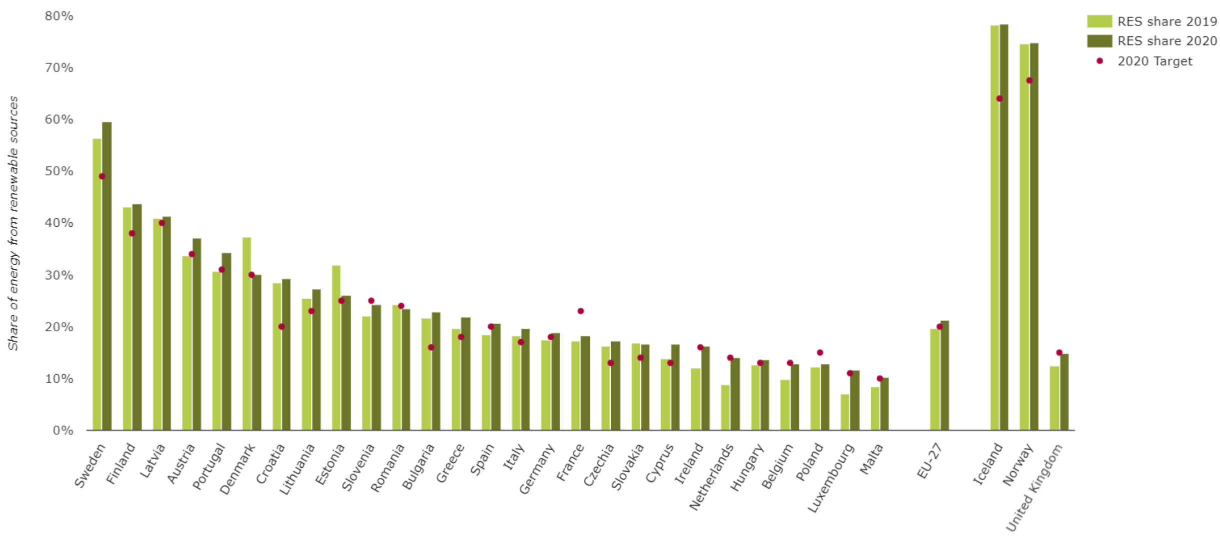
According to our theoretical framework, the effect of independence on achieving current renewable energy targets will depend on the trade-off of increasing the share of renewable energies. Our results suggest that for 2020 targets, the trade-offs in most countries are not significant enough to impede governments achieve their climate objectives, as for 2020, the EU as a whole achieved its objective.

To look into the detail of how the discretion of governments to achieve their targets, may change amongst country in the EU, we present ***Erreur ! Source du renvoi introuvable.***. It shows the targets that each country set themselves for 2020 and their share of renewable energies. According to the European Environment Agency (EEA), 22 Member States reached their 2020 targets, Belgium, Romania, and Slovenia remain close to meeting the target (<

[15] This measure is less sensitive to changes in electricity consumption patterns.

1 %), and France and Poland were the countries furthest away from their 2020 target, over 2 percentage below their targets (EEA; 2021).

Figure 7: Progress towards renewable energy targets by country (EEA; 2021)



