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Assessing the Impact of Renewable Energy Policies on Decarbonization in Developing Countries

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Abstract

This study offers the first consistent attempt to identify how energy sector decarbonization policies have affected the energy mix over the past four decades across more than 100 developing countries. It applies systematic regression analysis to five energy sector decarbonization outcomes and more than 75 policy instruments aggregated into seven policy packages. Combining instrumental variables with country interactions and country and time fixed effects in regional panels helps address potential endogeneity issues. Only a handful of energy policy packages significantly affect the decarbonization of developing countries' energy mix, and the packages more often achieve a negligible or opposite result than intended three years after implementation. Policies that address counterparty risk have the highest immediate effects. Effects of renewable policies on various decarbonization outcomes improve slightly five and seven years after their implementation.

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ASSESSING THE IMPACT OF RENEWABLE ENERGY POLICIES ON DECARBONIZATION IN DEVELOPING COUNTRIES

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1 INTRODUCTION

Since the end of the last century, countries around the world have enacted a plethora of power sector and renewable energy policies at different points in time, in different combinations, to advance one or several environmental, economic, security, or equity policy goals. These policies encompass instruments ranging from feed-in tariffs for renewable energy generation to renewable energy targets and from biofuel blend mandates to carbon pricing mechanisms. More recently, these policies were also motivated by the growing challenge of mitigating climate change on a global scale.

We offer the first comprehensive and systematic assessment of how energy policies, largely related to the deployment of renewable energy, shaped the decarbonization of the energy mix 3 to 7 years after their implementation across more than 100 developing countries and four decades.

In doing so, our study fills an important knowledge gap. A systematic review of published research that assessed the impacts of a wide range of decarbonization policy instruments related to renewable energy indicated that most existing studies focus on advanced industrialized countries (Peñasco et al., 2021).

We consider five inter-related decarbonization outcome indicators of the energy mix, all in relative terms as a share of the total: (1) renewable energy consumption; (2) renewable electricity output; (3) fossil fuel energy consumption; (4) oil, gas, and coal energy electricity production; and (5) oil electricity production.

Our policy variables are grouped into seven energy policy packages leveraging the World Bank Regulatory Indicators for Sustainable Energy (RISE) data.[2] The dataset includes over 75 policy instruments related to renewable energy, power, and fuel use implemented

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[2] For a detailed description of the database, please refer to its official website: https://rise.esmap.org/.

over the last four decades. The seven energy policy packages are (1) Legal framework (LF); (2) Planning for expansion (PE); (3) Incentives and regulatory support (IR); (4) Attributes of financial and regulatory incentives (AI); (5) Network connection and use (NC); (6) Counterparty risk (CR); and (7) Carbon pricing and monitoring (CP).

1.1 CONTEXT AND MOTIVATION

Our study is closely related to two large empirical literature streams. First, we position our analysis within the broad social science literature that analyzes the effect of individual renewable energy policies and their outcomes.

Peñasco et al., (2021) conducted a systematic review of 211 studies that evaluate "the effect of a specific policy instrument [related to the clean energy transition] into a specific outcome" across all the social sciences. Overall, their review includes studies of 50 countries. A relevant finding is that the existing literature is heavily biased toward the OECD countries. So, instead, we look only at non-OECD and cover more than 100 developing countries.

The 211 studies on developed countries suggest a significant variation across the effects of energy policy instruments. They help support the evidence that material endowment and “integrated policy and economy-wide approaches” coupled with “enabling conditions (governance, institutions, behavior, innovation, policy, and finance)” are key to decarbonization (Bang et al., 2015; Bednar-Friedl et al., 2022; Boasson et al., 2020; Lamb & Minx, 2020).

Second, this study also engages with and contributes to a large body of economics literature on the reform of energy sector governance (see Foster & Rana (2020) and Jamasb et al. (2005, 2015) for excellent surveys of this literature) that began in the 1980s. In the spirit of this literature, our work subjects the supposed benefits of energy sector reform to econometric examination based on multi-decade panel datasets of developed and developing countries using program evaluation techniques.

A small body of this research (Cubbin & Stern, 2006; Nagayama, 2009; Sen et al., 2016; Urpelainen et al., 2018), like this study, attempts to address endogeneity issues using the instrumental variables (IVs) approach. None of the studies using IV approaches has examined climate-related outcomes of power sector reform. However, Mallawaarachchi et al. (2021) discuss how studying the climate-related outcomes of power sector reforms can help coordinate policy agendas with differing economic and environmental objectives.

Our most closely related study is Doumbia (2021), which analyzes the relationship between the degree of a power market's competitiveness and power sector outcomes in developing countries, including renewable energy penetration. However, unlike our study, Doumbia (2021) does not address endogeneity issues, and their analysis is limited to conditional correlations.

Several well-known challenges confound the quantitative assessment of the power sector and renewable energy policy impacts (Bacon, 2018). These include endogeneity resulting from omitted variables related to the country and regional characteristics and simultaneity and reverse causality of policy enactment and outcomes. Estimates are also prone to measurement errors resulting from a lack of accounting for the depth of reform and collinearity of policies.

We design the study to engage with each of these challenges systematically. We include time and country fixed effects to account for the country and temporal omitted variables and estimate instrumental variable (IV) regressions across six regional panels.

Our identification strategy for selecting appropriate IVs assumes that developing countries are more likely to implement renewable energy policies when they exhibit "closeness" to major donors that champion today's best practices in energy markets. The IVs are relevant because the policy instruments recorded in the RISE database are meant to reflect today's best practices in energy markets (ESMAP, 2022).

Our main IV is developing countries' foreign policy and political proximity to the major World Bank donors (France, Germany, Japan, the United Kingdom, and the United States) as estimated in Bailey et al.'s (2017) database on voting in the United Nations General Assembly. In addition, we consider two other IVs that measure closeness associated with trade for robustness purposes, described in detail in Section 3.3.

While achieving perfect identification in cross-country panel regressions is difficult, if not impossible, the "closeness" measured through our IVs is relevant because we show that finance from donors often facilitates or promotes the implementation of the policies in the first place and that they are plausibly exogenous to developing countries' energy mix.

We also address the difficulties of coding variables to consistently reflect the depth of reform and issues related to the collinearity of many renewable energy policies. Finally, we design two alternatives to the default RISE policy index developed by the World Bank to operationalize each of the seven renewable energy policy packages into variables for regression analysis.

The first index addresses the depth of the reform problem because it weighs all policies within each policy reform type equally. Compared to the weighting by the World Bank, it is comparatively more sensitive to the number of policies implemented. The second index addresses the collinearity of policies within each policy reform type by weighting uncorrelated policies more than those highly correlated to others.

The resulting combinations of indices and models create 18 "base" regression specifications. We estimate each of these regression specifications over five indicators of the energy mix, seven policy reform types, and six geographical regions, leading to 3,780 regressions in total.

Additionally, following (Wooldridge, 2001), we apply two-stage least squares (2SLS) country interactions, rendering tens of thousands of first-stage coefficients. When we restrict the sample to the IV regressions that plausibly meet the relevance criterion and are theoretically consistent, we obtain 540 first-stage regressions that constitute the basis for our analysis.

Overall, this paper fills a gap by focusing on a broad set of energy policy packages, a wide range of developing countries over a long period, and important decarbonization outcomes using quasi-experimental econometric techniques. Doing this provides new insights regarding the extent to which energy policy packages linked to emissions reductions (and renewable deployment) in industrialized countries are also associated with similar results in developing countries over the short- and medium-term (Bednar-Friedl et al., 2022).

1.2 CONTRIBUTIONS

The main results of our analysis suggest that controlling for time, country, and regional differences, the effects of most renewable energy policy packages on the energy mix in developing countries three years after passing the policies are largely insignificant. Only 15.7 percent of the estimated second-stage regressions meet the statistical significance threshold of a p-value below 10 percent.

Moreover, most of the estimated statistically significant second-stage regression coefficients are negative or negligible. That is, renewable energy policies counterintuitively result in the same or a higher share of fossil fuel sources in the developing countries energy mix. However, the performance of these policies generally improved – becoming negligible or slightly positive - to achieve their goals five and/or seven years afterward. We interpret and discuss these results in the context of the Sailing Ship Effect (Gilfillan, 1935; Ward, 1967), wherein incumbent fossil fuel technologies dampen the short-term effects of renewable energy policies.

Our results may differ when considering the impact on modern (non-hydro) renewables instead of all renewables. To address this concern, we conduct robustness checks excluding hydropower and find similar results.

The limited impact of these policies could be driven by a host of interrelated factors leading to difficulties in securing finance in these countries (Egli et al., 2019; Moner-Girona et al., 2021). This explanation regarding difficulties securing finance is in line with the results in this paper, indicating that the energy policy package that addresses counterparty risk is the one that is more consistently associated with increases in the renewables in developing countries' energy mix three years after implementation.

This finding of the importance of addressing counterparty risk supports the rationale for policies that make projects bankable for private investors, including government guarantees for electricity auctions. In juxtaposition to other policies, the effects of the counterparty risk package tend to moderate over time, perhaps because they address major financing hurdles in the shorter term, making room for other policies to have positive effects over time.

Therefore, the findings of this paper contribute further evidence to the notion that significantly increasing climate finance for developing countries is an essential element complementing domestic renewable energy policies. Merely requesting additional domestic decarbonization policies in developing countries will unlikely yield significant and timely changes in the energy mix, and the developed world should at least fulfill its climate finance commitments under the Paris Agreement.

In combination with the relative dearth of research on the impact of decarbonization policies in developing countries, this paper's findings show that countries need to adopt a sustained and credible policy effort. Such an effort should holistically consider the energy sector, domestic institutions and capabilities, the innovation system, socioeconomic impacts, and broader SDGs while adopting an experimental attitude and implementing data collection, learning and adaptation mechanisms, and international knowledge sharing.

2 EMPIRICAL SPECIFICATION

We examine a continuum of linear relationships between a renewable energy policy package x and an energy mix outcome, y in a country c and a year t (l). As energy sector policies take time to implement, we assume that policy implementation does not have an immediate effect on the outcome variable and consider three-year, five-year, and seven-year lags, as is common in policy evaluation literature (Choi & Anadón, 2014; Doblinger et al., 2019). Each regression equation can be summarized as follows:

$$y_{c,t} = \alpha_c + \beta x_{c,t-l} + \gamma_t + \varepsilon_{c,t}, \tag{1}$$

where β is the coefficient of interest, α and γ are the country- and time- fixed effects, and ε is the unobserved error term.

The time fixed-effect estimate of the econometric model (1) will be biased and inconsistent if an unobserved time-varying country or regional characteristics, such as economic growth and other socio-economic variables, play a part in policy outcomes, leading to omitted variables bias. To mitigate these problems, we explicitly control for regional characteristics by estimating country fixed-effect regression models separately within the World Bank regional groups (Appendix Table A.1).

Other endogeneity biases could result from the simultaneity and reverse causality of policy enactment and outcomes. We attempt to correct endogeneity bias using the instrumental variables (IV) approach. In theory, IVs successfully address the biases by isolating the exogenous portion of the relationship between the independent variable of interest, x, and the dependent variable, y. In our context, the IV approach implies finding a variable, z, which affects the enactment of the renewable energy policy, but not the energy mix, except through this policy. The main challenge is finding a suitable IV, a topic we discuss in the next section.

Following the literature (Stock & Watson, 2011; Wooldridge, 2001), we estimate the model (1) in the following two stages:

$$x_{c,t} = \alpha_c + \beta z_{c,t} + \sum_{c=1}^{n} \delta_c z_{c,t} D_c + \gamma_t + u_{c,t} \tag{2}$$

$$y_{c,t} = \theta_c + \sum_{c=1}^{n} \vartheta_c \widehat{x_{c,t-l}}\, D_c + \sum_{c=1}^{n} \rho \widehat{x_{c,t-l}} + \mu_t + \nu_{c,t}, \tag{3}$$

where D is a country dummy variable, $\hat{x}$ is the instrumented policy variable, α, $\theta, \gamma,$ and μ are the country- and time- fixed effects, and u and v are the unobserved error term.

The key coefficients of interest are the second-stage (S2) estimates of policy variables interacted by country fixed effects, ϑ_c. We restrict our analysis to the sub-set of the second-stage estimates that are likely to satisfy the IV relevance condition (i.e., z must be strongly correlated with x) and the exclusion restriction (i.e., z only affects y through its impact on x).

Assessing the IV *relevance* criterion is straightforward by checking the F-statistic of the first-stage regression (2). As there is no valid statistical test for the *exclusion* restriction, we keep the first-stage estimates that are statistically significant and have theoretically consistent signs. We discuss the strength of our IVs in Sections 4 and 5.

3 DATA AND CONSTRUCTION OF VARIABLES

3.1 DEPENDENT VARIABLES

We use the World Bank World Development Indicators (WDI) as a data source for our dependent variables spanning the last four decades and more than a hundred developing countries. Appendix Table A.1 provides a list of all the countries included in this study and their regional classification.

For robustness purposes, we consider five relevant dependent variables (Table 1). We expect renewable energy policy packages to negatively affect the first three energy mix measures in Table 1. In contrast, we expect renewable energy policy packages to positively affect the remaining two energy mix measures in Table 1.

