The Impact of Regulatory Independence on the Growth of Renewable Energies: A Panel Data Analysis of European Member States between 2013 and 2018

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Carlos Gonzalez-Regalado[1], Diego Cebreros[2], and Eric Brousseau[1]

[1]Chaire Gouvernance et Régulation, Université Paris Dauphine-PSL
[2]Chaire Armand Peugeot, Université Paris-Saclay, CentraleSupélec

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Abstract: Using a panel data analysis of 24 EU countries, we show that between 2013 and 2018, the degree of independence from the government of National Regulatory Agencies (NRAs) has a negative and robust relationship with the share of renewables in the electricity supply. Our results help us to derive some policy implications regarding the roles of governments and NRAs in the decarbonization of the electricity sector. We suggest an ongoing tension between environmental policy and the will to support renewable energy development, with the competition policy established on the NRA mandates since the liberalization reforms.

1 Introduction

In electric systems, energy policy plays a crucial role in encouraging the adoption of renewable energies. Indeed, most investments in renewable energy power plants still rely on some subsidies (e.g., tax subsidies, feed-in tariffs, purchase obligations, and long-term contracts) to promote their development. The main motivation behind these support schemes is that experience effects will eventually make renewable technologies competitive with conventional generating technologies.

However, subsidy schemes and renewable generation have undermined the established market design, reducing the returns of conventional power plants and increasing the costs of balancing and capacity adequacy of electric systems (Newberry, 2016). The electricity production from solar and wind sources challenges the current *"economic logic"* of electricity markets: they are *"intermittent"* and have almost zero short-run marginal cost (Joskow 2011). In contrast, most conventional generating technologies (e.g., coal, gas, nuclear) are *"dispatchable"* and have higher short-run marginal costs that depend on their fuel and operation costs.

Much of the work on energy policy addressing the growth of renewable energy has implicitly assumed the institutional framework in which policymakers operate (Blazquez et al. 2018; Lund 2009; Newbery et al. 2018; Tolmasquim et al. 2021). Nevertheless, the literature on institutional economics has shown evidence that the institutional framework might substantially affect the performance of economic policies (Scully 1988). Therefore, in this paper, we analyze the relationship between *de jure* and *de facto* power and its influence on renewable energy growth. While the former is the type of political power allocated by political institutions, the latter emerges from the ability to engage in collective action (i.e., in the form of lobbying or brute force) (Acemoglu and Robinson, 2006a). We use this theoretical relation from institutional economics as an entry point to analyze the relationship between National Regulatory Agencies (NRAs) with the executive power from European Member States (MS). Our research question is: *to what extent do independent NRAs resist the growth of renewable energies in the EU electricity system?*

In the EU, initially, most electric systems were controlled by nationally owned vertically integrated monopolies. With the liberalization reforms, MS took a step back on energy policy, enabling the NRAs to decide on the *"economic rules"* of the electric system (Joskow, 2008). Indeed, NRAs were designed as specialized parties with the objective of establishing fair competition and stable rules for market participants. In this context, independence establishes the separation between the *de-facto* power of the MS and *de-jure* power of NRAs to steer the economic rules of electricity markets, with the objective to create a credible commitment to secure private investments.

Considering the fact that MS in the EU have committed to decarbonizing their electric

system for 2050, not NRAs. Our thesis is that NRAs independence generates *"resistance"* to the speed at which renewable energies grow. For us, resistance means that NRAs will be cautious about how renewable energies might impact negatively on competition because their main objective is to provide a stable market that attracts investments to have a reliable and efficient electric system. For example, mechanisms such as renewable energy subsidies or changes in market design might be to the detriment of the position of incumbents which are the prominent investors in current electricity markets.

To test our thesis we perform an empirical analysis using panel data to measure the impact of regulatory governance on the renewable energy share and electricity tariffs in the EU member states. However, governance is not easy to measure, nor are publicly available indicators. Therefore, we use OECD regulatory governance surveys (Brousseau and Gonzalez-Regalado, 2022) in combination with text-analysis metrics to derive governance indicators. This method uses data variability to identify the relevant features of a governance regime and the participants' weights assigned to each dimension.

Our results show that between 2013 and 2018, independent NRAs were negatively associated with the share of renewable energy sources (RES) in total energy consumption. Our contribution is two-fold. First, previous work analyzing the institutional context of policy makers (Alesina et al., 2005; Égert, 2018; Anderton et al., 2020) focuses on the effects of the reforms (policy output) on economic performance (investments, factor productivity, and labor markets). We contribute to the empirical literature on the effects of the liberalization of utilities by separating the impacts of regulation per se from the impacts of governance arrangements that implement it. Second, we contribute to the literature on the drivers of decarbonization by discussing the policy implications that our results have for NRAs and environmental objectives. We suggest an ongoing tension between the will to support renewable energy development and guaranteeing low electricity prices to consumers through competition. Furthermore, we put our results in context, discussing the policy implications of the ambitious targets to decarbonize electricity systems in EU for 2050.

This study has eight sections. In the second section, we propose an overview of the emergence of NRAs from an EU perspective, considering the mandates of liberalization reform on their design. The third section provides the background on the tension between renewable energies and current market design. The fourth section describes our theoretical framework. Seciton five the data used and our empirical strategy. Section six presents our main results, while section seven discusses them in detail. Section eight offers our main conclusions.

2 National regulatory agencies in the EU

In Europe, the liberalization reforms aim to facilitate the integration of EU electric systems: incentivize the investments needed to develop transmission lines for exchanging electricity amongst MS and improve the system reliability and efficiency Joskow (2008). These reforms required the privatization and vertical separation of formerly state-owned (national) monopolies, which, in many cases, controlled the totality of electric assets within a country. However, the unbundling of state-owned vertically integrated monopolies appeared insufficient to attract investments in the EU from the start of the liberalization process. Furthermore specialized wholesale markets were created, and the development of a common regulatory framework to guarantee fair competition.

However, the market power from the ancient monopolists was still relevant, and NRAs emerged to steer the market implementation and become technical referees to guarantee fair competition. The reasoning was that new investors needed stronger guarantees of fair treatment while competing with state-owned incumbents, as well as protection from short-term political interests that could threaten their returns by changing market rules [1]. Indeed, until the liberalization reforms, policy-making and enforcement were primarily in the hands of public bodies directly overseen by ministries. Therefore, politicians in power could have incentives to favor the state-owned (private) incumbent (Stigler, 1971) or to depart from long-term policy commitments in exchange for political support (Majone, 1996).

Consequently, during the early 1990s, several European governments delegated regulatory functions to independent NRAs to signal policy stability and transparency to new investors (Glachant, 2012). In addition, independent bodies could solve information gaps (Glachant et al., 2013), policy commitment concerns (Gilardi, 2002, 2005; Gilardi and Maggetti, 2011), arbitrate disputes, and monitor industry performance.

As shown in table 1, there are several European Directives that set overarching principles of competition on the NRA institutional framework. The regime was gradually implemented, with member states transferring regulatory tasks to NRAs (e.g., interconnection rate setting, monitoring duties) that could contribute to ensuring fair third-party access to the transmission and distribution segments (Article 4 of (2003/54/EC)) [2]. Later, the Third Electricity Package expanded the NRA regulatory powers/responsibilities by allowing them to modify contract terms and conditions, oversee interconnection issues, and solve disputes between market actors (Article 36 of (2009/72/EC)).

The Third Electricity Directive formally established independent NRAs in member

[1] Investment in utilities requires the deployment of high-cost specialized capital. Under the presence of return risk (political instability), firms might not deploy optimal capital levels (underinvestment) or even not invest at all (hold-up problem).

[2] The Second Electricity Package likewise included provisions for NRA independence, with a focus on limiting the possibility of incumbents' regulatory capture.