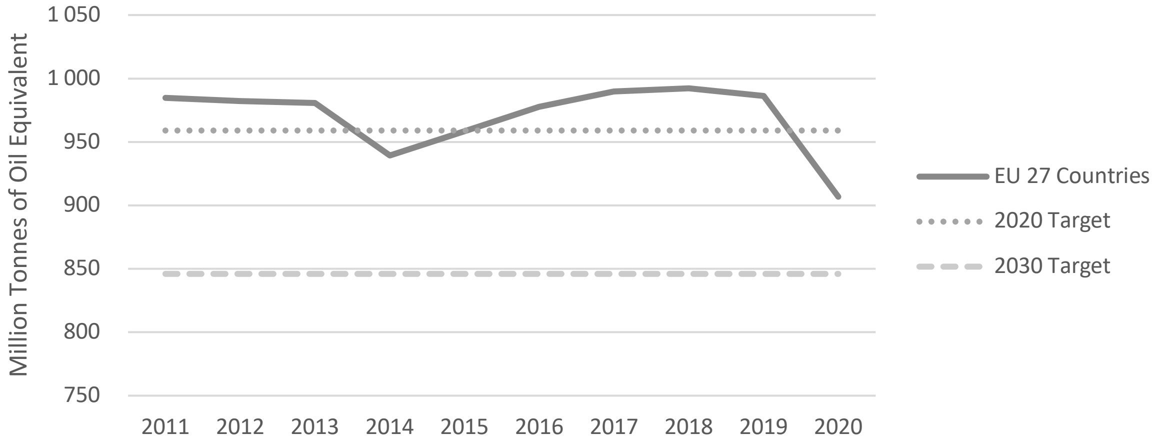
We found in the literature, three mechanisms that give discretion to governments to increase the share of renewable energy and achieve their climate change targets for 2020 and below: (i) Increasing efficiency in consumption; (ii) transferring efficiency from liberalized electric markets to renewables; and (iii) efficiency in generation creating national industries.

i) Increasing efficiency in consumption

Current renewable energy targets are not only dependent on renewable electricity production, but instead on final energy consumption, i.e. the indicator depends on the energy consumption of the whole economy and not just in the electric sector. This gives discretion to governments to achieve their objectives through implementing policies in different sectors, for example in the residential sector, through energy efficiency programs.

The joint EU target was to reach that 20% of total energy consumption came from renewables by 2020. The EU met its 2020 target, with renewable energy increasing from 16.6% of gross final energy consumption in 2013 to 19.1% in 2018, and finally **to** 22.1% in 2020 (Eurostat; 2021). However, it helped that total gross final energy consumption decreased substantially between 2019 and 2020 (-6.1%) due to the impact of measures to contain the Covid-19 pandemic (EEA; 2021). Figure 8, displays the evolution in the final energy consumption of the 27 EU member states, and the energy efficiency targets of the EU for 2020 and 2030. The evolution in energy consumption have

Figure 8: Evolution of final energy consumption and energy efficiency targets (Eurostat, 2021)



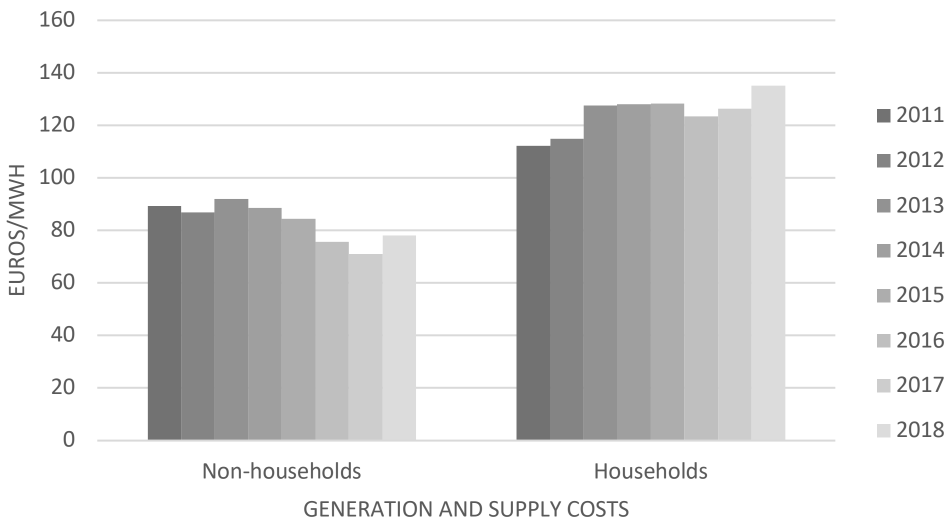
ii) Transferring efficiency from electric markets to renewables

The efficiency gains from liberalized markets have not been totally transferred to the customer, instead have been used to cover the costs of supporting the development of renewable energies. On one hand, governments used subsidies to increase renewable energy deployment. On the other hand, a stable market and competition increased the efficiency of electricity production, by giving a signal to attract investments and allocating resources through efficient price mechanisms. Consequently, electricity tariffs have been affected by the rate of change between efficiency gains and renewable subsidies.