To standardize our estimation results across different specifications, we multiply the estimated coefficients of interest for the first three energy mix measures by minus one to indicate that a positive coefficient leads to impacts aligned with decarbonization. Conversely, a negative coefficient denotes impacts that are not aligned with decarbonization.

Appendix Figures A.1 and A.2 show the times series of each dependent variable over time, aggregated over regions to preserve space. Temporal patterns indicate clear differences across regions in all outcome variables. For example, the share of fossil fuels in the energy mix is consistently higher in relatively oil-dominated regions (e.g., the Middle East and North Africa) than hydro-dominated regions (Latin America). These patterns reinforce our rationale to estimate the regressions separately across regions.

Table 1: Dependent Variables

Variable	**Acronym**	**Unit**	**Expected Impact of Renewable Energy Policies**
Fossil fuel energy (oil, gas & coal) consumption	FCC	Percent of total	Negative
Electricity production from fossil fuel (oil, gas & coal) sources	EFF	Percent of total electricity output	Negative
Electricity production from oil sources	EOS	Percent of total electricity output	Negative
Renewable energy consumption	REC	Percent of total final energy consumption	Positive
Renewable electricity output	REO	Percent of total electricity output	Positive

Source: World Bank World Development Indicators (WDI) database, 2020.

3.2 EXPLANATORY VARIABLES

Our explanatory variables come from the 2018 disaggregated policy instrument data behind the Regulatory Indicators for Sustainable Energy (RISE) renewable energy "traffic light" indicators that the Energy Sector Management Assistance Program (ESMAP) at the World Bank has published since 2010. Concretely, our independent variables are indexes that represent seven energy policy packages. Each energy policy package comprises the disaggregated policy instruments in the RISE data. In this section, we describe the primary RISE dataset and the three alternative methods we designed to reduce the dimensionality of the dataset and create our independent variables indexes.

In the primary RISE dataset, each policy is coded in two variables: one indicating whether the policy exists through yes/no answer, and the second specifying the year of the first instance of the policy, if applicable.[3] When restructuring the dataset, we combine the two variables for each policy instrument into one. Its value changed from 0 to 1 when the first policy was put into place, creating the panel dataset needed for the rest of the analysis.

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[3] For instance, "Does a legal framework for renewable energy development exist?" and the year for the first legal framework.

We address at least two further challenges with the structure of the primary dataset for creating our independent variables. First, we find several discrepancies between the same policy's yes/no and years variables. Appendix Table A.2 describes the eight types of discrepancies in the dataset and our solution to address each type of discrepancy.

Second, there are occasional continuous variables in the dataset and variables that we cannot transform into panel data. These occasional continuous variables disrupt our efforts to address collinearity and reduce the dimensionality of the dataset, as discussed in the following section. Please refer to Appendix Table A.3 for more details.

The final dataset has 76 policies over a panel of 133 countries between 1980 and 2018, as most policies were not implemented before then (see Appendix Table A.4).

Reducing dimensionality

We must reduce the highly dimensional policy instrument data appropriately for regression analysis and interpretation. ESMAP indicators include 76 renewable energy policies grouped into seven high-level energy policy packages, or "Headings" (Table 2). Each energy policy package contains a different number of policies and sometimes contains clusters (or groups) of policies. The dendrogram in Appendix B shows that similar policy instruments usually reside within the same Heading. We, therefore, use these Headings, or energy policy packages, as our independent variables.

Table 2: Headings in the RISE Renewable Energy Pillar

	Heading / Energy policy package	**Acronyms**
1	Legal framework for renewable energy	LF
2	Planning for renewable energy expansion	PE
3	Incentives and regulatory support for renewable energy	IR
4	Attributes of financial and regulatory incentives	AI
5	Network connection and use	NC
6	Counterparty risk	CR
7	Carbon pricing and monitoring	CP

Source: RISE website, https://rise.worldbank.org.

It is necessary to design indexes that represent the energy policy packages so that theoretical and statistical comparisons between them make economic sense and reflect characteristics like the extent of renewable energy policy reform or the extent to which policy instruments are adopted together. We use three different methods to tally policies or "operationalize" each energy policy package, potentially affecting the regression results.

The first alternative is the “RISE index,” based on the practices ESMAP uses to create the aforementioned aggregate traffic light indicators in institutional publications (Foster et al., 2018). The RISE index weighs policy groups equally, but as shown in Appendix A.3, groups and sub-nested groups can contain different quantities of policies. Therefore, in the RISE index, the weight given to each policy is affected by how many policies are in the group this policy belongs to. For instance, when there are four policies in a group, each is worth 25 percent, and when there are two policies, each is worth 50 percent. The arbitrary aspect of weighing the policies within groups is part of our motivation to seek alternative methods to create other indices that we can use as independent variables.

An alternative approach is to create an index that sums up the enacted policies at each time. Such an index, which we will call the "Summation index," has been tried before (Cubbin & Stern, 2006) and is the simplest alternative to the RISE index for each of the seven energy policy packages shown in Table 2. When applied at the Heading level, the Summation index weighs all policies equally and produces a manageable number of independent variables. Arguably, because all policies are weighted equally within Headings, it is also a proxy for the depth of reform across countries. We use the Summation index as our second option.

We propose a third, "Composite Index," based on correlation analysis for robustness. The Composite index first reduces dimensionality by dropping highly correlated variables so that highly collinear policies are not counted several times over. It then sums the remaining variables by Heading. We describe details of constructing the Composite index in Appendix C. Appendix Table A.5 compares the weights between indexes.

In addition to the three indexes, we run and discard Principal Component Analysis (PCA) as a last alternative to reduce the dimensionality of the dataset. PCA makes use of how variables relate to each other in their correlation matrix, summarizing the directions in which the data is dispersed (Eigenvectors) and the relative importance of the directions (Eigenvalues). Based on the input, PCA creates the same number of new variables (“components”) but orders them to decrease the amount of information contained. Using only the first few computed components, it is possible to reduce the dataset's dimensionality and retain its information.

Nevertheless, it is hard to justify using PCA because its components lack meaning, which is essential to our research question. This is exactly the problem that Cubbin and Stern (2006) run into when running regressions with output from PCA analysis. In the case of our dataset, we find that PCA retains too many components and loses too much information compared to the RISE and Summation indices.

Overall, each independent variable represents an aggregate of renewable energy policies or energy policy packages. However, to construct the representation of renewable energy policy packages useful for regression analysis, we employ three weighting methods: the RISE, the Summation, and the Composite indexes.

Because we are working in a panel format, each country has three versions of each of the seven independent variables over several decades. Appendix Figure A.3 compares each index by Heading, aggregated by region, for 2015. That figure shows, as expected, that the difference between indices is the largest across Headings that contain many different policies.

3.3 INSTRUMENTAL VARIABLES (IVS)

To find suitable IVs, we explore international political economy aspects highlighted in the literature on energy sector governance reform that spans several decades and regions.

We posit that countries are more likely to implement regulatory energy policies when they display a relatively higher level of affinity, or closeness, with developed countries that champion increased private sector participation and other related changes in their loans related to power markets. This assumption broadly satisfies the *relevance* condition.

The importance of conditionality of reform for financial aid in energy sectors of developing countries is well recognized in the literature. (Henisz et al., 2005) (Henisz et al., 2005), for example, argue that "international pressures of coercion and emulation strongly influence the domestic adoption of market-oriented reforms.”[4]

The literature has also established that the political ideology of developing country governments matters for accepting and complying with the conditionality terms of economic reform (Smets et al., 2013), including power sector reform (Rufín, 2003). For example, Imam, Jamasb, and Llorca (Imam et al., 2019) find that left-wing governments in the Sub-Saharan Africa region are consistently less likely to successfully implement power sector reform and improve power sector outcomes (i.e., installed capacity and electricity access). Based on the above consideration, we argue that developing countries' governments whose political ideology is closer to major Western donors are more likely to implement renewable energy reforms.

We consider two channels that may represent affinity to the main G-7 donors (France, Germany, Japan, the United Kingdom, and the United States) while otherwise not correlated to energy mix outcomes: (1) similarity in foreign policy; and (2) connection through trade.

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[4] They find that coercion occurs “[…in] as many as 205 countries and territories between 1977 and 1999 [with] the coercive effect of multilateral lending from the IMF, the World Bank or Regional Development Banks […] increasing over time."

We pinpoint three measurable ways this rapport may be measured and evidenced over time in the data. Table 3 summarizes the chosen IVs, which we describe and support in the paragraphs below. Appendix Figures A.4 and A.5 illustrate the temporal path of the three IVs aggregated over regions from 1980 to 2018.

Table 3: Summary of Instrumental Variables

Closeness to donors	**IV**	**Supported in**
Foreign policy	UN General Assembly voting	Bailey et al. (2017)
Trade	Relative trade value aggregates	(Rufín, 2003)
Trade	Trade agreements in place	

Sources: Bailey et al. (2017); United Nations Comtrade dataset via the Database for International Trade Analysis (BACI), by the Center for Prospective Studies and International Information (CEPII); European Commission.

We consider that it may take time to implement policies following an increase in closeness measured through our IV. Therefore, we use a moving average over five years of the IVs. Although bilateral relationships can be relatively slow to change, administration changes in democracies may result in more abrupt changes, so we also consider the moving average over three years of the IVs.

Foreign Policy Closeness IV

To represent changes in foreign policy preferences, we use a dyadic dataset behind the Affinity of Nations index by Bailey et al. (Bailey et al., 2017). They use a dynamic ordinal spatial model on a single dimension to estimate state preferences toward the US-led liberal order, as reflected through the United Nations General Assembly voting. The measure is the *Ideal Point Index*.

On the other hand, the Ideal Point Distance is the difference between the Ideal Points for all country dyads that participate in the United Nations General Assembly (e.g., France and Gabon). Therefore, the Ideal Point Distance suggests the difference between the preference for the US-led liberal order for any two countries in any given year.

Observe that the voting dataset does not simply measure similarity across all votes. Rather, it estimates the distance of voting toward a specific topic. Anchoring the content of the estimates in one topic helps address the issue that the G-7 donors do not always vote the same way.

To understand how preferences in our sample changed compared to the five donors over time, we sum the yearly Ideal Point Distance between each country and the donors. Since we want a *closeness* indicator rather than a *distance* indicator (i.e., we want our IV to be positively associated with relative closeness to the donors), we multiply the summed Ideal Point Distance by the negative one.

International Trade Closeness IV

Henisz, Zelner, and Guillén (Henisz et al., 2005) observe that countries implementing economic reforms often imitate their trade-related peers. They argue that "the intensity of trade transactions reflects the density of the social network in which a given country is embedded […] and therefore the level of formalized conformity within the network."[5]

To capture changes in closeness through trade, we compute the percentage of trade that corresponds to exchange with the donors for each recipient country each year. The exchange data comes from the United Nations Comtrade dataset via the Database for International Trade Analysis (BACI) (Gaulier & Zignago, 2011). We also generate a panel dataset on the existence of Trade Agreements with the European Union. The source of the data is the EU Commission's "current state of play" agreements in place (see Appendix Table A.6). This

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[5] Furthermore, they argue that "…policies directly reflect the level of formalized conformity within a trade network. In a world characterized by uncertain cause-effect relationships, the policy initiatives undertaken by "relevant others" such as trade partners represent a normative model that lends credence to analogous domestic policy innovations and may trigger a cross-national diffusion process."

variable is binary and takes a value of 1 since the time the trade agreement came into force. If there is no trade agreement, the variable is 0 for the entirety of the time series.

4 RESULTS

We present estimation results and specification tests of the empirical model (equations 2 and 3) estimated over six regions, five dependent variables, seven policy-type variables, three IVs, two IV moving averages, and three aggregation indices. Altogether we estimate 3,780 regressions, to which we also apply country interactions. The regressions render thousands of coefficients that constitute the base for our analysis (Table 4).

Table 4: Estimated empirical specifications

Specification	**Options**
IV type	1. Affinity through United Nations General Assembly voting 2. Affinity through bilateral trade 3. Affinity through EU trade agreements
IV moving average	1. Five years moving average 2. Three years moving average
Indices	1. RISE 2. Composite 3. Summation
Regions	1. East Asia & the Pacific (EAP) 2. Europe & Central Asia (ECA) 3. Latin America & Caribbean (LAC) 4. The Middle East & North Africa (MENA) 5. South Asia (SAS) 6. Sub-Saharan Africa (SSA)
Dependent variables	1. Fossil fuel energy consumption, % of the total (FFC) 2. Electricity production from fossil fuels (oil, gas & coal sources), % of the total (EFF) 3. Electricity production from oil sources, % of the total (EOS) 4. Renewable energy consumption, % of total final energy consumption (REC)

Specification	Options
	5. Renewable electricity output, % of total electricity output (REO)
Renewable Energy Policies	1. Legal framework for renewable energy (LF) 2. Planning for renewable energy expansion (PE) 3. Incentives and regulatory support for renewable energy (IR) 4. Attributes of financial and regulatory incentives (AI) 5. Network connection and use (NC) 6. Counterparty risk (CR) 7. Carbon pricing and monitoring (CP)

Following the literature, we define the first stage estimate for the IV regressions as statistically significant when it has a p-value at or below 5% and an F-statistic above 10 (Stock & Watson, 2011).

Additionally, we impose a theoretical restriction that the estimated relationship between the instrumental and the endogenous variable in the first stage is positive (i.e., closeness to donors increases the likelihood of adopting a renewable energy policy). With the theoretical restriction above, the second-stage coefficients arguably represent the causal effect of the seven energy policy packages on the five energy mix outcomes.