Table 1: Summary of legal instruments for EU NRAs in Europe

Actors	Legal origins Principles and tools	Delegation
Member States	Competition - MS shall ensure electricity markets are operated following the competition, security, and environmentally sustainable principles. (Article 3 Directive 2003/42/EC; Article 3 Directive 2009/72/EC).	Delegation - ME shall designate a single national regulatory authority at the national level. (Article 35 Directive 2009/72/EC)
	Non-Discrimination – If financial compensation (other forms) and exclusive rights that ME grants for fulfilling the obligations shall be done in a non-discriminatory and transparent way (Article 3 Directive 2003/42/EC).	Independence - Member states shall guarantee the independence of the regulatory authority and shall ensure that it exercises its powers impartially and transparently. Member states shall ensure that regulatory authority can take autonomous decisions independently from any political body and has separate annual budget allocations (Article 35 Directive 2009/72/EC)
	ME shall ensure the implementation of a system of third-party access to the transmission and distribution systems based on published tariffs. (Article 24 Directive 2003/42/EC)	
	Monitoring - ME shall ensure the monitoring of the security of supply. Where MS consider it appropriate, governments may delegate this task to the regulatory authorities (Article 4 Directive 2003/42/EC)	
NRAs	Responsibilities - Regulatory authorities shall ensure non-discrimination, effective competition, and efficient market monitoring. (Article 36 Directive 2009/72/EC)	Independence - Regulatory authorities shall be wholly independent of the interests of the electricity industry (Article 35 Directive 2009/72/EC)
	They should be responsible for: (a) rules on the management and allocation of interconnection capacity, (b) the level of transparency and competition, (c) methodology to calculate tariffs, and (d) help achieve in the most cost-effective way the development of secure, reliable and efficient production of electricity (Article 36 Directive 2009/72/EC).	Accountability - Regulatory authorities shall submit formal decisions to the relevant body in the Member State regarding the methodologies to calculate tariffs. Member states may approve or reject the propositions of regulators (Article 36 Directive 2009/72/EC).
		Authority – Regulators shall have the authority to require transmission and distribution system operators, to modify the terms and conditions, tariffs, and rules, to ensure that they are non-discrimination. Regulators may also act as dispute settlement authority between parties (Article 36 Directive 2009/72/EC).

states. First, it required member states to delegate regulatory responsibilities to a *single* national body, and second, it ruled on measures that granted this authority autonomy while limiting undue political influence on its decisions. The Directive, in particular, created limits between the NRA's top management and the government (and with the industry). Several rules, for example, prohibited top management from working for both the government and the NRA simultaneously or established "cooling-off" periods before NRA top management could join the industry. Additional measures restricted politicians' and political cycles' influence by creating fixed governing periods and limiting arbitrariness in executive management dismissal. Furthermore, the Directive required member states to ensure proper NRA operation by providing stable funds/human resources and allowing the NRA to administer its resources autonomously (Article 35 of (2009/72/EC)).

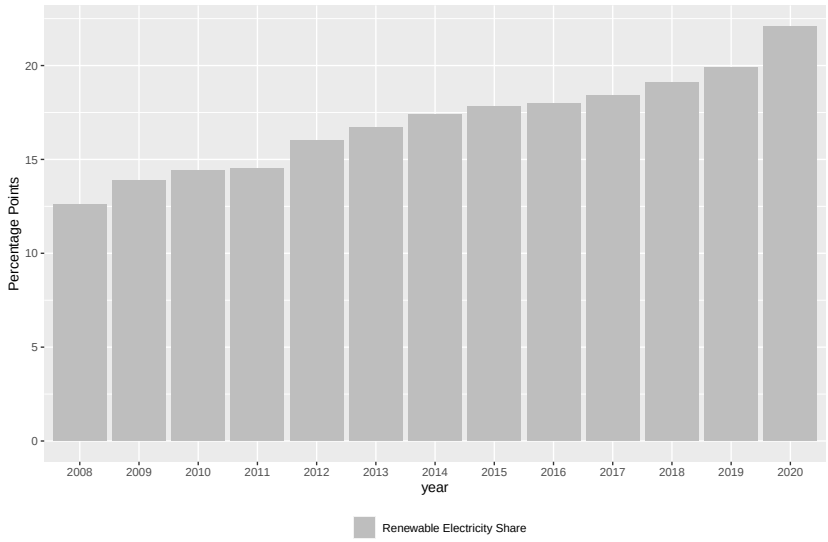
The CEP has deviated from the previous regime by implementing new sustainability mandates for the NRA operations. The NRAs are tasked with creating the technological and economic conditions that allow renewable electricity and "flexibility" services to participate in the market. In other words, NRAs' actions must guarantee the inclusion of additional renewable energy generation, electricity storage systems, and demand management mechanisms cost-efficiently. Yet, as discussed in the following section, these additional environmental requirements create contradictions between the market reform, the governance regime, and sustainability objectives.

3 Tension in the economic logic between renewables and conventional sources of electricity.

Since 2004, the share of renewable energies has doubled, reflecting the political commitment to decarbonization targets. Governments either supported the reduction in the investment costs in renewable generation (mainly for solar and wind units) or guaranteed positive and stable revenue streams through support mechanisms such as feed-in-tariffs / premiums, quotas, and other instruments. Figure 1 shows the positive evolution in the share of renewable energy as a percentage of total energy consumed in the 27 EU member states. The support instrument used the most was feed-in tariffs, which represented a subsidy of €53 billion in 2019 (EC, 2021). Because feed-in tariffs have supported renewable energies, and renewable energies reduce the price in wholesale electric markets, the subsidies from feed-in tariffs have become more expensive over time (Henriot and Glachant, 2013; MacLean et al., 2015; Council of European Energy Regulators, 2021).

The growth of renewable energy has been a main driver of several EU Directives ruling on decarbonization that have focused mainly on setting emission targets. These directives started in 2001 under the Kyoto Protocol, which agreed on a binding target for the EU to reduce 2012's emission levels by 5% to its 1990s emissions. The first renewable electricity

Figure 1: Evolution in the share of renewable energy as a share of gross energy consumption



directive (2001/77/EC) ruled that member states should define renewable energy targets, update them every five years, and encourage them to use national economic mechanisms until the EU defines a common framework. Its update in 2009 (2009/28/EC) required member states to 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. European Green Law (Regulation EU/2021/1119) is the most recent commitment from the EU to climate change targets. It legally binds the Green Deal, defining a target of achieving a 55% reduction in emissions below 1990 levels by 2030, increasing the ambition of the existing EU Emission Trading System (EU ETS), and the ambitious objective of EU climate neutrality by 2050.

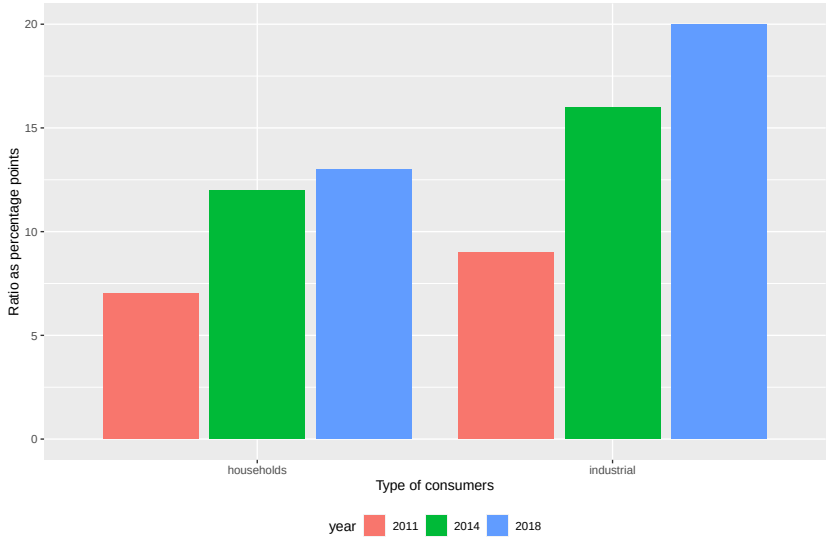
However, the current wholesale market organization is designed to reward generators based on cost efficiency in a setting where generators have positive marginal costs (e.g., the fuel cost for thermic plants) and can produce energy at any given time. Plants with low marginal costs supply electricity to the network first. As the demand increases, generators with higher marginal costs deliver electricity until the demand is met. The marginal cost of the last generator participating in the market sets the wholesale price paid to all electricity suppliers.

Therefore, additional renewable generation leads to lower wholesale electricity prices because of the zero marginal cost of producing an additional electricity unit. Low prices in the wholesale market may not provide enough incentives for new investors and may prevent current plants from covering their costs or not utilizing their total capacity (Blazquez

et al., 2018). To correct this problem, European member states implemented onerous subsidy schemes to incentivize renewable generation. The importance of these subsidies has increased over time, as evidenced in fig. 2, which shows the extent of subsidies as a fraction of the cost of an electricity unit [3].

The rise of renewable energy support has stressed the need for additional investments in the power system to handle the mismatch between unmonitored supply and market demand. In response, capacity markets have been developed to rectify the balance, focusing on compensating backup generation, frequently of a thermal nature [4]. Nonetheless, a notable drawback of these markets lies in their dependence on complex calculations grounded in various technical assumptions. Unfortunately, these assumptions, while considered effective in meeting the real needs of the power grid, have led to an excess of available power and consequently have raised the prices consumers pay. Empirical studies show a significant correlation between the share of renewables in the energy mix and higher electricity prices in the OECD countries (Moreno et al., 2012; da Silva and Cerqueira, 2017).