Under, our theoretical framework, governments have been able to increase subsidies to renewables, by taking advantage of liberalized markets that have contributed to reducing the cost of generation and supply of electricity. Consequently, reducing the impact of taxes and levies for renewable energy subsidies on consumers. Our results support this interpretation. First, independent regulators reduce government discretion by constraining the increase of subsidies, reducing the speed of renewable energy adoption. While our results in the correlation of prices and transparency are explained through the increase of the efficiency on the market, reducing electricity tariffs.

Figure ***9*** shows the evolution of generation and supply costs for non-households and households, between 2011 and 2018. Generation and supply (network costs), which considers the largest part of the electricity tariffs that consumers have to pay are overall decreasing once control for factors that affect grid congestion. Our results in **Table *2*** (non-household analysis) and **Table 7** (household analyses), evidence the efficiency gains from transparency in resource allocation, that are easier to see in Figure 8 for non-household. For households, the evolution is less clear, but once that controls are applied for network costs the trend is negative but less significant.

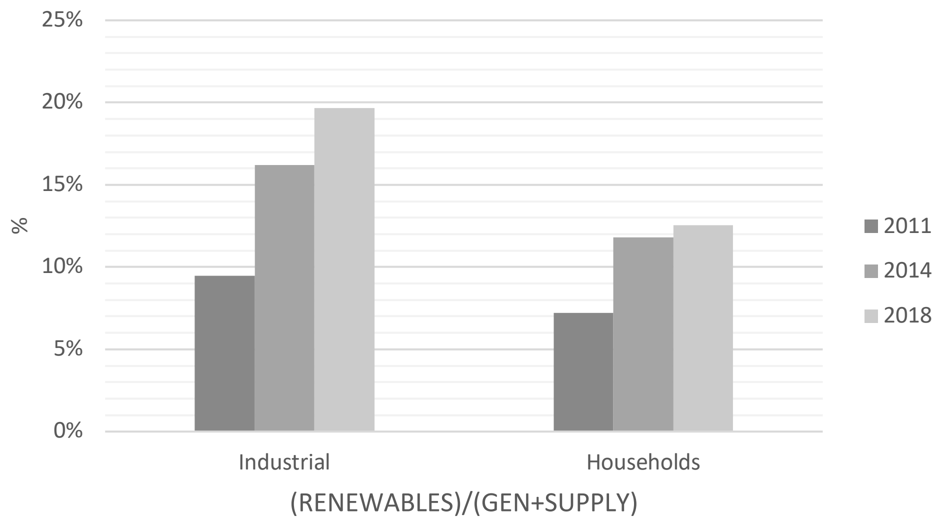
Figure 9: Evolution of average EU-27 Generation and Supply costs in € per MWh charge to Non-households and Households (Eurostat; 2021).



According to the last report on renewable energy subsidies from the European Commission. During 2015 and 2019 subsidies for energy production as a whole, went up by 4%, roughly €3 billion. Particularly, renewable subsidies were up by 8% in the same period, which is an increase of €6 billion in 2019 compared to 2015. Most of the renewable energy subsidy was used in the instruments in the EU Member States were feed-in tariffs (amounting to €53 billion in 2019 (EC; 2021). Feed-in tariffs affect electric tariffs, by fixing a market price in long-term contracts to which operators are obliged to buy the electricity generated by the renewable energy source, even if feed-in tariffs are now less implemented as a tool to support renewable energy.

Figure ***10***, shows that the ratio between the total support given to renewable energies divided by the gross MWh consumed; and the costs of generation and supply (network costs) which are displayed in Figure ***9***, is increasing for non-households and households. Most of the support given to renewable energies are from general taxation or non-tax levies paid via the electricity bill by electricity consumers (CEER, 2021).