While the exogeneity of the second-stage estimates cannot be established with certainty, we perform additional robustness tests to establish the validity of chosen instrumental variables. One established finding in the economics literature is that "getting similar results from alternative instruments enhances the credibility of instrumental variable estimates" (Murray, 2006) p.118.

The uniqueness of our empirical approach allows us to conduct a formal test for differences in the second-stage estimates resulting from different instrumental variables. We regress a vector of estimated second-stage coefficients for each of the five energy mix outcomes on the dummies for the instrumental variable used to obtain the second-stage estimate, the energy policy package, the type of index used, and the country and fixed-effects.

Table 5 shows the estimated regression results. We only observe statistically significant differences between the second-stage estimates obtained from affinity through the UNGA voting and the other two instrumental variables for one of the five energy mix outcomes (electricity production from oil sources). There are either no statistically significant differences across estimated second-stage coefficients, and the three chosen instruments, or the differences are only marginally significant for all other energy mix outcomes. These results give us greater confidence that our second-stage estimates reflect the causal outcome of renewable energy policy reforms.

Table 5: Specification Regression Test for IV Exogeneity

	(1) FCC	(2) EFF	(3) EOS	(4) REC	(5) REO
IV: EU Agreements	0.27	0.78**	1.85	-0.43	-0.22
	(0.16)	(0.34)	(1.44)	(0.30)	(0.24)
IV: Affinity through bilateral trade	0.79	6.34*	4.23***	-0.15	-1.27*
	(0.67)	(3.27)	(0.72)	(0.42)	(0.67)
Policy: Planning for renewable energy expansion	-1.11*	-2.95***	-2.5*	1.8**	3.06**
	(0.57)	(0.93)	(1.48)	(0.68)	(1.33)
Policy: Incentives and regulatory support for RE	-0.33	-1.02	-1.02	0.21	1.16
	(0.69)	(1.06)	(1.56)	(0.44)	(0.94)
Policy: Attributes of financial and regulatory incentives	-0.47	-0.9*	-0.95	0.73	2.21*
	(0.33)	(0.52)	(0.87)	(0.73)	(1.13)
Policy: Network connection and use	-0.14	-0.39	1.38	0.74**	2.19**
	(0.33)	(0.39)	(1.00)	(0.35)	(0.89)
Policy: Counterparty risk	0.15	0.47	0.73	-0.26	0.51
	(0.36)	(0.96)	(1.86)	(0.44)	(0.84)
Policy: Carbon pricing and monitoring			-0.45	0.81***	1.68**
			(0.84)	(0.29)	(0.80)
Index: Composite	-0.22**	-0.1	-0.98**	0.67**	.99**
	(0.08)	(0.30)	(0.46)	(0.32)	(0.38)
Index: Summation	-0.05	0.14	-0.28	-0.09	0.02
	(0.07)	(0.23)	(0.45)	(0.12)	(0.14)
Constant	-0.62*	-1.65***	-3.61***	0.24	-0.2
	(0.33)	(0.50)	(0.84)	(0.36)	(0.88)
Observations	707	717	726	947	923
R-squared	0.071	0.146	0.075	0.01	0.055
Country Fixed Effects	YES	YES	YES	YES	YES

We also perform Kruskal-Wallis H specification tests to determine whether there is a statistically significant difference between the number of eligible first-stage results obtained using any indices, IVs, and IV moving averages summarized in Table 4. We chose this test because it is impervious to the normality assumption, likely to be violated across distributions of estimated first-stage coefficients.

The results in the first column of Table 6 reject the hypothesis that different ways of tallying policies within energy policy packages make a difference in the regression estimates. In other words, there is no significant difference between the three indices across the number of eligible first-stage regressions.

The choice of an IV variable does make a significant difference across the number of eligible first-stage regressions (Table 6, second column). However, as shown in Table 5, these first-stage differences do not affect the second-stage estimates consistently.

Finally, there is no significant difference across the number of eligible first-stage regressions when comparing moving averages of 3 and 5 periods for our IVs (Table 6, third column).

Table 6: Kruskal-Wallis H tests summary

Indices		**IV**		**IV moving averages**	
chi-squared	p-value	chi-squared	p-value	chi-squared	p-value
0.88	0.64	15.16	0.0005	0.195	0.66

Note. Statistical ties are not accounted for. Results with statistical ties are indistinguishable from the ones reported in the Table.

Based on the outcomes of the two tests above, we continue our analysis with the empirical specification that yields the highest number of positive and statistically significant first-stage coefficients: (i) the RISE index; (ii) the IV based on affinity through the United Nations General Assembly voting, and (iii) the IV moving average of 5 years.

Of the 1,902 first-stage regressions in the chosen empirical specification, 28 percent (or 540 coefficients) are eligible for the second-stage estimation (Appendix Table A.7).

The total row of Table 7 shows the share of significant second-stage coefficients as a percentage of total eligible first-stage regressions. Only 15.7 percent (or 85 coefficients) of the estimated second-stage regressions meet the statistical significance threshold of a p-value below 10 percent. These results indicate that, on average, roughly one out of six renewable energy policy packages have had *any* impact on the developing countries energy mix such that limiting this study to a more recent time frame during which climate concerns gained importance in energy policy decisions would have severely restricted our analysis.

In addition, a mere 4.8 percent (or 26 coefficients) of the estimated second-stage regressions are positive and statistically significant. More than two out of three significant energy policy packages have had the *opposite* effect than intended. As the input data are standardized, the relationship is measured in units of standard deviation distance from the mean and can be compared across energy policy packages and energy mix outcomes.

The significance and effectiveness of the reform seem to vary across geographic regions. With the exceptions of the Europe and Central Asia, and the Sub-Saharan Africa regions, all other regions had a less than 5 percent share of the renewable energy policies with a significant effect on the energy mix (Table 7, top). Moreover, contrary to what one would expect, both the significance and effectiveness of renewable energy policies decline with income level. (Table 7, bottom). Appendix Table A.8 displays this same information by energy policy package and energy mix outcome.

Table 7: Significant second-stage coefficients as a percentage of eligible first-stage regressions, combining the results for all 7 energy policy packages.

	Group	**Total eligible first-stage regressions**	**Share with significant second-stage coefficients**	**Share with positive and significant second-stage coefficients**
Region	SSA	224	22.8%	6.7%
	EAP	86	4.7%	1.2%
	ECA	50	44.0%	18.0%
	LAC	116	6.0%	0.0%
	MENA	36	2.8%	2.8%
	SAS	28	0.0%	0.0%
	Total	540	15.7%	4.8%
Income	High	49	0.0%	0.0%
	Upper Middle	113	15.0%	0.9%
	Lower Middle	246	15.4%	5.3%
	Low	132	22.7%	9.1%
	Total	540	15.7%	4.8%

Notes: Regression specification: RISE index, UNGA affinity IV with five years moving averages. SSA: Sub-Saharan Africa. EAP: East Asia & the Pacific. ECA: Europe & Central Asia. LAC: Latin America & Caribbean. MENA: the Middle East and North Africa. SAS: South Asia.

While the aggregate results suggest that renewable energy policies had a modest significant effect on the energy mix, they fall short of explaining the effect of each of these policies separately and over time. Figure 1 illustrates the results of our main research question, which shows distributional boxplots of the effects of each energy policy package aggregated across all regions.

In addition to the default lag of 3 years, we consider the possibility that the effect of each energy policy package changes with time and analyze lags of 5 and 7 years. When breaking down by energy policy package, it becomes important that coefficients related to different energy mix outcomes for the same country cluster together (e.g., Kenya, Eritrea, and Angola in Appendix Figure A.6) due to the inherent similarity of the outcome variables.

To avoid biasing the results by energy policy package towards the countries for which there are more available outcomes, we keep only one outcome coefficient at random by energy policy package and country in subsequent analysis. Because there is no theoretical reason to prefer any outcome variable over another, and because we have shown that they tend to cluster, we simply choose the first available coefficient from the outcomes from a list ordered in the same way as the left to right columns in Table 5.

Here, we take a moment to consider that of our three fossil fuel variables, only one of them (electricity from oil sources) excludes natural gas, which may be considered a transition fuel in some countries. Appendix Figure A.6 helps us consider the possibility that lumping gas in with other fossil fuels could theoretically be driving our pessimistic results regarding the impact of energy policy packages on the decarbonization of the energy mix. Because the effects of the energy policy packages on fossil fuels (red) and renewables (blues) tend to cluster, potential misclassification of natural gas is unlikely to drive our results.

Patterns from Figure 1 (and Appendix Tables A.9-A.10, which summarize the means of estimated second-stage coefficients across regions and income categories) show that all energy policy packages except counterparty risk had consistently higher average effects over time. Moreover, planning for expansion, incentives, and regulatory support, attributes of financial and regulatory incentives, and network connection and use energy policy packages overcome negative medians seven years after their implementation (Figure 1).

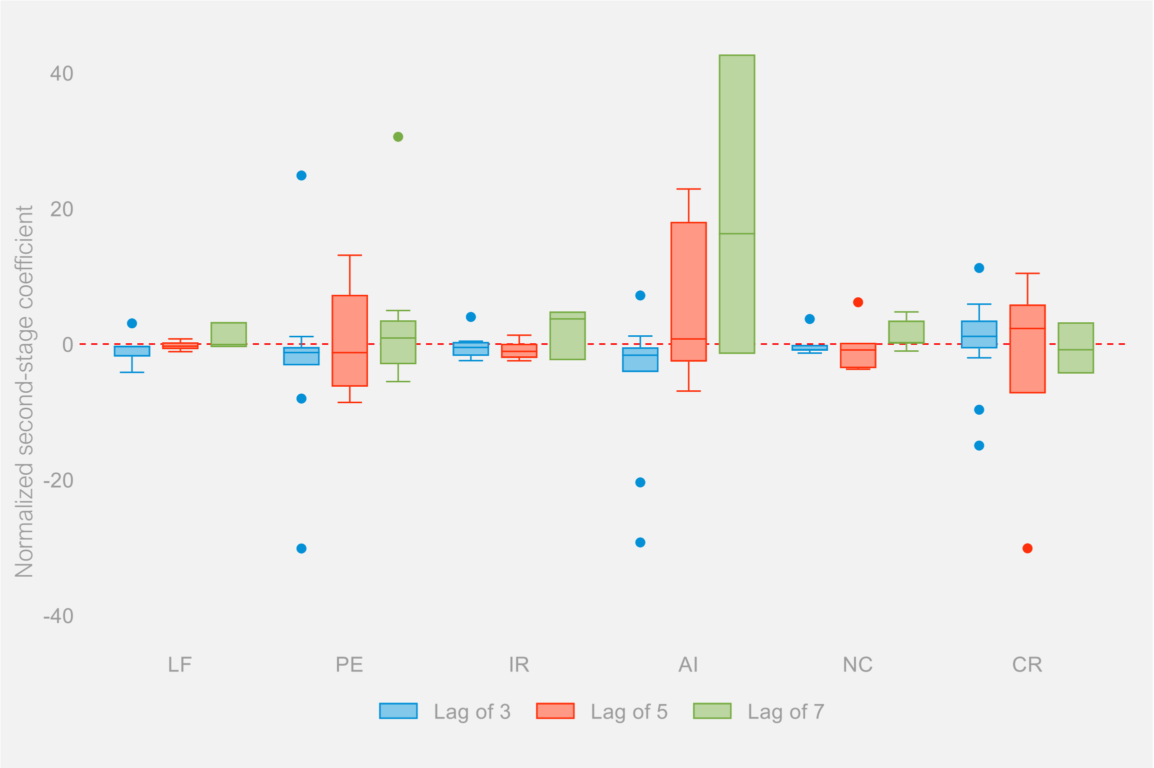

Figure 1: Boxplot of normalized second-stage coefficients by an energy policy package

Notes: The unit of lags are years; different lags are denoted by the colors in the legend. LF=Legal framework; PE=Planning for expansion; IR=Incentives and regulatory support; AI=Attributes of financial and regulatory incentives; NC=Network connection and use; CR=Counterparty risk. Regression specification: RISE index, UNGA affinity IV with five years moving averages. In the boxplot, there is a box from the first quartile to the third quartile, with the 2nd quarter (50% percentile) marked by the internal line of the box. The whiskers extending from the boxes go from each quartile to the minimum or maximum, excluding outliers.

Table 8: Average of normalized second-stage coefficients by energy policy packages and yearly lags

	Lags in years		
Energy policy package	3	5	7
Legal Framework	-0.66	-0.25	0.90
Planning for expansion	-2.20	0.48	3.02
Incentives and regulatory support	-0.30	-0.92	2.04
Attributes of financial and regulatory incentives	-5.35	5.48	19.17
Network connection and use	-0.08	-0.43	1.48
Counterparty Risk	0.38	-2.24	-0.67

Notes: Regression specification: RISE index, UNGA affinity IV with five years moving averages.

Unlike other energy policy packages, the counterparty risk type has the highest and only positive median and mean closest to implementation (lag of 3 years). Its median is higher when using a time lag of 5 years, too, except when compared to financial and regulatory incentives attributes.