Figure 2: Renewable energy tariff support / electricity tariff ratio by type of consumer



Estimations by authors, based on Eurostat and CEER:

Given the tension between renewable generation, the current market design, and, ul-

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

[4] Capacity mechanisms usually rely on decentralized carbon-based generation plants that do not participate in the market.

timately, the liberalization objectives, we explore the role of NRAs in easing or stressing the tensions introduced by renewables, given the liberalization mandates. Although the reform set broad environmental principles for NRAs, they are mandated and accountable for reducing system costs, transmitting rents to customers, and encouraging new investments. The extent to which NRAs can carry out their mandates or choose to pursue other (environmental) objectives highly depends, among other elements, on the preferences of agencies, national governments, and European institutions (Alesina and Tabellini, 2008), and the NRAs' degree of autonomy from external intervention, discretion on resource usage and the breadth of powers delegated to execute their assignments.

4 Theoretical framework

4.1 Governance regime's characteristics

The assessment of governance regimes has focused on exploring whether NRAs carry out their mandates and objectives independently and on methodologies to estimate NRAs autonomy (Thatcher and Sweet, 2002; Levi-Faur, 2005). Gilardi (2002, 2005) compared the governance of NRAs in economic and social sectors by assessing their decision-making independence (from the government and the industry). Following the literature on central bank independence, the author estimated a metric that considered the appointment length of agency authorities and provisions for their dismissal, budgetary autonomy, internal resource management, and delegated tasks as the most essential features of NRA independence [5].

However, recent studies suggest that even if *independence* is a fundamental dimension, other dimensions are needed to contrast regimes and study their impacts. Hanretty et al. (2012) discuss the role of transparency and accountability in improving the regulatory decision-making process. They suggest that both features encourage bureaucrats to perform better in their duties and to stick to the agency mandates. Transparency in regulatory intervention has increased substantially in the electricity sector since the beginning of the market reform Pollitt (2019). The decision-making processes are open to public scrutiny, and regulatory authorities and staff are evaluated periodically by legislative bodies. However, these features are complex to measure because regulators differ in objectives and are embedded in different institutional systems.

Besides *independence* and *transparency*, the breadth of delegated powers is also relevant to describe and discriminate among governance regimes. OECD (2016) stresses the importance of regulatory levers to enforce market regulation, such as specifying network

[5] Gilardi (2002) operationalizes the independence dimension by constructing a weighted index that summarizes survey information by assigning different scores when agencies have or not a head/board appointment process, budget, and organizational levers, and the scope of regulatory powers.

access conditions, setting prices and tariffs, settling disputes between market actors, and requesting information from market players. The availability of such powers increases the regulators' abilities to solve complex and unexpected problems (Jamasb and Pollitt, 2005).

Jordana et al. (2018) and Brousseau and Gonzalez-Regalado (2022) used factor analysis and text analysis algorithms, respectively, to identify alternative regime arrangements. Both studies proposed alternative arrangements that partially contrast with mainstream studies (e.g., OECD (2016)). Jordana and co-authors propose a four-dimension model (Political independence, Managerial Autonomy, Regulatory Responsibilities, and Public Accountability) to discriminate between economic and social regulators worldwide. In contrast, Brousseau and Gonzalez-Regalado proposed a four-dimensional model focusing on economic European NRAs in network industries, including the electricity sector.

Their model uses detailed OECD surveys to follow the implementation of the current EU governance regime (part of the EU electricity market reform) across NRAs between 2013 and 2018. In detail, the model defines regime features as follows:

1. **Independence from the government** estimates the degree of separation between the regulatory agency and the executive's undue influence [6]. The main objective of independence is to support the stability of market access and competition rules (Gilardi and Maggetti, 2011).

2. **Discretion** describes the agency level of "flexibility.". The dimension portrays an agency's freedom to manage its internal decision-making process and resources and to interpret its mandates.

3. **Scope of market monitoring** describes the regulator's ability to monitor/coordinate the competitive process, supervise the industry behavior, and manage economic incentives.

4. **Transparency** reflects the regulators' role in reducing information asymmetries between operators, public authorities, and users [7]; in particular, to ensure compliance and limit behavioral drift.

In the following sections, we use the model in Brousseau and Gonzalez-Regalado (2022) to associate differences in NRAs' governance regimes to energy mix heterogeneity across European countries.

[6] Gilardi and Maggetti (2011) use a similar definition, in which describe independence as the institution that separates the government bureaucracy from the elected politicians

[7] The dimension aggregates measures of the obligation for (public) reporting imposed on the RA and the reporting obligation imposed on the market players by the RA.

4.2 The reform, system efficiency, and the environment

The literature evaluating market reforms and their impact on renewable electricity generation cannot showcase a significant relationship. Generally, market reforms improve member states' environmental performance but do not necessarily encourage new renewable generation units to enter the market. Pollitt (2019) suggest that the decrease in pollutant emissions associated with market reforms results from the entry of efficient gas generators (replacing coal generators) and not new renewable units. Asane-Otoo (2016) finds similar results and suggests that the introduction of competition in generation and privatization attracted efficient (thermic) generators to the market and reduced emissions, but surprisingly, they did not find evidence of an increase in renewable generators. Nicolli and Vona (2019) propose that the market reform, particularly the reduction of entry barriers and the access of new generators, reduced the incumbent's power to lobby against renewable support policy. Their empirical evidence displays that an extended market reform (OECD PMR index) positively correlates with public support for renewable energy. However, no empirical evidence of superior renewable energy generation is provided.

This overview suggests that market reforms enhanced overall system efficiency but did not create market conditions that encouraged investment in renewable generation. Yet, the role of the sectoral governance regime on renewable generation has not been discussed. The following section analyzes the relationship between governance regimes and the electricity sector performance and proposes connections between governance regimes and renewable energy generation.

4.3 Hypothesis formulation

NRAs' actions depend on the interaction between the agencies' preferences (principles and mandates), their internal resources, and the interests of governments and industry players. In this context, the agencies' governance regimes have a strong influence on their outcomes and, hence, on industry performance. Governance features such as decision-making autonomy, agency discretion, and the breadth of delegated powers are expected to influence performance differently.

The market reform aims at incentivizing industry players to invest in competitive and integrated electricity systems. To deploy new investments, potential investors need a guarantee about their expected returns. The reform envisioned independent NRAs as bureaucratic bodies able to monitor and steer the market in a stable and predictable mode and reduce the likelihood of short-term politicians' opportunistic policy deviation (Majone, 1996). Consequently, regimes with independent NRAs are expected to attract superior investment levels. In this regard, Cubbin and Stern (2006) finds a strong association between the presence of an independent regulator and superior electricity generation per capita. In

some circumstances, the effect of independence is conditional on privatizing utilities. While Zhang et al. (2008)'s results indicate that *independence* characteristics are significantly associated with a higher generation per capital but only in the presence of private incumbents. This claim supports previous work by Zhang et al. (2005), who show that privatization increases sector per capital output only when an independent regulator is established before the reform. Independence is significantly associated with other sector performance measures, such as investment and firm leverage. Égert (2009) rely on a cross-section of 13 countries and six utility sectors in 2008 to show that the setup of an independent regulator and the application of incentive price regulation reduce return risk and, therefore, foster investments. Moreover, Cambini and Rondi (2017) highlight that establishing an independent regulator positively impacts investments in 80 EU utilities, including 37 energy firms in distribution and transmission. After controlling for political and institutional variables, they found significant investments from the private sector increased between 1994 and 2004 because the setup of independent regulators enhanced policy credibility among investors.

The previous evidence supports the premise that independent NRAs commit to the reform's mandates, which has attracted investments that improved the overall system performance based primarily on monitorable sources. The inclusion of non-monitorable sources in the current market design stresses the system's efficiency by increasing its costs to match supply and demand [8]. When conflicted with increasing system costs of renewables, which could translate into higher prices to consumers and efficiency losses (especially in the capacity market), independent NRAs serve the overall system efficiency. Thus, we expect that:

- Hypothesis 1: More independence is associated with a lower share of renewables in the energy mix.

The NRAs' ability to interpret its mandates relies on the institutional design of the agency, societal demands, and the stakeholders' preferences about those demands. In the case of decarbonization needs, a particular group (e.g., citizens) could advocate for a more decarbonized energy mix, while another group (e.g., consumers) could express concerns about the impact of decarbonization on the rise of electricity prices. The NRA's conduct would depend on its preferences about the societal demand and the power distribution among groups. Therefore, we do not expect a significant effect of *discretion* on the electricity mix.

[8] The "merit order" market design rewards generators in the queue line with marginal cost equal to or below the least efficient generation unit that entered the market. Assuming that the most efficient CO2-generating units enter the queue, the CO2 units with higher operational costs will provide capacity services in case of need. This implies that balancing costs increase under additional intermittent renewable units that demand superior balancing capacity.

- Hypothesis 2: More discretion should not be associated with a higher share of renewables in the energy mix.