Figure 10: Ratio of the cost of renewable support respective to the costs of supplying electricity. (Authors, based in Eurostat and CEER)[16].



iii) Creating national industries

Less *independence* is not immediately translated into a higher share of renewables. Resource endowments learning and industrial capacities may support the creation of "*National Industries*" that reduces the incentives of governments to separate themselves from the regulator. Governments may create national industries, to develop economic growth through the energy sector, which depending on the technology selected impacts positively or negatively the share of renewable energies.

Just to illustrate the case, **Figure 11** and **Figure 12** compare the annual growth in the share of renewable energies of Denmark, which had the highest growth in the sample, and Hungary, which was the only country to reduce their share of renewable energy during 2013 and 2018. Both countries' NRA's display low independence scores in our sample. Yet, their performance in the growth on the share of renewable energies differ substantially, as it is not the effect of independence the main drivers of their growth, but instead other institutional and economic factors.

On one hand, Denmark is a rich country that has developed its wind industry as a national industry, because of its natural resources and a strategy to divest from fossil fuels. On the other hand, Hungary is a country that relies heavily on the legacy of its past energetic infrastructure which uses Gas and Coal for energy production.

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[16] For 2011, the share was calculated using the renewable energy support of 2010 and the generation and supply costs of 2011. All ratios were calculated by the authors. The data used in the numerator is the weighted average of the countries in the surveys as calculated by the Council of European Energy Regulators (CEER) in their 2011, 2014 and 2018 Renewable Energy

Figure 11: Denmark and Hungary annual growth of renewable energy share. Source: Authors, based on Eurostat (2021).

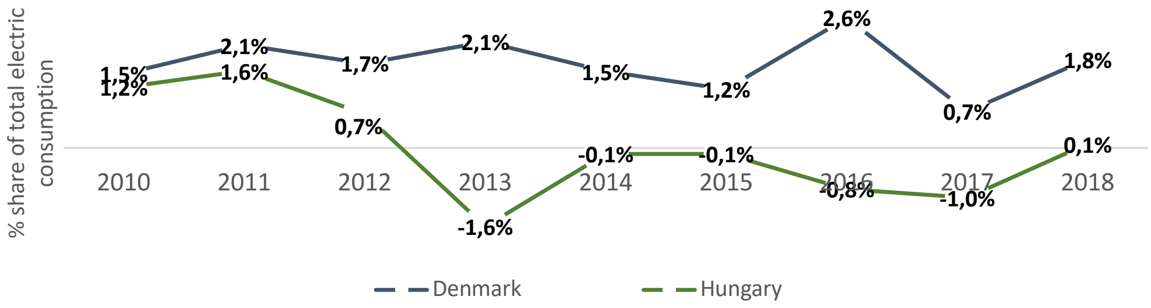


Figure 12: Denmark and Hungary, share of renewable production. Source: Authors, based on Eurostat (2021)