Appendix Table A.3 describes the content of the energy policy packages. The counterparty risk package includes government guarantees or other means to ensure the creditworthiness of projects procured through auctions or otherwise. One interpretation is that mitigating counterparty risk could have comparatively immediate effects. Another interpretation of the result is that addressing counterparty risk influences outcomes positively while supporting other energy policy packages that take more time to have the intended outcomes.

Either way, this result gives credence to the idea that policies that address the bankability of private investment in renewable energy are crucial for energy decarbonization. In the following section, we challenge our results in three ways and arrive at similar conclusions.

5 ROBUSTNESS CHECKS AND DISCUSSION

Below we explore the robustness of our findings to assumptions used in constructing the data sample and variables. We then discuss the caveats and policy implications of our findings.

5.1 ROBUSTNESS CHECKS

Limiting the country sample

Our analysis of the second-stage estimates' variation across time assumes that econometric methods such as country-fixed effects and regional panels can fully eliminate all confounding country-specific characteristics from the data and make cross-country comparisons possible. If this were not the case, one could not take our results at face value because the country sample is not homogenous across all lags and energy policy packages. For instance, estimated coefficients of the legal framework for the renewable energy policy package exist for Ghana only in lag 3 and Peru only in lag 5.

For robustness purposes, we challenge our results by narrowing the comparison only to countries with significant coefficients across all three time lags. There are only nine countries that fulfill this criterion. The results in this restricted sample still point to a temporal dimension of effects across energy policy packages. Examples of consistent improvements in energy mix metrics by energy policy package are evidenced in attributes of financial and regulatory incentives and incentives and regulatory support for renewable energy policy packages for Kenya and Ukraine, respectively.

Unfortunately, the size of the data sample available for this robustness check restricts us from reasonably averaging over energy policy packages separately. However, averages of the effects of all energy policy packages together still yield increases over time (0.73,1.72, 3.83 in lags 3, 5, and 7, respectively). Moreover, the result holds even when we exclude outliers (in this sample, averages are 0.14, 0.24, and 0.29 in lags 3, 5, and 7, respectively).

Keeping only modern renewables by removing large hydropower

We acknowledge that the introduction of large hydropower instead of modern renewables may obscure the effects of the energy policy packages we study. Therefore, for robustness, we re-estimate the final specification (i.e., using (1) the RISE index; (2) the IV based on affinity through United Nations General Assembly voting; and (3) the IV moving average of 5 years) without large hydropower.

We remove hydropower by replacing REC and REO (“Renewable energy consumption” and “Renewable electricity output”) variables with the shares of “Modern Energy Generation over Total Generation” and “Modern Energy Capacity over Total Installed Capacity” as our dependent variables. We refer to the new five dependent variables as the “altered dependent variables.”

Results are little changed. Although some regions experienced improvements compared to the results of Table 7 (Appendix Table A.11), the energy policy packages still had a minimal or negative impact on the energy mix, while second stage results still clustered together (Appendix Figure A.7).

Figure A.8 and Table A.12 in the Appendix replicate the main results using the altered dependent variables. The median and mean results are slightly different.

The means of types related to the legal framework, attributes of financial and regulatory incentives, and network connection and use hover close to zero instead of having immediate negative effects. The means of planning for expansion and attributes of financial and regulatory incentives still increase consistently over time, though the means of all remaining three energy policy packages peak in the second period. The energy policy package that deals with counterparty risk remains the one with the highest mean closest to implementation, and it goes down over time.

Medians are negative or close to zero for all energy policy packages, except for attributes of financial and regulatory incentives, which increases over time, and for counterparty risk, which peaks after five years and becomes negative after seven years.

Considering absolute instead of relative changes in modern renewables

We consider that the absolute effects of the two new modern renewable outcomes ("Modern Energy Capacity" and "Modern Energy Generation") are obscured by similar or disproportionate growth in the overall energy mix (the denominator), which includes incumbent technologies like fossil fuels and large hydropower.

We, therefore, re-estimate the final specification (i.e., using (1) the RISE index; (2) the IV based on affinity through United Nations General Assembly voting; and (3) the IV moving average of 5 years) considering the absolute, not relative, changes in modern renewables.

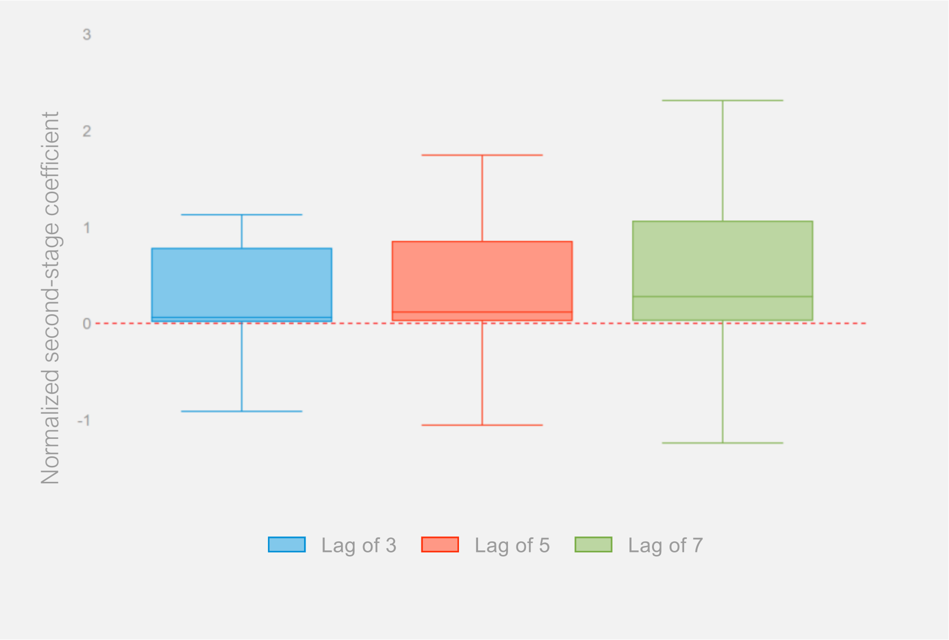

Figure 2: Boxplot of normalized second-stage coefficients for only the absolute modern renewable capacity outcome

Notes: The unit of lags are years; different lags are denoted by the colors in the legend. LF=Legal framework; PE=Planning for expansion; IR=Incentives and regulatory support; AI=Attributes of financial and regulatory incentives; NC=Network connection and use; CR=Counterparty risk. Regression specification: RISE index, UNGA affinity IV with five years moving average. In the boxplot, there is a box from the first quartile to the third quartile, with the 2nd quarter (50% percentile) marked by the internal line of the box. The whiskers extending from the boxes go from each quartile to the minimum or maximum, excluding outliers.

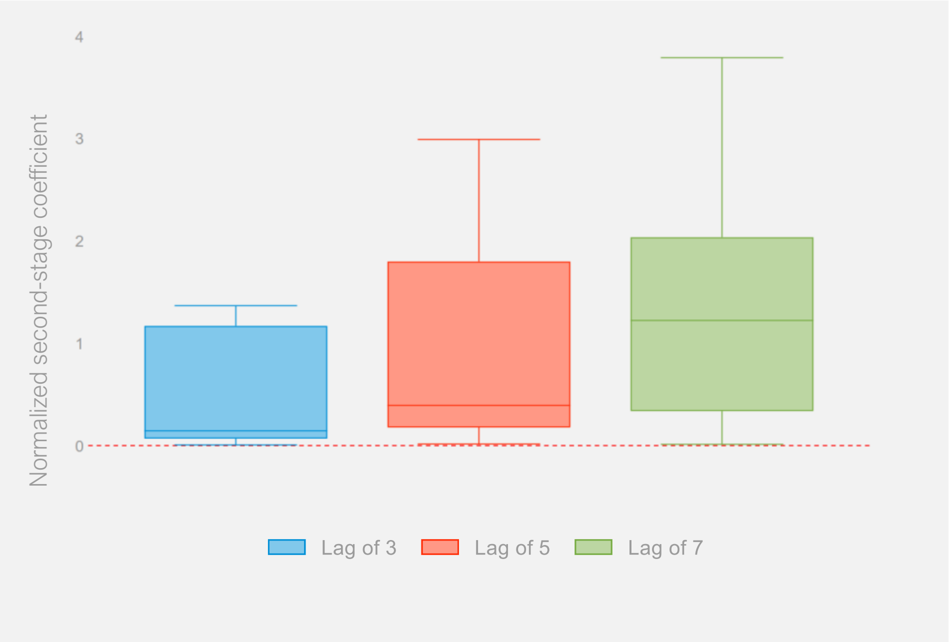

Figure 3: Boxplot of normalized second-stage coefficients for only the absolute modern renewable generation outcome

Notes: Excludes outliers. The unit of lags are years; different lags are denoted by the colors in the legend. LF=Legal framework; PE=Planning for expansion; IR=Incentives and regulatory support; AI=Attributes of financial and regulatory incentives; NC=Network connection and use; CR=Counterparty risk. Regression specification: RISE index, UNGA affinity IV with five years moving average. In the boxplot, there is a box from the first quartile to the third quartile, with the 2nd quarter (50% percentile) marked by the internal line of the box. The whiskers extending from the boxes go from each quartile to the minimum or maximum, excluding outliers.

The number of coefficients for these two outcome variables individually is too low to visualize by the energy policy package. We, therefore, aggregate the results into boxplots (see Figures 2 and 3) that represent the three time lags we study. Appendix Table A.13 shows the average effect of the policy packages on these two absolute outcomes, by time lag. Overall, the immediate effects of policies are small and close to zero; temporal results also echo the results of previous analyses.

5.2 DISCUSSION

In this paper, we address the following questions: How do the effects of seven major energy policy packages on the deployment of clean energy technologies compare in developing countries? And how do such effects change from the short to medium term after implementation, by policy category?

Peñasco et al.'s (2021) relevant systematic review of developed countries can help guide expectations on our country sample. The review shows that about 50 percent of evaluations find that regulatory policies that establish renewable energy obligations, including legal frameworks for renewable energy, which is one of our energy policy packages, do not affect renewable deployment. Results of studies on GHG trading schemes in our energy policy packages on carbon pricing and monitoring are also mixed. Fifty-three percent report no impact, and 8 percent report a negative impact.

On the other hand, 75 percent of studies on the policy groups that include taxes and grants find positive effects. The literature broadly supports the effects of feed-in tariffs and feed-in premiums (broadly, subsidies for renewable energy and part of our incentives regulatory support energy policy package). About 86 percent of evaluations found that feed-in tariffs positively affected renewable energy deployment.

Today, feed-in tariffs are losing ground to auctions (competitive bidding processes for private sector investment in renewable energy deployment that are included in our energy policy package on attributes of financial and regulatory incentives). Fifty-nine percent of studies on auctions report a positive impact, and 41 percent report a negative or negligible impact on deployment. While there are relatively less data to assess auctions, it is understood that design elements are crucial to success.

Consistent with the literature on the energy sector reform in developing countries (Foster & Rana, 2020; Jamasb et al., 2005, 2015), our main results and robustness checks point to very low effectiveness across energy policy packages to near the decarbonization of the energy mix.

In our results, only one-sixth of the coefficients representing energy policy packages have even modest statistical significance. Moreover, most of them are the sign opposite to what one would expect. As they stand, these results seem to suggest that, at least within 3-7 years studied, decarbonization policies in our country samples fail to deliver on their goals of reducing the share of fossil fuels in their energy mix.

The results may be driven by a host of interrelated issues in developing countries, and they all likely play a role. The institutional capacity in the countries we explore is weaker as compared to the countries covered by the policy evaluation literature in developed countries (Foster & Rana, 2020), where the impact on energy mixes and renewable energy technology deployments seem to be more positive.

A relative lack of institutional capacity can also negatively affect the ability to secure finance in developing countries. This problem is itself connected to factors such as macroeconomic conditions and a lack of infrastructure (Egli et al., 2019; Moner-Girona et al., 2021), although the crucial role finance plays in decarbonization (Buchner et al., 2019; IRENA and Climate Policy Initiative (CPI), 2020; Macquarie et al., 2019; Steckel et al., 2017).

The importance of securing finance is in line with our results surrounding the counterparty risk package. Indeed, it is the only energy policy package that yields an increase in renewables in developing countries energy mix three years after implementation. This result again ties in with existing research. According to Peñasco et al., (2021), “due diligence of projects from commercial or investment banks” is crucial for the success of auctions in developed countries.

In addition to the relatively positive effects of policies that address counterparty risk, there is some further basis for optimism, as the effectiveness of the energy policy packages improves over time overall. We posit that the Sailing Ship Effect (Gilfillan, 1935; Ward, 1967), where incumbent technologies temporarily improve their productivity in response to competitive threats by new technologies, could be a potential driver for these dynamics.

Interaction between energy policy packages could also help explain greater positive effects over time. Addressing counterparty risk first might buttress and support other energy policy packages over time.

Despite our efforts to identify the causal relationship between energy policy packages and decarbonization, our analysis is limited by the extent to which our methods, through Ivs and controls, can address other patterns shaping the energy sector in our country sample. These include, for example, changes in enforcement capabilities over time, which static country fixed effects cannot control.

While we establish the limited effectiveness of the renewable energy policies in achieving decarbonization in our sample, the validity of the exclusion restriction of the Ivs could be a limitation potentially affecting the results. In addition, as measured through foreign policy and trade Ivs, closeness to major donors could affect policies outside the power sector. Those non-power sector policies, in turn, may have had some effects on the energy mix. Nevertheless, we could not find alternative instruments and data that covered the breadth of geography, power sector policy, and outcomes that our research questions entailed. Further research may be able to consider other instruments, especially if the analysis is narrower in scope.