The breadth of delegated powers granted to a regulatory agency (monitor and steer competition in the industry) describes in practice the NRA's capacity to accomplish its goals. Brousseau and Gonzalez-Regalado (2022) distinguish NRA's powers between the ones used to supervise competition (scope of market monitoring) and the ones to supply information to the industry and reduce information asymmetries between operators, users, and public authorities (transparency) [9]. While political scientists have examined the reasons for governments to grant regulatory powers to NRAs (see Wassum and De Francesco (2020)), the effects of this breadth of powers on industry performance have been overlooked.

Several analyses have focused on the links between the breadth of NRA's powers and the agency's ability to conduct its work accurately. However, their results do not indicate the existence of a significant link. Hanretty et al. (2012) examine the correlation between accountability, which partially overlaps with the NRA's capacity to reduce information asymmetries, and the perceived regulatory quality in energy, telecommunication, and transport. A regulatory quality measure was derived from self-administered surveys about the NRA's performance. The authors found a positive but non-significant relationship between the two variables. Similarly, Hanretty and Koop (2018), using an ordered probit regression, did not find any correlation between accountability and regulatory quality (proxied by scores from the Global Competition Review) for 30 OECD competition authorities in 2005-2014.

These results indicate that regulatory powers do not affect the players' investment behavior. Principles, mandates, and policy commitment are determinants of investment decisions. As a result, we anticipate:

- Hypothesis 3: More market scope monitoring should not be associated with a higher share of renewables in the energy mix.
- Hypothesis 4: More transparency should not be associated with a higher share of renewables in the energy mix.

[9] Wassum and De Francesco (2020) contrast regulatory powers between "hard" and "soft" competencies. "Hard" competencies are related to direct intervention capacity, as in the case of setting prices or price controls, emitting licenses, and issuing sanctions and penalties. "Soft" competencies describe the capability of the NRA to modify behavior through non-binding actions. Examples of these competencies are issuing industry and consumer standards, guidelines, and codes of conduct and collecting information from industry players.

5 Data and methodology

5.1 Data

Because of data availability, our econometric analysis relies on 24 countries: Austria, Belgium, Bulgaria, Cyprus, Czech Republic, Germany, Denmark, Estonia, Spain, Finland, France, Greece, Hungary, Ireland, Italy, Luxemburg, Lithuania, Latvia, the Netherlands, Poland, Portugal, Sweden, Slovenia, and Slovakia. We analyze the European electric systems for the period 2013-2018. The appendix A gives a detailed summary of the data used and statistical characteristics, particularly table 4.

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 consumption in MWh [10]. Moreover, we constructed a second variable that captures the non-monitorable (i.e., solar and wind generation) sources' participation in the electricity mix to estimate whether the governance regimes conflict with these renewable sources.

To capture the NRAs' governance regime, i.e., independence, transparency (accountability), and Scope of action, we use the indicators computed by Brousseau and Gonzalez-Regalado (2022). The normalized scores range from 0 to 1 for each of these dimensions [11]. The metrics measure the evolution of the governance regime between 2013 and 2018.

Their metrics offer several advantages. First, they are derived from surveys on network sector governance regimes (electricity, gas, telecommunication, rail, and air transport) conducted by the OECD. The OECD (2016) provides the most comprehensive dataset about regulatory governance to date for both periods. Second, the characteristics and number of dimensions were defined using text-analysis algorithms [12] (word co-occurrence) to uncover latent dimensions using the data variability without predefined assumptions about the most contrasting differences among regimes. Third, their metrics allow comparing regimes over time, enabling the evaluation of whether changes in governance have implications for the industry's output. Finally, the metrics summarize scores based on the data variation and not in a predefined weighting scheme.

[10] European Environmental agencies use this metric to track country decarbonatization target performance

[11] The OECD estimates governance scores with the same survey (Casullo et al., 2019). However, scores are not comparable across time because of significant changes in their questionnaire. Brousseau and Gonzalez-Regalado (2022) NLP method allows bypassing this time-comparability issue

[12] Brousseau and Gonzalez-Regalado (2022) use a coding scheme to transform survey categorical responses into textual documents. Using topic modeling, textual sources uncover co-occurring clusters of terms named topics. Based on these clusters and their terms' semantic meaning dimensions are identified and defined.

To measure the extent and evolution of the liberalization reform, we constructed a *market access* variable that captures to what extent legal provisions support entry in the generation and retail segments. The estimation method (see Annex 2) follows the approach proposed by Brousseau and Gonzalez-Regalado (2022). The metric was estimated using information from the OECD Product Market Regulation survey for 2013 and 2018 (Vitale et al., 2020). Similarly, we also utilize the OECD PMR index, which aggregates information on the industry entry barriers, market structure, vertical integration, and price controls. The data is available from 1975 to 2018.

In addition, our dataset considers national, sectoral, and institutional variables that affect the supply of renewable energy. Data on electricity consumption, production, and system capacity are obtained from EUROSTAT (2018) and International Energy Agency (2018), while the economic and demographic variables (GDP and population) from the Penn World Tables version 10 (Feenstra et al., 2015). The measures that capture the quality of institutions are gathered from various sources. The Freedom House Political Rights Score (Freedom House, 2018) accounts for political and institutional stability. Besides, the IHS-Market indicator and the Corruption Perception Index (CPI), from Transparency International (2018), measure the legal system's protection to prevent an arbitrary exercise of power. The society's preferences for environmental policies are estimated by the number of seats green parties hold in the legislative. The information is collected from the Comparative Political Data Set (Armingeon et al., 2023). To proxy for the most prominent firm's decision power in the sector, we use the market share of the largest generation firm available in Vitale et al. (2020). Finally, the measure of the industry's ability to innovate is gauged by the number of patents per millions of habitants and extracted from the International Renewable Energy Agency (2018) database.

In addition, we construct three variables that portray the support (or opposition) to renewable electricity generation. The first measure accounts for the (lobbying) power that non-renewable technologies would have to preserve the current mix structure. Technologies with larger market shares are expected to spend more resources to keep the status quo. We followed Pfeiffer and Mulder (2013) and estimated the Hirschman-Herfindahl (HH) index for non-renewable technologies. [13]. The shares are extracted from EUROSTAT (2018). The second variable captures the extent to which lawmakers have produced public policies to support renewable generation. The variable is constructed by counting the years that particular policies or programs that support renewable generation (e.g., incentives or direct subsidies) have been in force [14]. More extended promotion of green energy should trigger entry in the generation segment (Nicolli and Vona, 2019). The third index accounts exclusively for the importance of policies that provide direct financial incentives to generators.

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

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

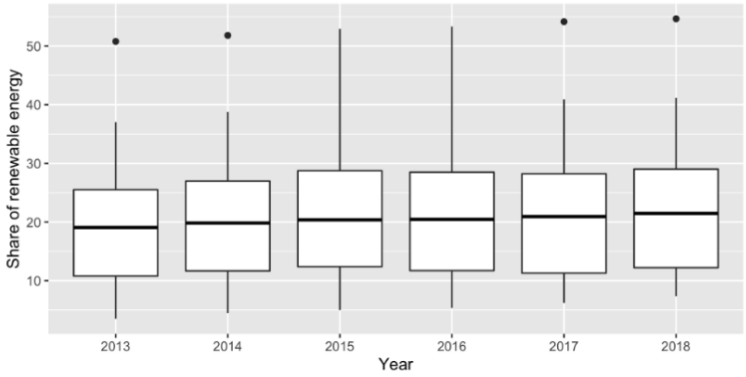
This importance is proxied by the percentage of policies granting subsidies, loans, and tax incentives as a share of total renewable support policies. We use the International Energy Agency (2018) Policy Database to identify the policies, type, status, and duration period.

To measure consumer electricity prices, we use end-use consumer year-averaged prices (for industrial and household customers, excluded VAT). The data is gathered from *Energy Prices and Taxes Statistics database* (International Energy Agency, 2018).

5.2 Evolution of renewable shares, liberalization, and governance regimes

The shares of renewables have grown for our sample between 2013 and 2018. Figure 3 shows that disparities across countries remain over time despite this growth. This heterogeneity reflects differences in geographical location, national energy resources, and institutional and economic long-run conditions (Bourcet, 2020). As discussed in the following subsection, a fixed-effects model could account for these structural differences.

Figure 3: Distribution in the growth of renewable energies



The liberalization reform that started in the early 1990s kept pace during the 2000s, although at different paces. Most European OECD countries reduced regulatory barriers to firm entry and competition and implemented pro-competition regulations in their regimes. Figure 4 shows the evolution of the electricity market reform implementation between 2000 and 2018, measured by the OECD PMR indicator (each line represents a country in our sample). Since 2013, only a few countries have liberalized their markets further, while the majority have followed a steady trajectory.