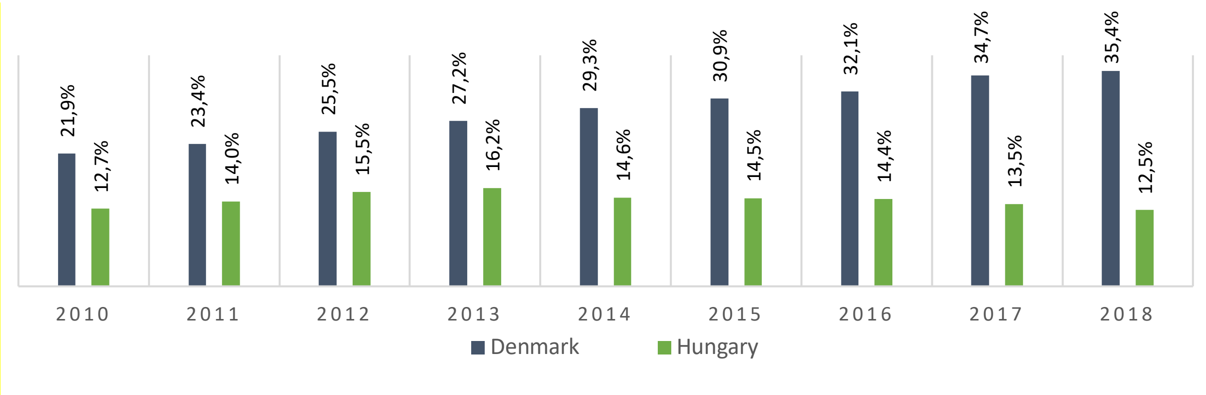
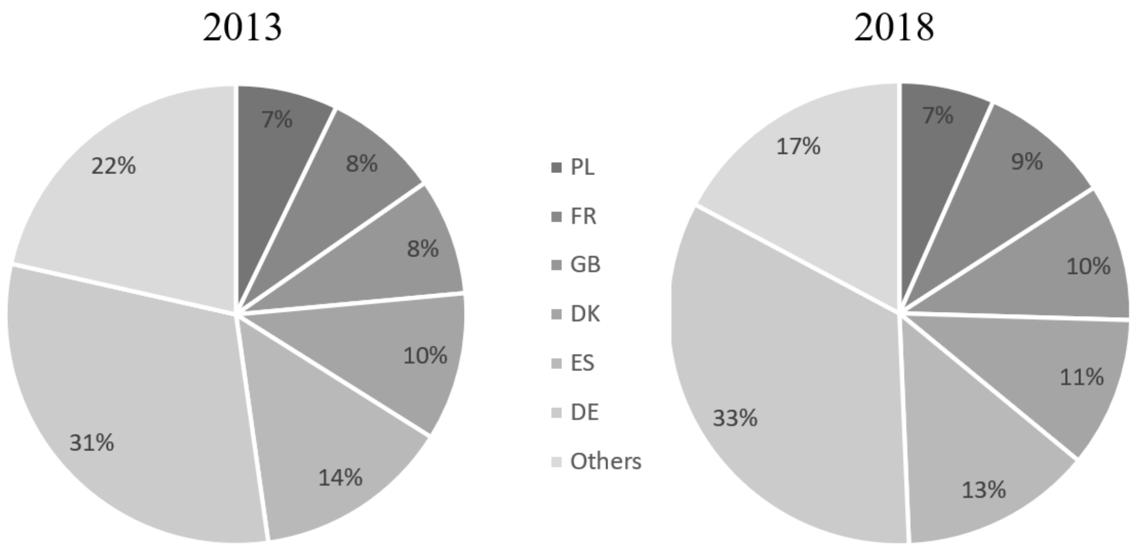


Figure 13, shows the six countries that had more than 5% of total patents registered in 2013 and 2018 in Europe. The seventh country has less than 2% of the total share of patents. The graph showcase, that Germany (DE), Spain (ES), Denmark (DK), Great Britain (GB), France (FR), and Portugal (PL) are significantly developing more research in the development of the renewable energy industry in their countries. The results shown in **Table *3*** also validate our interpretation, being the number of patents on renewable energies is a positive driver for the growth of renewable energies independent from the governance regime effect. Hence, being a relevant tool for the government to increase renewable energies.

Figure 13: Distribution of new patents in the EU and GB (Elaborated by authors, based in IRENA 2021)



b. Innovations on NRAs mandate

Given that evidence show that the measurement of IRA dimensions is converging amongst NRA's in Europe (Brousseau & Gonzalez-Regalado, 2021; OECD, 2019). That our results show that independence is negatively correlated with the share of renewable energy. And, future climate change targets will become more stringent as an unprecedented transformation in the energy system will be necessary to meet the 32% renewable energy target set for 2030 and full decarbonization for 2050. We expect that if changes in NRA mandates are not made, the effect of the governance regime will become more significant over time. Under this hypothesis, a question, that seems obvious to ask is: Which is the role of the IRA model and liberalized markets in reducing the trade-offs to achieve climate change objectives?