Last, this discussion considered that the interrelation between energy policy packages could help explain our finding of more positive effects over time. The evolving interdisciplinary analytical framework of policy mixes spearheaded by Rogge & Reichardt

(2016) is a descriptive conceptual framework for the policy-making process and is appropriate for social science research questions in multiple fields. The limited relevant empirical work in energy includes Schmidt & Sewerin, (2019), who analyze policy mixes in nine developed countries, although that study does not consider policy interactions.

6 CONCLUSIONS AND POLICY IMPLICATIONS

Achieving decarbonization worldwide requires a robust understanding of how effective different renewable energy and climate policies are in a broad range of countries and their dynamics over time. Research on the topic is especially important in developing countries, where the literature is relatively scarce.

This study sheds light on these important issues by conducting a first systematic assessment of how seven renewable energy policy packages affect the energy mix in developing countries over time.

We rely on the background data behind the RISE indicators published by the ESMAP at the World Bank. We address several well-known econometric issues in the existing literature that uses similar datasets, including omitted variables and simultaneity and reverse causality between energy policy packages and outcomes. We estimate thousands of indicator-instrument-outcome-level country and time fixed-effects regressions over regional panels covering more than 100 developing countries and four decades of energy sector policies.

We credibly evaluate the robustness of indicators' measurement, quality of instrumental variables used, and significance and direction of estimated energy policy package coefficients. Notably, we find no major measurement differences when we try different policy instrument aggregation outcomes, allowing us to conclude that the aggregation method used by the World Bank is robust to potential under- and overweighting problems. We also find no major differences in the second-stage estimates obtained by different IVs, which exploit different sources of arguably exogenous variation in renewable energy policies. This result adds robustness to our identification approach.

Our findings of the effects of renewable energy policies on decarbonization outcomes in developing countries are quite pessimistic. Only one-sixth of the estimated policy coefficients have even modest statistical significance. Moreover, many of these policies have a sign opposite to what one would expect (they are associated with negative impacts on energy mixes in terms of promoting decarbonization) or minimal effects.

These results suggest that at least short- to medium-term renewable energy policies in developing countries may fail to deliver on their goals of reducing the share of fossil fuels in their energy mix without other concurrent changes both at the international and domestic levels.

The results point to important avenues for policy and future research. We suggest the possible drivers of this result, such as weak institutional capacity, that translate into difficulties securing finance. The results suggest that without additional international climate finance and investments in institutional capacity, efforts to create additional decarbonization policies may not significantly impact the energy mix in these countries in the short to medium term. Fulfilling (and likely exceeding) commitments made during the Paris Agreement and the Glasgow Climate Act for climate finance are essential to enable lower carbon energy mixes. Our results also point to a possible role for additional South-South interactions to build on experiences related to policy design, enforcement, and monitoring.

There are, however, some findings that lend a basis for optimism. We see that the effectiveness of renewable energy policies improves over time and discuss evidence for the Sailing Ship Effect. Additionally, policies that address counterparty risk have the greatest immediate impact, underscoring the importance of access to finance on incorporating renewables into the energy mix.

Our results are robust to different ways of coding and aggregating policies and to various robustness checks, which include analyzing a more stringent country sample, removing large hydropower from outcome variables, and assessing absolute instead of relative outcome variables, among others.

We see several venues for future research. Understanding of the causal mechanism explaining our results can be further improved. Studies that utilize more granular data at the industry level are necessary to elucidate the effects of unobserved factors in developing countries, such as the extent to which renewable policies are enforced. Another important direction for future research is to study firm-level responses to renewable energy policies, including implications for productivity, entry and exit, the turnaround of capital stock, and other constraints to renewable energy technology adoption.

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APPENDIX A: SUPPORTING TABLES & FIGURES

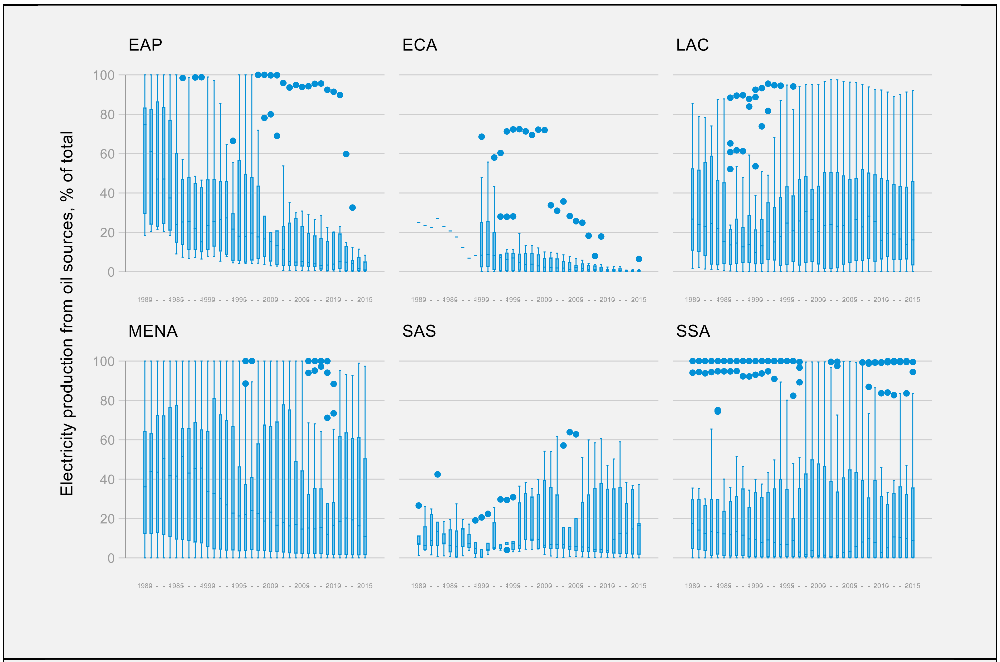
Table A.1: Countries in the dataset

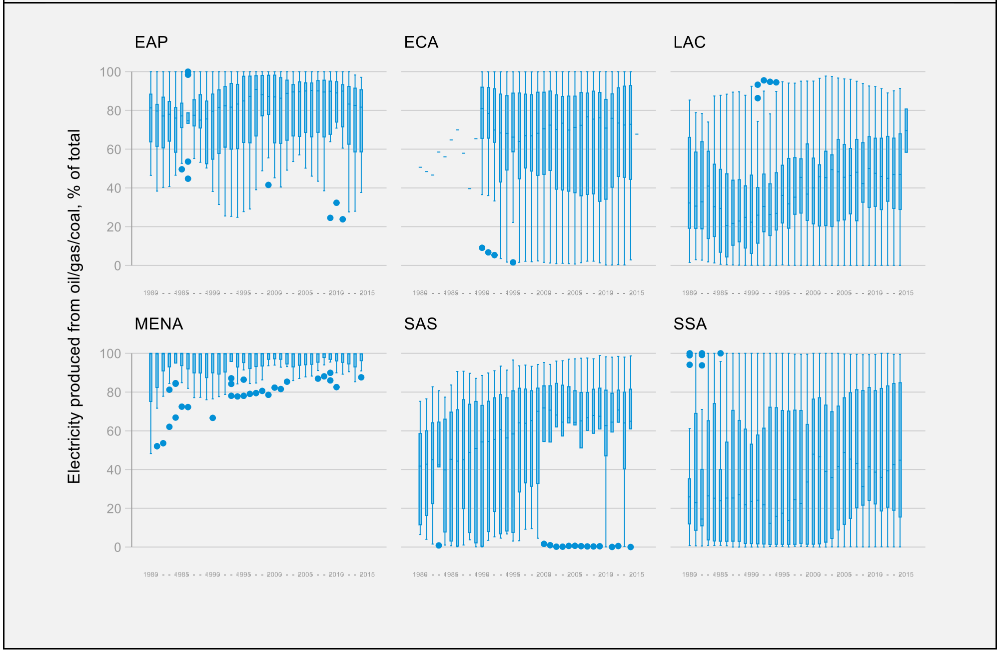
Count	Country	Reg.	Kept	Count	Country	Reg.	Kept	Count	Country	Reg.	Kept
1	Cambodia	East Asia & Pacific (EAP)	1	49	Australia	OECD	0	92	Afghanistan	South Asia (SAS)	1
2	China		1	50	Austria		0	93	Bangladesh		1
3	Indonesia		1	51	Belgium		0	94	India		1
4	Lao PDR		1	52	Canada		0	95	Maldives		0, missing data
5	Malaysia		1	53	Chile		1, moved to LAC	96	Nepal		1
6	Mongolia		1	54	Czech Republic		0	97	Pakistan		1
7	Myanmar		1	55	Denmark		0	98	Sri Lanka		1
8	Papua New Guinea		1	56	Finland		0	99	Angola	Sub-Saharan Africa (SSA)	1
9	Philippines		1	57	France		0	100	Benin		1
10	Singapore		1	58	Germany		0	101	Burkina Faso		1
11	Solomon Islands		1	59	Greece		0	102	Burundi		1
12	Thailand		1	60	Hungary		0	103	Cameroon		1
13	Vanuatu		1	61	Ireland		0	104	Central African Republic		1
14	Vietnam		1	62	Israel		0	105	Chad		1
15	Armenia	Europe & Central Asia (ECA)	1	63	Italy		0	106	Congo, Dem. Rep.		1
16	Azerbaijan		1	64	Japan		0	107	Congo, Rep.		1
17	Belarus		1	65	Korea, Rep.		0	108	Côte d'Ivoire		1
18	Bulgaria		0, EU member	66	Netherlands		0	109	Eritrea		1
19	Croatia		0, EU member	67	New Zealand		0	110	Ethiopia		1
20	Kazakhstan		1	68	Norway		0	111	Ghana		1
21	Kyrgyz Republic		1	69	Poland		0	112	Guinea		1

22	Romania		0, EU member
23	Russian Federation		1
24	Serbia		1
25	Tajikistan		1
26	Türkiye		1
27	Turkmenistan		1
28	Ukraine		1
29	Uzbekistan		1
30	Argentina	Latin America & Caribbean (LAC)	1
31	Bolivia		1
32	Brazil		1
33	Colombia		1
34	Costa Rica		1
35	Dominican Republic		1
36	Ecuador		1
37	El Salvador		1
38	Guatemala		1
39	Haiti		1
40	Honduras		1
41	Jamaica		1
42	Mexico		1
43	Nicaragua		1
44	Panama		1
45	Paraguay		1
46	Peru		1
47	Uruguay		1
48	Venezuela, RB		1
70	Portugal		0
71	Slovak Republic		0
72	Spain		0
73	Sweden		0
74	Switzerland		0
75	United Kingdom		0
76	United States		0
77	Algeria	The Middle East & North Africa (MENA)	1
78	Bahrain		1
79	Egypt, Arab Rep.		1
80	Iran, Islamic Rep.		1
81	Jordan		1
82	Kuwait		1
83	Lebanon		1
84	Morocco		1
85	Oman		1
86	Qatar		1
87	Saudi Arabia		1
88	Tunisia		1
89	United Arab Emirates		1
90	West Bank and Gaza		1
91	Yemen, Rep.		1
113	Kenya		1
114	Liberia		1
115	Madagascar		1
116	Malawi		1
117	Mali		1
118	Mauritania		1
119	Mozambique		1
120	Niger		1
121	Nigeria		1
122	Rwanda		1
123	Senegal		1
124	Sierra Leone		1
125	Somalia		1
126	South Africa		1
127	South Sudan		0, missing data
128	Sudan		1
129	Tanzania		1
130	Togo		1
131	Uganda		1
132	Zambia		1
133	Zimbabwe		1

Source: ESMAP RISE dataset.

Notes: Our country sample excludes EU members and Australia, Norway, Great Britain, Japan, Korea, and Switzerland.


Electricity production from oil sources, % of total
EAP
ECA
LAC
MENA
SAS
SSA
100
80
60
40
20
0
1989
2015


Electricity produced from oil/gas/coal, % of total
EAP
ECA
LAC
MENA
SAS
SSA
100
80
60
40
20
0
1989
2015

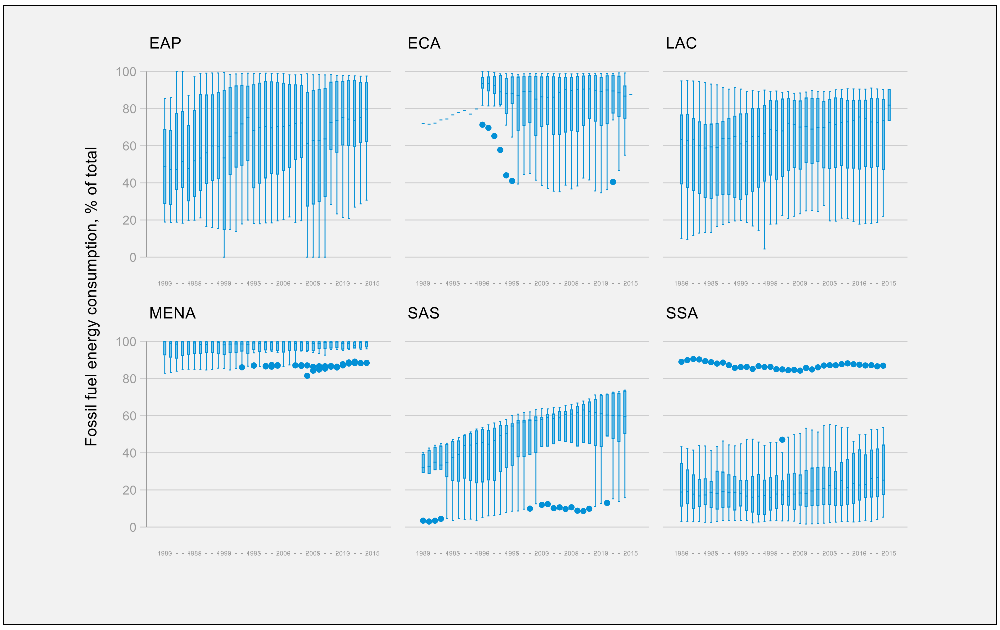


Figure A.1: Dependent variables negatively affected by renewable energy policies (distribution by regions)

Source: WDI and authors' elaboration based on the methods described in this paper.
Notes: SSA=Sub-Saharan Africa; EAP=East Asia & the Pacific ECA=Europe & Central Asia; LAC=Latin America & Caribbean; MENA=the Middle East and North Africa; SAS=South Asia.