In contrast, governance regimes experienced significant changes between 2013 and 2018. Figure 5 shows that NRAs are more independent (red) from the government and were granted higher levels of formality (reduced discretion in purple). However, regulators are still far from converging to a similar independence level. The variance of the score remains

quite significant. In contrast, the transparency (green) and scope of market monitoring (blue) tasks increased their homogeneity over the period. Transparency increased while the scope of market monitoring remained similar to the previous period level.

The NRA governance model is a fundamental part of the liberalization reform in the European Electricity markets, as explained in section 2. This association challenges identifying the potential effects of governance on industry performance because changes in the governance regime might reflect a deepening of the liberalization reform. The considerable changes in the governance regimes and the relatively modest evolution of the liberalization reform between 2013 and 2018 provide a possibility to isolate the governance effects on performance.

5.3 Econometric model

The national electricity mix is the result of technical and political characteristics but also of various geographical, historical, and institutional factors that occasionally are unobserved for a researcher. The two-way fixed effect panel data model accounts for those unobserved factors that vary only over long periods. Besides, this model also controls for common shocks that could have affected electricity systems during specific periods [15].

$$\ln(performance_{i,t,}) = \alpha + \beta_1 * govern\_regime_{i,t} + \beta_2 * regulatory\_regime_{i,t} + \beta_3 * controls_{i,t} + \mu_{i,t} \quad (1)$$

In eq. (1), the share of renewable energy and electricity price are our outcome variables ($\ln(performance_{i,t,})$). The effects of the governance dimensions ($govern\_regime_{i,t}$), i.e., *independence*, *discretion*, *scope of market monitoring*, and *transparency*, on the outcome variables are captured by the term β_1. Despite the liberalization reform's stability between 2013 and 2018, the term $regulatory\_regime_{i,t}$ is introduced to capture the impact of any variation in the liberalization reform. The term β_2 captures the reform's effects.

Moreover, the error term structure $\mu_{i,t} = \delta_i + \nu_t + \gamma_{i,t}$ controls for unobserved electricity and renewable sector characteristics. The δ_i term captures time-invariant system and national characteristics (e.g., the lasting aspects of geography and institutional traditions).

[15] 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. Our specification also assumes a constant effect of independence over countries and time. However, we tested whether the overrepresentation of negative heterogeneous treatment effects might artificially negatively bias our average estimates. We follow de Chaisemartin and D'Haultfœuille (2020) test to test if the effect direction comes from a true prior or is the result of overrepresentation. Our model is not driven by the issues presented on de Chaisemartin and D'Haultfœuille (2020).

The ν_t captures unobserved common shocks that could have affected electricity systems during a particular period, and the $\gamma_{i,t}$ term is an idiosyncratic individual error term.

In addition, we added a set of covariates $controls_{i,t}$ to account for other determinants of the energy mix, such as changes in demand (primary energy demand, income, energy security) and supply factors (policy support towards particular technologies, innovation, and specialization effects), and institutional quality (government effectiveness and the rule of law). The vector β_3 captures the effects of our control variables on system performance.

6 Results

6.1 Effect of governance regimes on renewable energy growth between 2013 and 2018

Table 2 shows the parameter estimates for the effects of the governance regime on the share of renewable energies. Models (1) to (4) test the individual effect of each dimension, while model (5) tests the overall regime effect.

Models (1) and (5) show a negative relationship between *independence* and the share of renewable energy after controlling for the rest of the dimensions. This estimate confirms the *Hypothesis 1*, which indicates that independent regulators are associated with a lower share of renewable electricity produced. At this point, we cannot explicitly distinguish between the independence granted to the regulator and its mandates (objectives). Therefore, we add a set of controls to account for other factors that might influence the share of renewables and the governance regime.

The rest of the dimensions do not seem to have a crucial influence on renewable generation. The effect of *discretion* is negative but is not statistically significant. Thus, we accept the *Hypothesis 2*. *Transparency* has a negative, but not significant, impact on renewable energy shares in models (2) and (5). In model (5), after controlling for the effects of the rest of the dimensions, the coefficient almost drops to zero. Thus, we accept *Hypothesis 3*. This result coincides with the one claimed by Koop and Hanretty (2018), where no strong associations are found between transparency and regulatory or industry performance. Finally, the *Scope of market monitoring* shows a positive but non-significant coefficient in models (4) and (5). These estimates confirm *Hypothesis 4*. The positive effects could indicate that regulators with market steering tools can organize markets that attract renewable generation better. However, more research is needed to support this connection.

Table 2: Fixed Effects: Impact of governance on renewable energies shares

	(1)	(2)	(3)	(4)	(5)
Independence	-0.817**				-0.968*
	(0.334)				(0.531)
Discretion		-0.203			
		(0.317)			
Transparency			-0.371		0.098
			(0.496)		(0.504)
Market				0.167	0.53
				(0.682)	(0.683)
Liberalization	1.456**	2.306**	1.725*	2.091**	1.452**
	(0.616)	(0.864)	(0.902)	(0.787)	(0.583)
Inst. Stability	0.038***	0.041***	0.039***	0.040***	0.039***
	(0.006)	(0.008)	(0.008)	(0.008)	(0.006)
Non-renew power	-1.039**	-1.328**	-1.148**	-1.297**	-1.084**
	(0.312)	(0.351)	(0.358)	(0.371)	(0.312)
Demand (GDP)	2.049**	1.739*	2.133**	1.887**	1.978**
	(0.861)	(0.843)	(0.977)	(0.910)	(0.852)
Wealth	-2.136**	-1.926**	-2.271**	-2.067**	-2.051**
	(0.921)	(0.918)	(1.029)	(0.971)	(0.934)
Trade balance	0.107	0.095	0.101	0.094	0.104
	(0.105)	(0.118)	(0.113)	(0.115)	(0.113)
Years ren. laws	0.262***	0.319***	0.274***	0.309***	0.255***
	(0.058)	(0.085)	(0.092)	(0.087)	(0.073)
Patenthundred	0.134**	0.125*	0.125*	0.123*	0.127**
	(0.056)	(0.067)	(0.067)	(0.070)	(0.053)
Individual effects	yes	yes	yes	yes	yes
Time effects	yes	yes	yes	yes	yes
adj. $R\hat{2}$	0.87	0.842	0.846	0.841	0.868
AIC	-141.4	-132.3	-133.5	-131.8	-139.5
Observations	48	48	48	48	48
F-statistic	33.137	18.331	23.049	24.334	36.048

Controls: *mkt access*: a measure of market reform implementation related to granting new incumbents access to the natural monopoly segment of the industry (i.e., the network). *Inst. Stability*: Freedom House political rights score. The metric captures the extent to which political institutions are stable. *Non-renew power*: Incumbent lobbying power of non-renewable generators in the industry. Higher metrics show that a traditional incumbent firm has significant generation participation and, therefore, a high lobbying power.*Demand(GDP)*: Gross domestic product measure in PPP USD of 2010. The measure proxies the electricity demand in a country. The correlation with primary electricity demand is above 0.98. *Wealth*: *Income per capita*: the variable measures average income in PPP USD 2010 per person. *Trade balance*: measures the net electricity trade (exports - imports) as a proxy of electricity security. *Years ren. laws*: measures the political support for renewables by legislation. The metric sums the years that different laws are set in logs. *Patenthundred*: captures the effects of specialization in renewables. The measure is the ratio of patents and the number of people in a country. Discretion is excluded in model (5) due to multicollinearity with the other gov. dimensions. Heteroskedasticity robust standard errors in parentheses * p < 0.1, ** p < 0.05, *** p < 0.01.

6.1.1 Confounding factors and additional controls

We assess confounding factors that might affect the share of renewables and the governance regime in table 2. First, we control for the effect of liberalization, which might influence the extent of the IRA model in a jurisdiction (Gilardi, 2005), and might foster renewable energies by removing entry barriers (Nicolli and Vona, 2019). The impact of market liberalization (*mkt access*) is positive and significant. Second, we consider the security of supply (*trade balance*). Countries with electricity deficits (more significant imports than exports) could be incentivized to set up independent regulators to foster investments. Besides, deficit countries might develop firm policies to support renewable generation since their territories might lack access to other generation capacities (hydro or nuclear plants), thus reducing their electricity deficit (Pollitt, 2019). We found that countries with positive trade balances (*trade balance*) are associated with larger renewable shares, yet all models' coefficients are insignificant. Finally, we control for the institutional environment and potential political capture following Baldwin et al. (2017). According to the authors, political capture threatens new investments by increasing the risk of expropriation. If political capture becomes large enough to hold up new investments, politicians set up independent regulatory agencies to attract new investments (Gilardi, 2005). In our specification, we use *FH pol rights* to measure the institutional stability in a country (lower probability of investments being expropriated) and find that it is positively and significantly associated with larger renewable shares. In the robustness check section, we use alternative indicators to control for other institutional national characteristics, such as the rule of law and government quality.