According to Bartle and Vass (2007), the expertise and specialized knowledge of NRAs position them to have a role of facilitators in the integration of renewable energies. They identified three areas that ease the conflict. First, regulators may take a role in coordinating actions, with other institutional actors to increase the exchange of information between actors and become a mediator to plan the paradigm change. For example, NRAs' experience may detect situations in which market reforms and policies account for externalities. Second, NRAs may take an advisory role in policy analysis or construction of scenarios in the policy elaboration process. This collaboration might detect policy conflicts, redundancies and assess trade-offs. Finally, the information disclosure with stakeholders should be augmented beyond the economic scope of the NRAs operation.

The previous solutions have of course some caveats. First, substantial coordination threatens agency independence, because measuring the distance between the regulator and the government may become more difficult, affecting the risk perception from investors. Second, if regulators are required to develop additional tools, they may require an increase in resources and might lose part of their specialization benefits. Third, if the extent of their role increases NRA's accountability may decrease as its difficult to benchmark agency performance in a fuzzy set of responsibilities. In addition, for all cases proposed by Bartle and Vass (2007) NRAs will require to increase their transparency, and measure their performance through additional indicators of performance. Future empiric research in the impacts of changing the mandate of NRAs in their performance are still gaps in the academic literature.

8. Conclusions

This paper assessed the impact of three dimensions (independence, transparency and scope of action) of governance regime on European NRAs in the share of renewable energies. The dimensions assessed came from the IRA model, designed to support the liberalization reforms in Europe.

We focus our analysis in the period between 2013 and 2018, because of data availability. Results show that NRA's independence is negatively correlated with the share from renewable energies. In addition, we found that transparency is also negatively correlated with industrial tariffs.

The findings suggest that the IRA model, creates a threat for NRA of deviating from their original mandate and that increasing the speed of adoption of renewable energies affects market stability and competition. Hence, independent regulators will be able to slow down the adoption of renewable energies, to protect competition and efficiency in electric markets.

The main paper's contribution provides quantitative evidence that during 2013 and 2018, NRAs governance regimes were decreasing the adoption of renewable energy in the electric sector. Finally, we discussed our results contrasting them with the literature. We found many arguments supporting that future climate targets will become harder to achieve and that they are open questions regarding the impact of changing the NRA mandate to align them with renewable energy growth.

9. Appendices

Table 5: Fixed Effects estimation: Additional dependent variables

	(1)		(2)	
Independence	-0.764*	(0.413)	-0.130*	(0.0647)
TA market access	1.585**	(0.719)	-0.269	(0.183)
Time effects	yes		yes	
Controls	yes		yes	
adj. R^2	0.850		0.938	
AIC	-125.4		-291.4	
Observations	44		44	
F-statistic	32.82		59.57	

Robust standard errors in parentheses
* $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$

Table 6: Fixed Effects estimation*:* Impact on industrial electric tariffs from governance dimensions

	(1) FH civil law		(2) IHS-RL		(3) TI Corrupt. Index		(4) OECD PMR	
Transparency	-0.512*	(0.298)	-0.495	(0.342)	-0.376	(0.312)	-0.559*	(0.281)
FH civil laws	-0.0104	(0.0112)					-0.0118	(0.0122)
IHS-RL			-0.109	(0.297)				
TI Corr.Index					-0.00358	(0.00600)		
TA market access	0.626	(1.280)	0.330	(1.635)	0.699	(1.393)		
oecd_pmr							-0.0433	(0.0737)
Time effects	yes		yes		yes		yes	
Controls	0.845		0.836		0.839		0.844	
adj. R^2	-149.5		-146.7		-147.6		-149.3	
AIC	48		48		48		48	
Observations	32.10		31.64		32.84		37.19	

Robust standard errors in parentheses
* $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$

Table 7: Fixed Effects estimation: Impact on household electric tariffs from governance dimensions