Figure A.2: Dependent variables positively affected by renewable energy policies (distribution by regions)

Source: WDI and authors' elaboration based on the methods described in this paper.

Notes: SSA=Sub-Saharan Africa; EAP=East Asia & the Pacific; ECA= Europe & Central Asia; LAC=Latin America & Caribbean; MENA=the Middle East and North Africa; SAS=South Asia.

Table A.2: RISE discrepancies and variables removed from the analysis

	Type of discrepancy	**Dummy**	**Year**	**Decision**	**Rationale**
1	Dummy and year discrepancy	0	Year should not be specified but is specified	Favored the year column	The year column is more specific information than the dummy column. If there is input for the more specific column, then we assume that it has been verified and is correct.
2	Potential dummy and year discrepancy	0	Year should be 0, but it is NA, N/A, not applicable, or missing	Favored the dummy column, treated year as "0"	We cannot use a year if we do not have it.
3	Dummy and year discrepancy	1	Year should be specified, but is 0	Treated year as NA (".")	Treating years as "no" (with 0) would be incorrect because the reform seems to have been made. However, without a year, we cannot count them in a panel.
4	Dummy and year discrepancy	1	Year should be specified, but is missing	Treated year as NA (".")	Treating years as "no" would be incorrect because the reform was made according to the dummy column. However, without a year, we cannot count them in a panel.
5	Year looks suspicious	1	Year seems too early	No action	Some years are very early, examples re.2.1.6.yr (1895) or re.6.3.1.3.yr (1923). We give the dataset the benefit of the doubt.
6	Dummy and year discrepancy	NA	Year should be NA, but is specified	Favored the year column	The year column gives more information than the dummy column. If there is input for the more specific column, then we assume that it has been verified and is correct.
7	Potential dummy and year discrepancy	NA	Year should be NA, but is 0	Favored the dummy column, treated year as NA (".")	Seems like the year column was given a "0" because it was "NA" in the dummy column. But we treat missing in the dummy column as "NA". So, we favored the dummy column.

Source: ESMAP RISE dataset and authors' elaboration based on dataset described in this paper.

Table A.3: Renewable energy policies covered in the RISE dataset

Headings	RISE ID	Our ID	Question
Legal framework for renewable energy (LF)	1.1.1	re_1_1	Does a legal framework for renewable energy development exist?
	1.2.1	re_1_2	Does the legal framework allow private sector ownership of renewable energy generation?
Planning for renewable energy expansion (PE)	2.1.1	re_2_1_1	Does an official renewable energy target exist?
	2.1.2	re_2_1_2	Is the target legally binding?
	2.1.3	re_2_1_3	Is the RE target linked to international commitments (e.g., NDC or regional commitment)?
	2.1.4	re_2_1_4	Is the target based on a transparent methodology?
	2.1.5	re_2_1_5	Is there a renewable energy action plan or strategy to attain the target?
	2.1.6	re_2_1_6	Is there any provision for consultation with the public on the renewable plan?
	2.2.1	re_2_2_1	Is there an assessment of the role of renewables in the electricity supply?
	2.2.2	re_2_2_2	Is there a target for renewables in electricity?
	2.3.1	re_2_3_1	Is there an assessment of the needs for heating and cooling in buildings and industry in the country and of how renewables can contribute?
	2.3.2	re_2_3_2	Is there a specific target for renewables for heating and cooling?
	2.4.1	re_2_4_1	Is there an assessment of the potential role for renewables in transport including s and electrification?
	2.4.2	re_2_4_2	Is there a specific target for renewables in transport?
	2.5.1	re_2_5_1	Does the renewable plan or strategy estimate the amount of investment necessary to meet the RE target?
	2.5.2	re_2_5_2	Is there an institution responsible for tracking progress in renewable energy development?
	2.5.3	re_2_5_3	Is there any periodic reporting mechanism for renewable energy progress?
	2.5.4	re_2_5_4	Is there a mechanism for adjusting the plan based on reporting of renewable energy deployment?
	2.5.5	re_2_5_5	Is current policy environment conducive to renewable energy deployment?
	2.6.1	re_2_6_1	Is generation and transmission planning integrated?
	2.6.2	re_2_6_2	Is planning for dispatch included in the generation and transmission plan?
	2.6.3	re_2_6_3	Is the generation plan based on a probabilistic approach?
	2.6.4	re_2_6_4	Does the current transmission planning consider renewable energy scale-up?
	2.7.1	re_2_7_1	Does the government endorse and use the solar/wind resource maps and data applicable to their country that are available through the Global Solar Atlas / Global Wind Atlas, or have they published some other solar/wind resource map that conforms to best practice in the last five years?
	2.7.2	re_2_7_2	Has the country carried out geospatial planning or produced zoning guidance to inform the commercial development of the RE resource?
	2.7.3	re_2_7_3	Has the geospatial planning or zoning guidance been carried out according to best practice by i) being undertaken as part of a strategic environmental and social assessment or equivalent process; and ii) by making the outputs publically available?
Incentives and regulatory support for renewable energy (IR)	3.1.1	re_3_1_1	Does the country offer long term PPA’s for renewable electricity production for large scale producers (e.g. via. Feed-in-tariffs, PPA’s awarded through auctions etc.)
	3.1.2	re_3_1_2	Does the country offer long term PPA’s for renewable electricity production for small scale producers (e.g. via. Feed-in-tariffs, PPA’s awarded through auctions etc.)
	3.1.3	re_3_1_3	Does the government publish clear and practical guidance on what permissions are required to develop a RE electricity project?
	3.1.4	re_3_1_4	Does the government offer other direct fiscal incentives for renewable electricity (e.g. capital subsidies, grants or rebates, investment tax credits, tax reductions, production tax credits, FITs for large producers?)
	3.2.1	re_3_2_1	Does the country provide prioritized access to the grid for RE?
	3.2.2	re_3_2_2	Do RE projects receive priority in dispatch?

Headings	RISE ID	Our ID	Question
	3.2.3	re_3_2_3	Are there provisions to compensate seller if offtake infrastructure is not built in time?
	3.2.4	re_3_2_4	Are there mechanisms to compensate RE projects for lost generation due to certain curtailments after project commissioning?
	3.2.5	re_3_2_5	Is the compensation due because of curtailment actually given out.
	3.3.1	re_3_3_1	Is there a biofuels blending mandate or other obligation to use biofuels?
	3.3.2	re_3_3_2	Are there sustainability criteria which biofuels which contribute to the mandate must meet?
	3.3.3	re_3_3_3	If there is a plan for producing biofuels in the country, has this included an assessment of sustainability impacts (e.g. against the GBEP Sustainability indicators) including an assessment of impacts on food security.
	3.3.4	re_3_3_4	Is there at least one scheme to encourage use of electric/hybrid vehicles? (e.g. Tax benefit to consumers and manufacturers, etc.)
	3.4.1	re_3_4_1	Are there any policies to encourage deployment of any renewable energy heating and cooling technologies?
	3.4.2	re_3_4_2	Are there specific measures (financial support or promotion) designed to encourage the use of renewables in the heating and cooling sectors?
	3.4.3	re_3_4_3	Are opportunities for renewable heat promoted alongside energy efficiency measures in buildings and/or industry?
Attributes of financial and regulatory incentives (AI)	4.1.1	re_4_1_1	Is competition used to ensure large scale RE generation (projects >10MW) is cost competitive (e.g. through auctions for PPA’s)?
	4.1.1.1	re_4_1_2_1	Is there a schedule for future bids/auctions available for investors?
	4.1.1.2	re_4_1_2_2	Is there a pre-qualification process to select bidders?
	4.1.2.3	re_4_1_2_3	Are tariffs indexed (in part or in whole) to an international currency or to inflation?
	4.1.1.4	re_4_1_2_4	Are there provisions to ensure full and timely project completion (e.g. bid-bonds, project milestones)
	4.1.1.5	re_4_1_2_5	Are projects awarded through auctions/bids online/on track to be online on stated date?
	4.1.1.6	re_4_1_2_6	Have auctions/bids met stated target for installations?
	4.2.1	re_4_2_1	Can small producers (residential, commercial rooftop PV,etc) connect to the grid?
	4.2.2	re_4_2_2	Are contracts with fixed tariffs available for such producers?
	4.2.3	re_4_2_3	Is there a schedule or clear rules (e.g. capacity based limits) for adjusting the tariff level over time?
	4.2.4	re_4_2_4	Are different tariffs available for different technologies and sizes of the generation plant?
	4.2.5	re_4_2_5	Is there a mechanism to control the capacity built under each tariff?
	4.2.6	re_4_2_6	Are tariffs indexed (in part or in whole) to an international currency or to inflation?
Network connection and use (NC)	5.1.1	re_5_1_1	Does the country have a grid code that clearly specifies connection procedures?
	5.1.2	re_5_1_2	Do the connection procedures meet international best practices?
	5.1.3	re_5_1_3	Does the grid code include measures or standards addressing variable renewable energy?
	5.1.4	re_5_1_4	Are there rules defining the allocation of connection costs?
	5.1.5	re_5_1_5	Is the type of the connection cost allocation policy considered shallow (grid operator pays for connection costs)?
	5.2.1	re_5_2_1	Are there rules that allow electricity customers to purchase power directly from a third party (i.e. an entity other than the designated utility in a service area)?
	5.2.2	re_5_2_2	Do the rules define the size and allocation of costs for use of the transmission and distribution system (e.g. wheeling charges, locational pricing?)
	5.3.1	re_5_3_1	Does the country carry out regular assessments of the flexibility of the electricity grid and the issues relating to renewables integration?
	5.3.2	re_5_3_2	Can renewable energy projects sell into balancing/ancillary services?
	5.3.3	re_5_3_3	Are there rules for exchanging power between balancing areas that penalize variable renewable energy, e.g. through imbalance penalties? (only scored in countries with multiple balancing areas)
	5.3.4	re_5_3_4	Are there provisions in the power exchange rules that allow for plant forecasting? (only scored in countries with multiple balancing areas)
	5.3.5	re_5_3_5	Does the country integrate high quality forecasting for any variable RE resources (either through subscription service or provided by national agencies) into their dispatch operations?

Headings	RISE ID	Our ID	Question
	5.3.6	re_5_3_6	Are dispatch operations being carried out in real time?
Counterparty risk (CR)	6.1.1	**	Are the following financial ratios of the counterparty deemed creditworthy?
	6.1.1.1	**	Current ratio, <1 – 0 in between – scale >= 1.2 – 25
	6.1.1.2	**	EBITDA margin; <0 – 0 in between – scale >= 15% -- 25
	6.1.1.3	**	Debt service coverage ratio; <1 – 0 in between – scale >= 1.2 – 25
	6.1.1.4	**	Days payable outstanding ; >180 – 0 in between – scale <=90 – 25
	6.2.1	re_6_2_1	Is the counterparty underwritten by a government guarantee or are there other mechanisms to ensure credit worthiness (e.g. through a letter of credit, escrow account, payment guarantee, or other)?
	6.2.2	re_6_2_2	Are standard PPAs bankable?
	6.3.1.1	re_6_3_1	Generation, Are the financial statements of the largest utility publicly available in the following categories?
	6.3.1.2	**	Transmission, Are the financial statements of the largest utility publicly available in the following categories?
	6.3.1.3	**	Distribution, Are the financial statements of the largest utility publicly available in the following categories?
	6.3.1.4	**	Retail sales, Are the financial statements of the largest utility publicly available in the following categories?
	6.3.2.1	re_6_3_2	Generation, If yes, are they audited by an independent auditor for the following categories of utilities?
	6.3.2.2	**	Transmission, If yes, are they audited by an independent auditor for the following categories of utilities?
	6.3.2.3	**	Distribution, If yes, are they audited by an independent auditor for the following categories of utilities?
	6.3.2.4	**	Retail sales, If yes, are they audited by an independent auditor for the following categories of utilities?
	6.3.3.1	re_6_3_3	Generation – Electricity available for sale to end-users, Are the following metrics published in a primary official document (by the utility, regulator or ministry and/or government)?
	6.3.3.2	**	Transmission – Transmission loss rate, Are the following metrics published in a primary official document (by the utility, regulator or ministry and/or government)?
	6.3.3.3	**	Distribution – Distribution loss rate, Are the following metrics published in a primary official document (by the utility, regulator or ministry and/or government)?
	6.3.3.4	**	Retail Sales – Bill collection rate, Are the following metrics published in a primary official document (by the utility, regulator or ministry and/or government)?
	6.3.4	re_6_3_4	Is the utility operating an incidence/outage recording system (or SCADA/EMS with such functionality)?
	6.3.5	**	Is the utility measuring the SAIDI and SAIFI or any other measurements for service reliability?
	6.3.5.1	**	Are the measurements reported to the regulatory body?
	6.3.5.2	**	Are the measurements available to public?
Carbon pricing and monitoring (CP)	7.1	re_7_1	Is there a carbon pricing mechanism (eg carbon tax, emissions trading scheme) implemented in the country, covering part or all of the country's greenhouse gas emissions?)
	7.2	re_7_2	Is there a monitoring, reporting and verification system for greenhouse gas emissions in place?