We also controlled for the national efforts to support renewable generation. We measured this support by adding the years that different "green" policies have been in force (*years ren. laws*) [16]. The variable's coefficient is positive and significant (as expected), as presented in table 2, model (2). Moreover, we incorporated electricity demand controls such as consumption and national wealth (income per capita). Regarding electricity demand, proxied by nominal GDP, we find a positive and significant effect. In other words, more consumption is associated with more significant electricity generation from all sources, but in particular from renewables [17]). However, more prosperous countries seem to prefer an energy mix that relies on thermic generation. This finding aligns with the argument that developed countries prefer to spend on thermic systems because renewable generation might not meet unexpected demand increases (Cadoret and Padovano, 2016). Similarly, we account for the (lobbying) power that non-renewable generators have to preserve their rents. High non-renewable lobbying power (*IHH gen*) should limit the entry of renewable

[16] We use a second variable to control for policy support. We estimated the share of policies that support subsidies from all the policies implemented in national legislation. Results in table 6 show no significant correlation between the variable and the share of renewable energy.

[17] 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.

generators. Our variable is negatively correlated with the share of renewables. Innovation effects (*patenthundred*) are also positively correlated with a larger share of renewables.

In addition, we evaluated other market conditions associated with renewables, like electricity prices and market concentration. Systems with high prices might call for deeper regulatory reforms (including regulatory independence) or changes in the energy mix to reduce prices. Model (2) in table 5 indicates a positive but not significant association between prices and the renewable share. After adding prices to our specification, the coefficient of *independence* remains negative and significant. [18]. In markets with high concentration, the largest incumbent firm (through its market power) might attempt to maximize rents, either by capturing the NRA or by choosing a profitable energy source portfolio. Model (3) in table 5 shows a negative relationship between the share of the largest generator and the share of renewable energy, suggesting that more concentrated markets are connected to thermic generation. However, the coefficient size does not significantly change from the one in table 2, model (1) [19].

6.2 Robustness check

6.2.1 Outliers

The distribution of our main variables indicates the presence of influential data points that might compromise our estimates. For instance, while the average share of renewable electricity lies around 20.1%, the share for Denmark stands more than two standard deviations away from the average. This issue is partially solved by our panel data specification that uses country within variation to identify the effect of governance regimes. However, some countries recorded significant changes (in our main variables) between 2013 and 2018, as shown in fig. 6. Countries like Malta (MT) and Luxembourg (LU) have considerably increased their shares of renewable generation, while Slovenia (SI) has improved its independence score performance compared to the rest of the sample [20].

To verify the robustness of our estimates, we determine the extent to which they depend on those influential points by re-estimating model (1) in table 2, leaving out one country (data row) at a time [21]. The results in fig. 7 show the *independence* coefficients do not

[18] The model also considers industrial consumer prices and displays similar results. The results are not reported

[19] The incumbent with the largest share was not included in the main specification because the sample size drops by three countries.

[20] On the vertical axis, we observe the change in the share of renewable energy (logs) from each country, while on the horizontal axis, we see the change in the independence score (logs). The figure highlights the presence of potential outlier observations that might drive our regression estimations.

[21] Belsley et al. (1980) discuss the implications that outliers have depending on whether they are present in the outcome variable or independent variable. Variables that record extreme values in the dependent

significantly vary from each other after excluding one observation, and all are significant at 10% level [22]. These outcomes suggest that influential observations do not drive either the direction or the significance of our estimates.

6.2.2 Policy and institutional channels

The policy and institutional environment (and its measures) might impact our results as well. Different aspects of national policies and institutions could add uncertainty to our estimations. Table 3 shows the estimation results with other policy and institutional variables used in the literature on renewable share determinants (surveyed by Bourcet (2020)) to verify whether our estimates remain robust after using alternative policy and institutional measures.

Model (1) displays the coefficients of our baseline model. In model (2), we use the OECD PMR index to track changes in the market reform policies as an alternative to our *mktaccess* variable. The independence coefficient varies slightly, but it becomes less significant [23]. However, the reform's coefficient shows the expected negative sign (lower values of the PMR highlight a more liberalized market).

Model (3) accounts for national policy initiatives to reduce greenhouse gas emissions nationally. We use the variation of greenhouse gas emissions per capita growth rates as an effort proxy. The positive estimate suggests that countries with higher emissions growth rates tend to support higher renewable energy generation; however, the coefficient is not statistically significant at conventional levels. Social preferences might also play a role in supporting or limiting the implementation of decarbonization policies. In model (4), we add the variable *Green Party* to capture environmental preferences beyond government policies. The coefficient remains robust (at a 10% level) and suggests that countries, where green parties have more delegates are associated with larger renewable preference shares. We did not include this variable in our main specification because it reduces estimation accuracy more than improving the model fitting, as pointed out by the Akaike Information Criterion (AIC) [24].

variable, as in the case of Malta, influence the regression intercept but do not have an effect on the slope. The effects on the line from the independent variable observations like Slovenia or Bulgaria need more attention because they can alter the model slope and increase the occurrence of type 1 or type 2 errors. Following their argument, we removed one data row (country) from the model (1) to verify whether our estimates became insignificant.

[22] In fig. 7, the y-axis displays the independence coefficient size, while the x-axis shows the excluded country. The blue area shows the coefficient confidence interval (90%) for each estimated model.

[23] We omitted the OECD PMR in our main specification because not all countries had a score. Missing country data was obtained by imputation. We decided to keep the variable as a robustness check.

[24] In table 2, a lower value of AIC indicates a robust model. Model 1 has an AIC of -141.5, and model 2, -136.6

Table 3: Fixed Effects: Additional political and institutional covariates

	(1) Base	(2) PMR	(3) EGR	(4) Green	(5) Corrupt.I	(6) IHS-RL
Independence	-0.817**	-0.736*	-0.824**	-0.860*	-0.898**	-1.309*
	(0.334)	(0.383)	(0.329)	(0.423)	(0.363)	(0.649)
OECD PMR		-0.0215*				
		(0.0118)				
Em.GR			0.0117			
			(0.296)			
Green				0.0186**		
				(0.00709)		
Corruption Index					0.0120	
					(0.00710)	
Rule Law						-0.693
						(0.480)
Time effects	yes	yes	yes	yes	yes	yes
Controls	yes	yes	yes	yes	yes	yes
adj. R^2	0.870	0.862	0.866	0.855	0.837	0.833
AIC	-141.5	-138.9	-139.5	-136.6	-130.8	-129.6
Observations	48	48	48	48	48	48
F-statistic	33.14	100.2	30.49	43.16	11.96	16.27

Model (1) shows the coefficients of the equation in $Model(1)$ - Table 2. *OECD.PMR*: score of market reforms calculated by the OECD between 0 (fully liberalized) and 6 (vertically integrated - state-owned industry). *Em.EGR*: emissions per capita in percentage annual growth rate. *Green*: number of shares of the green party in the legislative per person. *FH political rights*: Freedom house political right score. *Corruption Index*: Transparency international corruption index where higher scores stand for more transparent and efficient government. *Rule of Law*: IHS rule of law score. It represents the protection of private investments in a country. Heteroskedasticity robust standard errors in parentheses * p < 0.1, ** p < 0.05, *** p < 0.01.

Different aspects of institutions are able to influence renewable energy investments. In model (5), we use the Transparency International Corruption Perception Index (CPI) as a proxy for government quality. Lower corruption levels should translate into better-functioning public administration. The independence coefficient slightly varies compared to model (1), yet the CPI coefficient is not statistically significant. In model (6), we use the measure of "Rule of Law" constructed by the IHS-Market, which captures how investments are protected from expropriation. The independence coefficient changes in magnitude, but the effects' direction and statistical significance remain. However, the IHS-Market coefficient becomes negative and non-significant, which is probably linked to the fact that countries in our sample tend to stick to EU standards. All the previous results conclude that our model is robust to different instruments to measure institutions.

6.2.3 Overlapping sample

Finally, we measure the share of renewables using the overlapping sample (22 countries from the price regression analysis presented in the discussion section (Section 7) [25]) and the generation of solar and wind sources as a share of total electricity production [26]. In table 7 (in the appendix), the effect of independence in models (1) and (2) remains negative and significant at a 10% percent level. These parameter estimates suggest that the effect of the governance regime is present across different samples and renewable energy measures.

7 Policy implications

The EU has reinforced its commitment to improving environmental performance by introducing the Clean Energy Package (CEP) in 2019. This legislation sets environmental principles and mandates to member states and, more recently, to regulators while preserving the current market structure. In this context, we ask whether the new CEP's environmental principles and mandates provided to NRAs are compatible with the current market design. Our work proposes that the new environmental mandates will conflict with the liberalization (and NRAs) commitments, and additional actions are needed to reconcile the previous and more recent rulings.