	(1) Indep		**(2) Transp**		**(3) Market**		**(4) All gov. dim.**	
Independence	0.256	(0.471)					0.567	(0.587)
Transparency			-0.0992	(0.258)			-0.345	(0.397)
Market					-0.158	(0.779)	-0.317	(0.880)
Time effects	yes		yes		yes		yes	
Controls	0.433		0.425		0.425		0.423	
adj. R^2	-130.5		-129.9		-129.8		-128.1	
AIC	48		48		48		48	
Observations	3.281		3.762		3.253		3.186	

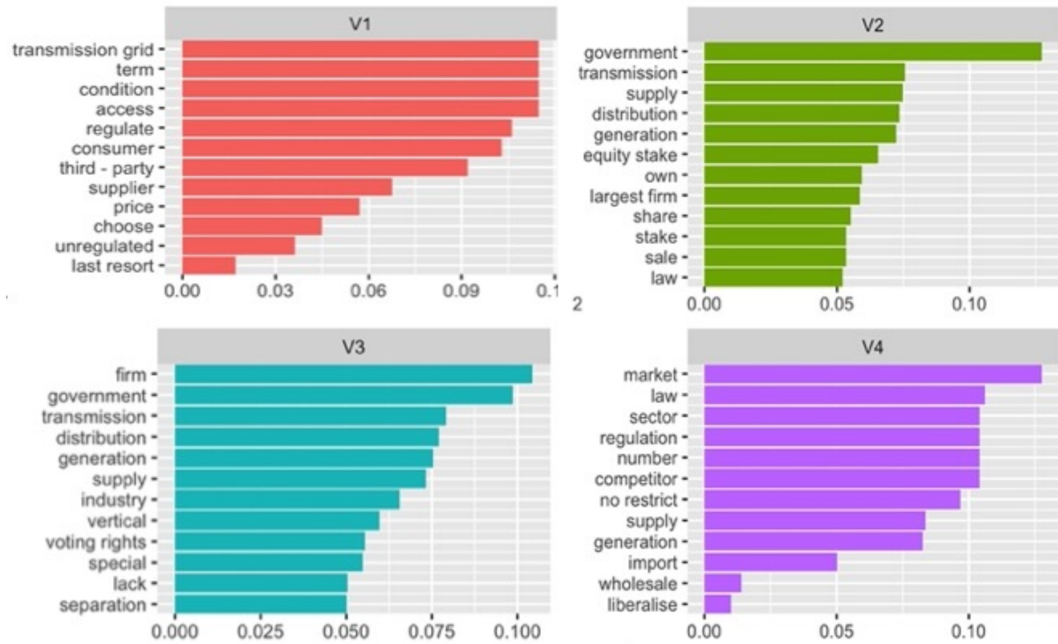
Robust standard errors in parentheses
* $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$

Textual analysis variable construction

To measure the intensity of market reform, we assessed the regulatory environment by using survey questions from the OECD PMR (Vitale et al., 2020). Instead of using the categorical content of the survey, we tracked changes in replies by assessing the textual information embedded in the survey. We applied the following steps to the data.

1. We created a set of documents using the textual information from the survey. The textual information comes from the words used to express country replies. In the following question, "Are market prices regulated?", we registered "market prices are regulated" for a positive reply, and "prices are unregulated" for a negative one in our database.
2. With the previous information, we constructed text documents for every country and time. Based on co-occurring terms in every document, we fit a topic model (LDA) and identify four groups[17] of terms that describe the country market reform, as shown in **Figure *14***.

Figure 14: Text Analysis of market regulation dimensions



3. Based on the co-occurring patterns, we assign a label, and interpret its meaning. Further trend visual inspection and econometric analysis shows that the "V1" topic captures significant variation in our models. The label "market access" stands for the non-discriminatory provisions that support new entrants

[17] There is no consensus on how to reach an optimal number of topics in textual analysis. In this setting, we used a coherence score (Jones, 2019) to evaluate which number fits our data better.

in the generation sector (third-party access, unregulated prices). This interpretation is supported by (CITE) that finds market entry barriers as the most meaningful dimension in the liberalization reform.

4. The rest of topics (V2, V3 and V4) cover regulatory aspects such as government involvement, vertical separation, and wholesale competition.

10. References

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