Source: ESMAP RISE dataset and authors' elaboration based on dataset described in this paper.

*Notes: **Do not contain the year, cannot be used in a panel format.*

Table A.4: Attributes of raw data

Countries	133
First year	1875, Switzerland*
Variables primary	168
Variables cleaned	76
Policies directly in headings/PICs	4
Policies in groups, nested once	66
Policies in groups, nested twice	6

Source: ESMAP RISE dataset and authors' elaboration based on dataset described in this paper.

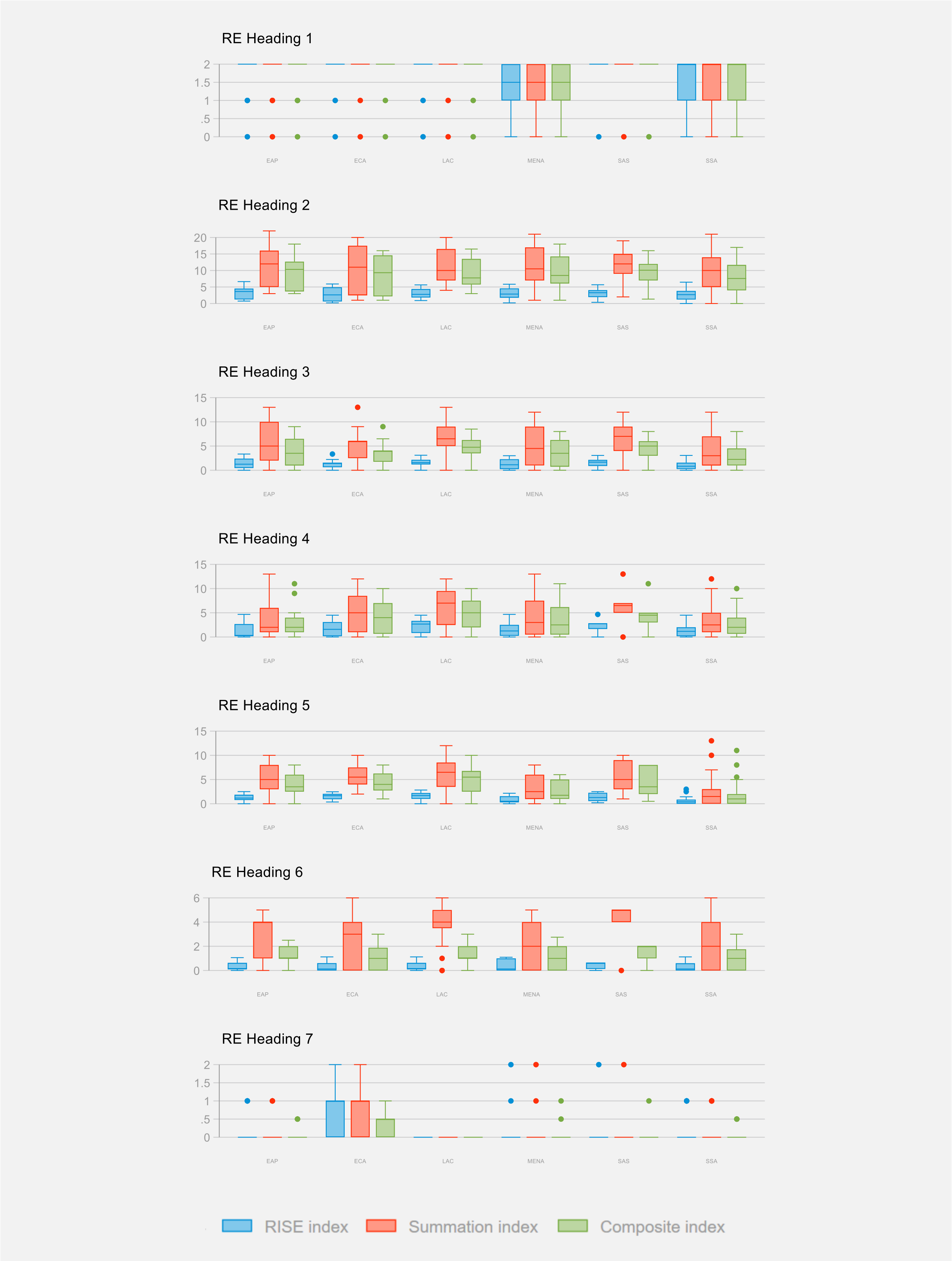


Figure A.3: Comparison of RISE, Summation, and Composite Indices, by heading, over the region, for 2015

Source: ESMAP RISE dataset and authors' elaboration based on dataset described in this paper.

Table A.5: RISE versus Composite weights used to create the explanatory variables in the “type” column

Type	Our ID	Composite index weight	RISE index weight	Type	Our ID	Composite index weight	RISE index weight
Legal framework for renewable energy	re_1_1	1	1	Network connection and use	re_5_1_1	0.5	0.2
	re_1_2	1	1		re_5_1_2	0.5	0.2
Planning for renewable energy expansion	re_2_1_1	0.333	0.167		re_5_1_3	1	0.2
	re_2_1_2	1	0.167		re_5_1_4	0.5	0.2
	re_2_1_3	1	0.167		re_5_1_5	0.5	0.2
	re_2_1_4	1	0.167		re_5_2_1	1	0.5
	re_2_1_5	0.333	0.167		re_5_2_2	1	0.5
	re_2_1_6	1	0.167		re_5_3_1	1	0.167
	re_2_2_1	1	0.5		re_5_3_2	1	0.167
	re_2_2_2	0.333	0.5		re_5_3_3	1	0.167
	re_2_3_1	1	0.5		re_5_3_4	1	0.167
	re_2_3_2	1	0.5		re_5_3_5	1	0.167
	re_2_4_1	0.5	0.5		re_5_3_6	1	0.167
	re_2_4_2	0.5	0.5	Counterparty risk	6.1.1	**	**
	re_2_5_1	1	0.2		6.1.1.1	**	**
	re_2_5_2	1	0.2		6.1.1.2	**	**
	re_2_5_3	1	0.2		6.1.1.3	**	**
	re_2_5_4	1	0.2		6.1.1.4	**	**
	re_2_5_5	1	0.2		6.2.1	1	0.5
	re_2_6_1	1	0.25		6.2.2	1	0.5
	re_2_6_2	1	0.25		6.3.1.1	0.25	0.03125
	re_2_6_3	1	0.25		6.3.1.2	**	**
	re_2_6_4	1	0.25		6.3.1.3	**	**
	re_2_7_1	1	0.333		6.3.1.4	**	**
	re_2_7_2	0.5	0.333		6.3.2.1	0.25	0.03125
	re_2_7_3	0.5	0.333		6.3.2.2	**	**
Incentives and regulatory support for renewable energy	re_3_1_1	0.5	0.25		6.3.2.3	**	**
	re_3_1_2	0.5	0.25		6.3.2.4	**	**
	re_3_1_3	1	0.25		6.3.3.1	0.25	0.03125
	re_3_1_4	1	0.25		6.3.3.2	**	**
	re_3_2_1	0.5	0.2		6.3.3.3	**	**
	re_3_2_2	0.5	0.2		6.3.3.4	**	**
	re_3_2_3	1	0.2		6.3.4	0.25	0.03125
	re_3_2_4	0.5	0.2		6.3.5	**	**
	re_3_2_5	0.5	0.2		6.3.5.1	**	**
	re_3_3_1	0.5	0.25		6.3.5.2	**	**
	re_3_3_2	0.5	0.25		re_7_1	0.5	0.5

Type	Our ID	Composite index weight	RISE index weight	Type	Our ID	Composite index weight	RISE index weight
	re_3_3_3	1	0.25	Carbon pricing and monitoring	re_7_2	0.5	0.5
	re_3_3_4	1	0.25				
	re_3_4_1	0.5	0.333				
	re_3_4_2	0.5	0.333				
	re_3_4_3	1	0.333				
Attributes of financial and regulatory incentives	re_4_1_1	1	Not scored				
	re_4_1_2_1	1	0.167				
	re_4_1_2_2	1	0.167				
	re_4_1_2_3	1	0.167				
	re_4_1_2_4	0.333	0.167				
	re_4_1_2_5	0.333	0.167				
	re_4_1_2_6	0.333	*				
	re_4_2_1	1	0.167				
	re_4_2_2	1	0.167				
	re_4_2_3	1	0.167				
	re_4_2_4	1	0.167				
	re_4_2_5	1	0.167				
	re_4_2_6	1	0.167				

Source: RISE dataset and authors' elaboration based on methods described in this paper.
*Notes: *Not scored; **Do not contain the year, cannot be used in a panel format.*

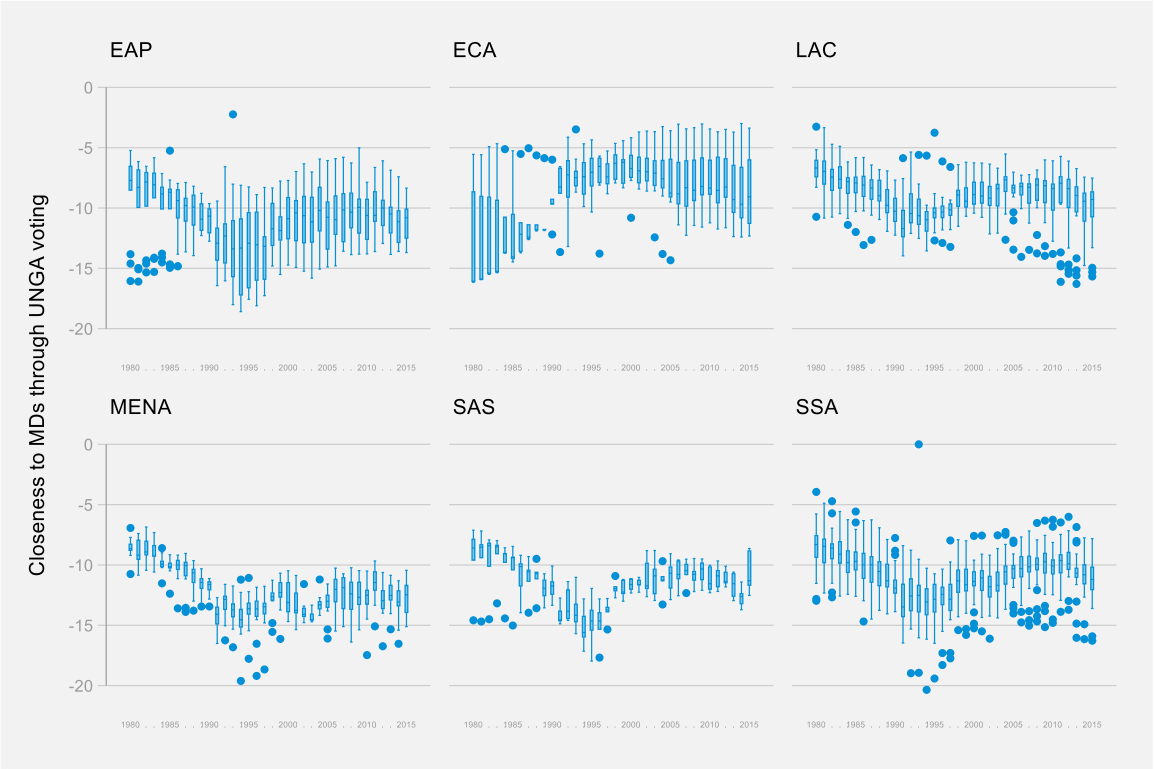


Figure A.4: Closeness to major donors through UNGA voting (distribution by regions)

Source: Author's elaboration based on (Bailey et al., 2017).