Policymakers should consider expanding the understanding of the conflict between liberalization, market designs, and environmental objectives (Pollitt, 2019). The first step is determining whether the conflict between the NRA's competition commitments (measured by independence) and renewable energy generation has slowed down current environmen-

[25] The price analysis includes Great Britain and Switzerland and excludes Bulgaria and Cyprus. Data availability drives this decision.

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

tal targets. Most European member states achieved their environmental targets in 2020. According to the European Environmental Agency (2020), 22 Member States reached their 2020 targets, Belgium, Romania, and Slovenia remain close to meeting the target (< 1 %), and France and Poland were the countries furthest away from their 2020 target (over two percent below). At that stage, the conflict did not seem to affect the member states' decarbonization performance.

However, it is uncertain whether the conflict's effects will remain negligible as the shares of renewable electricity grow. Future climate change targets will become more stringent as an unprecedented transformation in the energy system is necessary to meet the 32% renewable energy target set for 2030 and full decarbonization for 2050. As the share of renewables grows to meet the targets, the need for investments to match electricity supply and demand will increase, similarly to consumer bills. Thus, we expect the NRA tension to grow with the risk of decelerating the decarbonization pace.

If NRAs are not accountable for environmental performance, the independence negative impact will become more significant over time. A possible solution could be to evaluate the current NRA governance model and reconcile it with the environmental principles and mandates included in the CEP. According to Bartle and Vass (2007), coordination mechanisms between economic NRAs, the government, and other environmental stakeholders should be established without compromising the agency's independence. The NRAs' expertise and specialized knowledge place them as central actors in integrating renewable energies. There are three areas in which coordination can help NRAs to support decarbonization. First, NRAs can support information exchange between industry actors and provide their economic expertise to policymakers. The information flow can help decision-makers at any level to consider other actors' points of view and design optimal solutions. For example, economic NRAs' could share their experience on the undesired effects of policies. Second, NRAs may take an advisory role in policy elaboration. This should facilitate the detection of policy conflicts and the trade-off assessment between competition and environmental objectives. Finally, the information disclosure with stakeholders should be augmented beyond the economic scope of the NRAs' operation.

The proposed model "tweaks" have concerns. Investors could interpret NRA's involvement in environmental matters as a deviation threat from its competition principles and mandates. If the perceived threat is significant, some investors might decide to hold up their investments. Besides, the NRA's participation in non-economic advisory might reduce the levels of specialized knowledge and expertise that the agency can accumulate. Finally, agencies might fail legislative hearings and other types of evaluations because their performance assessment is currently based on economic results. NRA's accountability provisions should account for the tasks required to support environmental targets (Bartle and Vass, 2007).

8 Conclusions

In light of the challenges to achieve carbon neutrality on 2050, and the new "economic logic" that renewable energies have on current electric systems. This paper assessed the impact the institutional context in which policy makers operate, particularly focusing on analyzing the impact of *independence*, and other three indicators of NRAs govenance regimes (*discretion*, *transparency*, and *scope of Market Monitoring*) on the growth of renewable energies. Because of data availability we focus our analysis on the period between 2013 and 2018. Results show that NRA's *independence* negatively correlates with the growth of renewable energy share. In addition, we found that *transparency* is negatively correlated with electricity tariffs for industrial users.

The central argument of our work relies on the documented assumption that independent regulators were mandated to implement competition, reduce incumbent rents in favor of consumers, and ultimately trigger system reliability. Our findings suggest that independent regulators remained committed to their competition and efficiency mandates. This commitment conflicts with introducing renewables in the system because additional renewables increase system costs, e.g., excess power in the capacity market, which impacts competition, efficiency, and market stability.

Our main contribution is to provide robust quantitative evidence that between 2013 and 2018, the *independence* of NRAs decelerated the adoption of renewable power in the electric sector. Finally, we discuss the current and future consequences of not reconciling the current governance model and new environmental legislation. We found many arguments supporting that future climate targets should become a part of the NRA mandates.

Figure 4: Evolution of entry barriers in the European Electricity markets

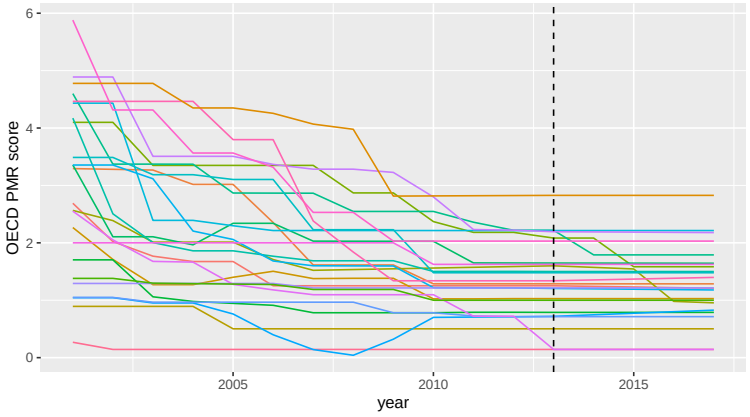


Figure 5: Evolution of the IRA dimensions in Europe between 2013 and 2018

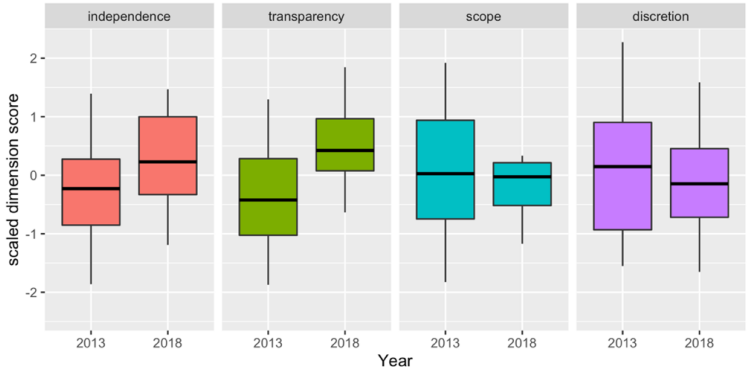


Figure 6: Correlation between renewable energy share and independence

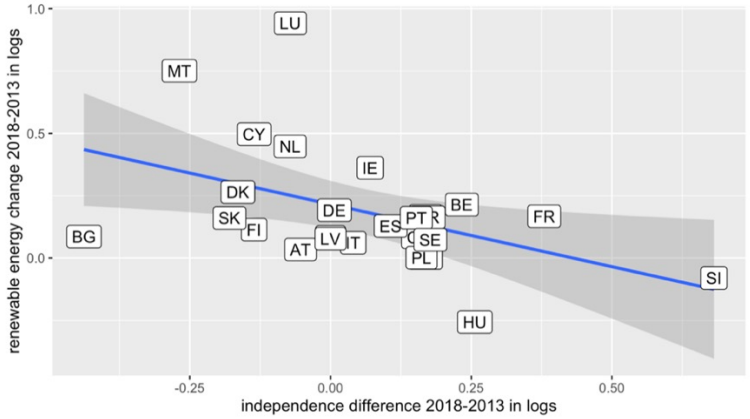
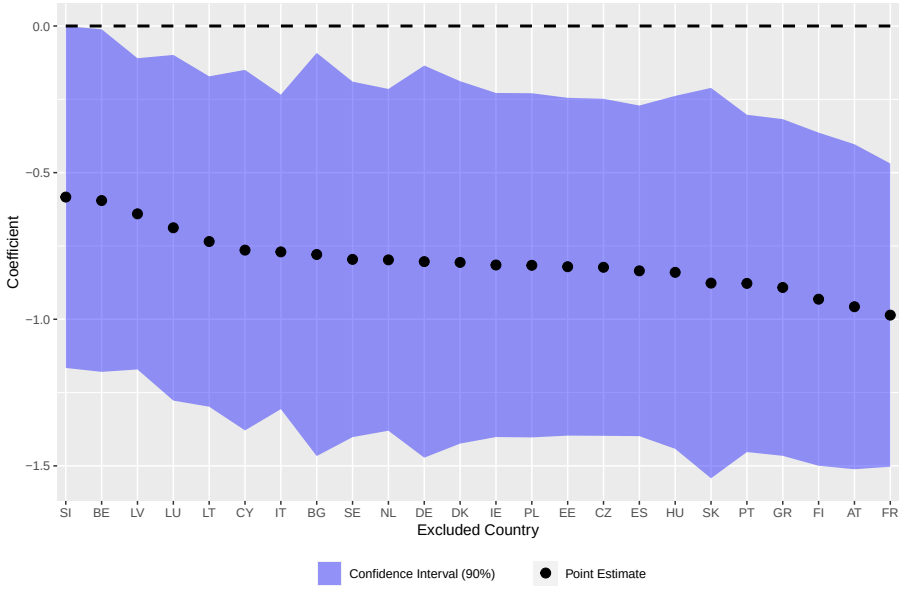


Figure 7: Effects of independence on renew. energy excl. one country



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A Data description

Table 4: 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	20.1	54.7	12.38
	Ind. electric	Tariff charged for consumption of a KWh by hou. (log(EUR/KWh))		4.245	4.8	5.47	0.272
Secondary dependent variables	Sh. windgen	Share of renewable energy wind (%)	EUROSTAT	0.021	9.5	45.8	10.75
	Sh. solar	Share of renewable energy solar (%)		0	2.15	7.82	2.194
	Hou. elecprice	Tariff charged for consumption of a KWh by households (log(EUR/KWh))		4.879	5.44	5.96	0.267
Governance and reform variables	Independence	Independence index (0 – 1)	Brousseau & Gonzalez, 2020)	0.185	0.3	0.37	0.043
	Scope	Market coord. Gov. index (0 – 1)		0.216	0.27	0.32	0.027
	Transparency	Transparency index (0 – 1)		0.167	0.25	0.35	0.052
	Discretion	Discretion index (0-1)		0.144	0.24	0.34	0.048
	OECD PMR	OECD PMR (1 - 6)	OECD-PMR	0.14	1.28	2.19	0.523
	TA mkt access	Market access index (0 - 1)	Constructed PMR survey	0.11	0.15	0.2	0.023
Electricity supply, demand, and security controls	Elec gen.	Total electricity supply (log GWh)	IEA OECD database	7.688	11	13.4	1.398
	Elec cons	Total electricity supply (log GWh)		15.27	17.3	19.6	1.211
	Trade balance	Elec. exports – imports (log GWh)		5.367	8.14	9.15	0.718
	GDP	GDP in const. (log 2017 million USD)	PWT ver10	24.3	26.6	29	1.318
	Income PC	GDP per capita (log USD/population)		10.05	10.6	11.4	0.363
Renewable's support controls	Years lawren	Policy time that supports renewable generation (log years)	Constructed IEA policy database	2.485	4.19	5.66	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	0.47	0.72	0.248
	1-IHH sshare NR	Diversification of elec. generation non-renewable sources (0 – 1)		0.082	0.58	0.95	0.214
	GHG em. grate	Greenhouse gas emissions growth rate (%)		-28.72	0.10	38.10	9.49
Institutions and government efficiency controls	FH civil law	Freedom House civil law scores (0-60)	Freedom in the World Report, 2021	44	55.9	60	3.471
	FH pol rights	Freedom House pol. rights scores (0-40)		28	38.1	40	2.29
	FH index	Freedom House total scores (0-100)		72	93.9	100	5.567
	IHS RL	HIS rule of law index (0-1)	IHS Markit	0.67	0.86	1	0.092
	TI CPI	Transp. International corruption perception index (0-100)	Transparency International	43	67.4	91	14.07

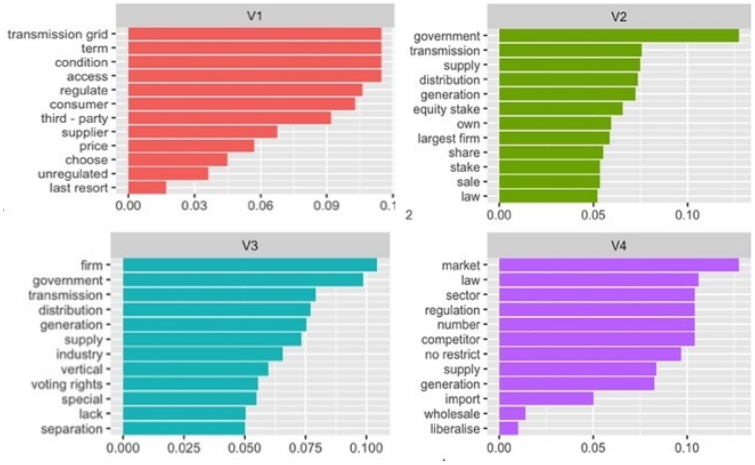
B Textual analysis construction variable

To measure the intensity of market reform, we assessed the regulatory environment 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 answer, and "prices are unregulated" for a negative one in our database.

2. We constructed text documents for every country and time with the previous information. Based on co-occurring terms in every document, we fit a topic model (LDA) and identify four groups of terms that describe the country's market reform, as shown in fig. 8.

Figure 8: Text Analysis of market regulation dimensions



C Additional controls renewable energy shares

Table 5: Additional controls renewable energy shares

	(1)	(2)	(3)
Independence	-0.817**	-0.861**	-0.861**
	(0.334)	(0.365)	(0.324)
Household Elec.Price		0.259	
		(0.223)	
Share L.incumbent			-0.293***
			(0.049)
Individual effects	yes	yes	yes
Time effects	yes	yes	yes
Controls	yes	yes	yes
adj. R^2	0.87	0.854	0.948
AIC	-141.475	-126.115	-161.093
Observations	48	44	42
F-statistic	33.137	39.885	240.344

Model (1) of Table 2 is used in all specifications. *Household Elec.Price*: electricity prices paid by residential consumers in EUR per GWh. *Share L.incumbent*: share of the largest electricity producer in percent points. Heteroskedasticity robust standard errors in parentheses * p $<$ 0.1, ** p $<$ 0.05, *** p $<$ 0.01.

Table 6: Different support mechanisms

	(1)	(2)
Independence	-0.817**	-0.994*
	(0.334)	(0.545)
Years ren. laws	0.262***	
	(0.058)	
Share Subsidies		-0.142
		(0.149)
Time effects	yes	yes
Controls	yes	yes
adj. R^2	0.87	0.833
AIC	-141.475	-118.835
Observations	48	42
F-statistic	33.137	26.951

Model (1) of Table 2 is used in all specifications. *Share Subsidies*: Share in percentage points (logs) of the legislation that grants subsidies to renewable energy generators over the total number of legal instruments that support green electricity. Heteroskedasticity robust standard errors in parentheses * p $<$ 0.1, ** p $<$ 0.05, *** p $<$ 0.01.

Table 7: Alternative dependent variable and overlapping sample

	(1) Base	(2) Wind-Solar.SH
Independence	-0.764*	-0.130*
	(0.413)	(0.065)
Liberalization	1.585**	-0.269
	(0.719)	(0.183)
Inst. Stability	0.037***	0.002***
	(0.006)	(0.001)
Non-renew power	-1.035**	-0.409**
	(0.311)	(0.051)
Demand (GDP)	2.122**	-0.172
	(0.866)	(0.126)
Wealth	-2.209**	0.18
	(0.928)	(0.132)
Trade balance	0.102	0.025
	(0.107)	(0.015)
Years ren. laws	0.209**	-0.026*
	(0.080)	(0.013)
Patenthundred	0.129**	0.003
	(0.058)	(0.011)
Individual effects	yes	yes
Time effects	yes	yes
adj. R^2	0.85	0.938
AIC	-125.413	-291.447
Observations	44	44
F-statistic	32.819	59.566

Model (1) of Table 2 is used in all specifications. The dependent variable *Wind-Solar.SH* in model (2) is the sum of wind and solar shares as part of the total electricity produced in GWh. The value varies between 0 and 1. Heteroskedasticity robust standard errors in parentheses * p $<$ 0.1, ** p $<$ 0.05, *** p $<$ 0.01.

Table 8: Fixed Effects estimation: Impact of governance regime in electricity price – complete table

	(1)	**(2)**	**(3)**	**(4)**	**(5)**
Independence	-0.116				0.225
	(0.291)				(0.438)
Transparency		-0.512*			-0.767*
		(0.298)			(0.410)
Scope			0.387		0.727
			(0.639)		(0.563)
Discretion				0.31	
				(0.303)	
Liberalization	0.91	0.626	1.069	0.8	0.761
	(1.176)	(1.280)	(1.179)	(1.440)	(1.286)
Inst. Stability	-0.009	-0.0104	-0.0103	-0.0076	-0.0144
	(0.011)	(0.011)	(0.013)	(0.011)	(0.0145)
Wealth	-0.57***	-0.60***	-0.57***	-0.60***	-0.61***
	(0.176)	(0.174)	(0.184)	(0.176)	(0.184)
Elec. Supply	0.243	0.297	0.184	0.249	0.221
	(0.183)	(0.198)	(0.197)	(0.208)	(0.200)
Non-renew power	-0.013	0.006	-0.073	0.025	-0.094
	(0.106)	(0.112)	(0.152)	(0.135)	(0.148)
Individual effects	yes	yes	yes	yes	yes
Time effects	yes	yes	yes	yes	yes
adj. $R\hat{2}$	0.828	0.845	0.83	0.834	0.851
AIC	-144.5	-149.5	-145.1	-146.1	-149.8
Observations	48	48	48	48	48
F-statistic	27.87	32.1	32.96	30.59	28.66

Model (1) of Table 2 is used in all specifications. Heteroskedasticity robust standard errors in parentheses * $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$.