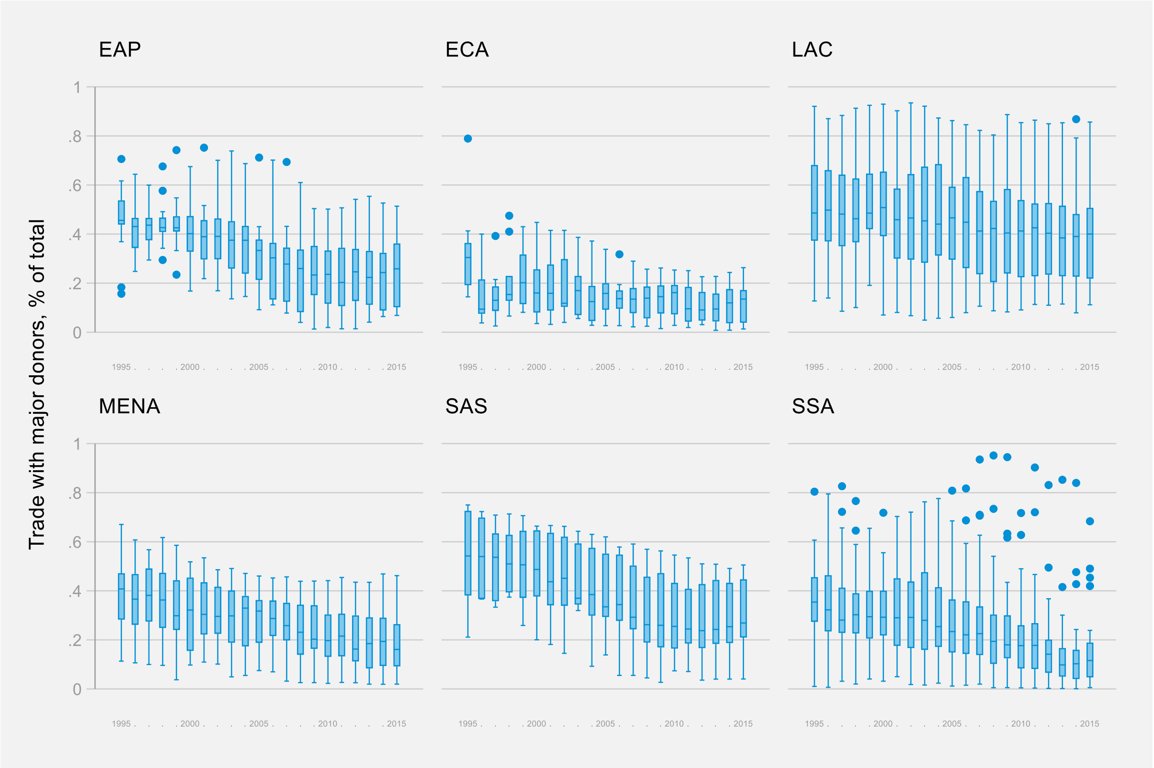


Figure A.5: Closeness with major donors through trade, 1995-2015, % of total (distribution by regions)

Source: UN Comtrade via the CEPII BACI dataset.

Table A.6: Trade agreements in place with EU Commission

Country	**Year in place**	**Country kept in sample (1=yes; 0=no)**
Armenia	1999	1
Azerbaijan	1999	1
Canada	2017	0
Switzerland	1980	0
Chile	2003	1
Côte d’Ivoire	2016	0
Comoros	2014	0
Colombia	2013	1
Costa Rica	2013	1
Dominican Republic	2008	1
Algeria	2005	1
Ecuador	2013	1
Egypt, Arab Rep.	2004	0
Ghana	2016	1
Guatemala	2013	1
Honduras	2013	1
Israel	2000	1
Jamaica	2008	1
Jordan	2002	1
Japan	2019	0
Kazakhstan	2016	1
Korea, Rep.	2015	0
Lebanon	2006	1
Morocco	2000	1
Madagascar	2012	1
Mexico	2000	1
Mozambique	2016	1
Nicaragua	2013	1
Norway	1994	0
Peru	2013	1
Singapore	2019	1
Solomon Islands	2020	1
El Salvador	2013	1
Serbia	2013	1
Tunisia	1998	1
Türkiye	1995	1
Ukraine	2016	1

Country	**Year in place**	**Country kept in sample (1=yes; 0=no)**
South Africa	2016	1
Zimbabwe	2012	1

Source: EU Commission website.

Table A.7: Eligible S1 coefficients for base specifications

Index	Ivs	Moving average	Significant, f>10	Significant, f>10, positive
Rise	UNGA aff.	5	784	540
Rise	UNGA aff.	3	698	516
Composite	UNGA aff.	5	713	479
Composite	UNGA aff.	3	656	471
Summation	UNGA aff.	5	703	471
Summation	UNGA aff.	3	640	449
Summation	EU agreements	5	262	194
Rise	EU agreements	5	248	180
Rise	EU agreements	3	245	177
Composite	EU agreements	5	243	175
Summation	EU agreements	3	242	174
Composite	EU agreements	3	240	172
Rise	Trade w. donors	3	953	31
Rise	Trade w. donors	5	934	28
Composite	Trade w. donors	3	914	25
Summation	Trade w. donors	5	907	24
Composite	Trade w. donors	5	885	23
Summation	Trade w. donors	3	897	21

Notes: Table is ordered by based specifications that, in addition to being significant at a p-value of 0.05 with an F-statistic of at least 10, had the sign we theorized for the IVs. Column four indicates the number of coefficients with a p-value below 5% and an f-statistic above 10. Column five contains the same information filtered for coefficients with a positive sign.

Table A.8: Eligible S2 coefficients, by policy and outcomes, lag 3.

	Fossil fuel energy consumption	**Electricity production from oil, gas & coal**	**Electricity production from oil sources**	**Renewable energy consumption**	**Renewable electricity output**	**Total**
Legal framework		1		3	2	6
Planning		2	1	5	2	10
Inc/reg. support	5	1		1	5	12
Attributes of fin/reg inc	5	6	1	4	3	19
Network conn. & use	6	4	1	2	2	15
Counterparty risk	5	6	3	3	6	23
Co2 price & mon.						0
Total	21	20	6	18	20	85

Note: Regression specification: RISE index, UNGA affinity IV with five years moving average.

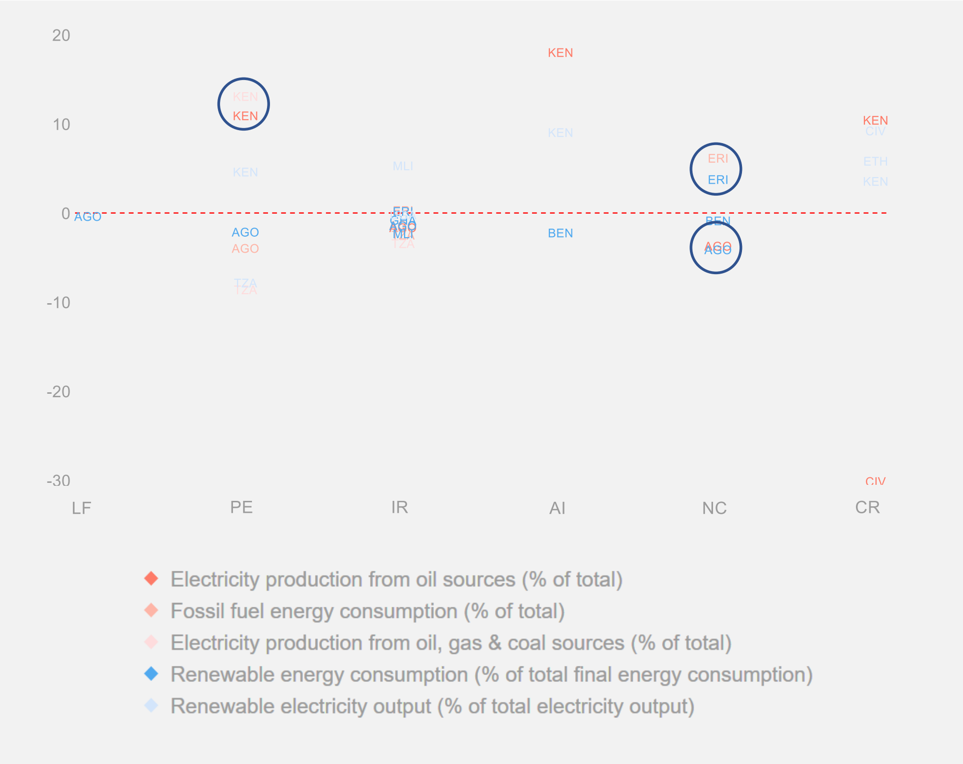


Figure A.6: Scatter plot of S2 coefficients for the SSA region showing that outcomes for the same country tend to cluster together, lag of 5

Notes: LF=Legal framework; PE=Planning for expansion; IR=Incentives and regulatory support; AI=Attributes of financial and regulatory incentives; NC=Network connection and use; CR=Counterparty risk. To avoid an overpopulated graph, we show one region only. Regression specification: RISE index, UNGA affinity IV with five years moving average. X-axis: Energy policy package. Y-axis: outcomes (colors). Clustered outcomes are shown in circles.

Table A.9: Average effect of policies across regions, by the second-stage lag

Region / Policy Lag	**3**	**5**	**7**
Sub-Saharan Africa	-0.07	1.63	2.50
Europe and Central Asia	-1.97	-0.18	8.28
All Other Regions	-0.14	-0.20	0.69

Notes: Data for regions excluding the Sub-Saharan Africa region and the Europe and Central Asia region were aggregated into All Other Regions due to a small number of observations for these regions. Regression specification: RISE index, UNGA affinity IV with five years moving average.

Table A.10: Average effect of policies across income categories, by the second-stage lag

Income Category / Policy Lag	**3**	**5**	**7**
Low-income economies	0.55	0.19	0.24
Lower-middle-income economies	-2.67	1.14	8.09
Upper-middle-income economies	-0.98	-2.19	-0.70

Notes: Regression specification: RISE index, UNGA affinity IV with five years moving average.

Table A.11. Share of significant second-stage coefficients as a percentage of total eligible first-stage regressions by regions (top) and income levels (bottom); replacing shares of "Renewable energy consumption" and "Renewable electricity output" with shares of "Modern Energy Generation over Total Generation" and "Modern Energy Capacity over Total Installed Capacity" to exclude large hydropower

	Group	**Total eligible first-stage regressions**	**Share with significant second-stage coefficients**	**Share with positive and significant second-stage coefficients**
Region	SSA	227	18%	13%
	EAP	93	12%	0%
	ECA	40	53%	35%
	LAC	96	6%	6%
	MENA	49	24%	22%
	SAS	32	38%	31%
	Total	537	19%	13%
Income	High	36	0%	0
	Upper Middle	142	17%	11%
	Lower Middle	252	25%	16%
	Low	107	15%	14%
	Total	537	19%	13%

Notes: Regression specification: RISE index, UNGA affinity IV with five years moving average.

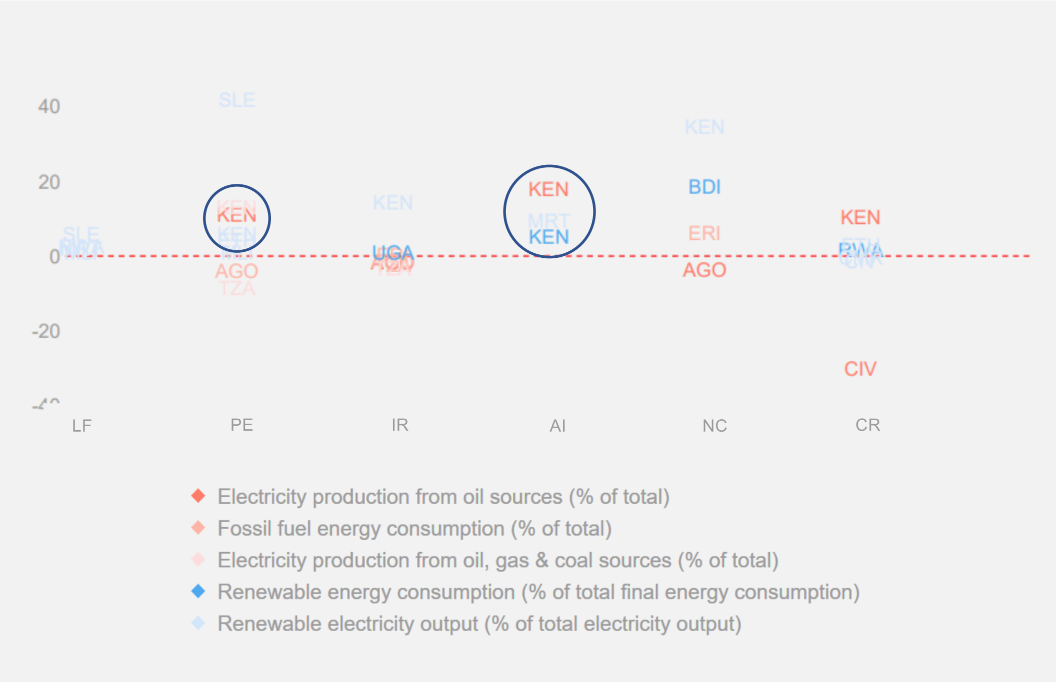


Figure A.7: Scatter plot of S2 coefficients for the SSA region, showing that outcomes for the same country tend to cluster together; replacing shares of "Renewable energy consumption" and "Renewable electricity output" with shares of "Modern Energy Generation over Total Generation" and "Modern Energy Capacity over Total Installed Capacity" to exclude large hydropower, lag of 5

Notes: LF=Legal framework; PE=Planning for expansion; IR=Incentives and regulatory support; AI=Attributes of financial and regulatory incentives; NC=Network connection and use; CR=Counterparty risk. To avoid an overpopulated graph, we show one region only. Regression specification: RISE index, UNGA affinity IV with five years moving average. X-axis: energy policy package. Y-axis: outcomes (colors). Clustered outcomes are shown in circles.

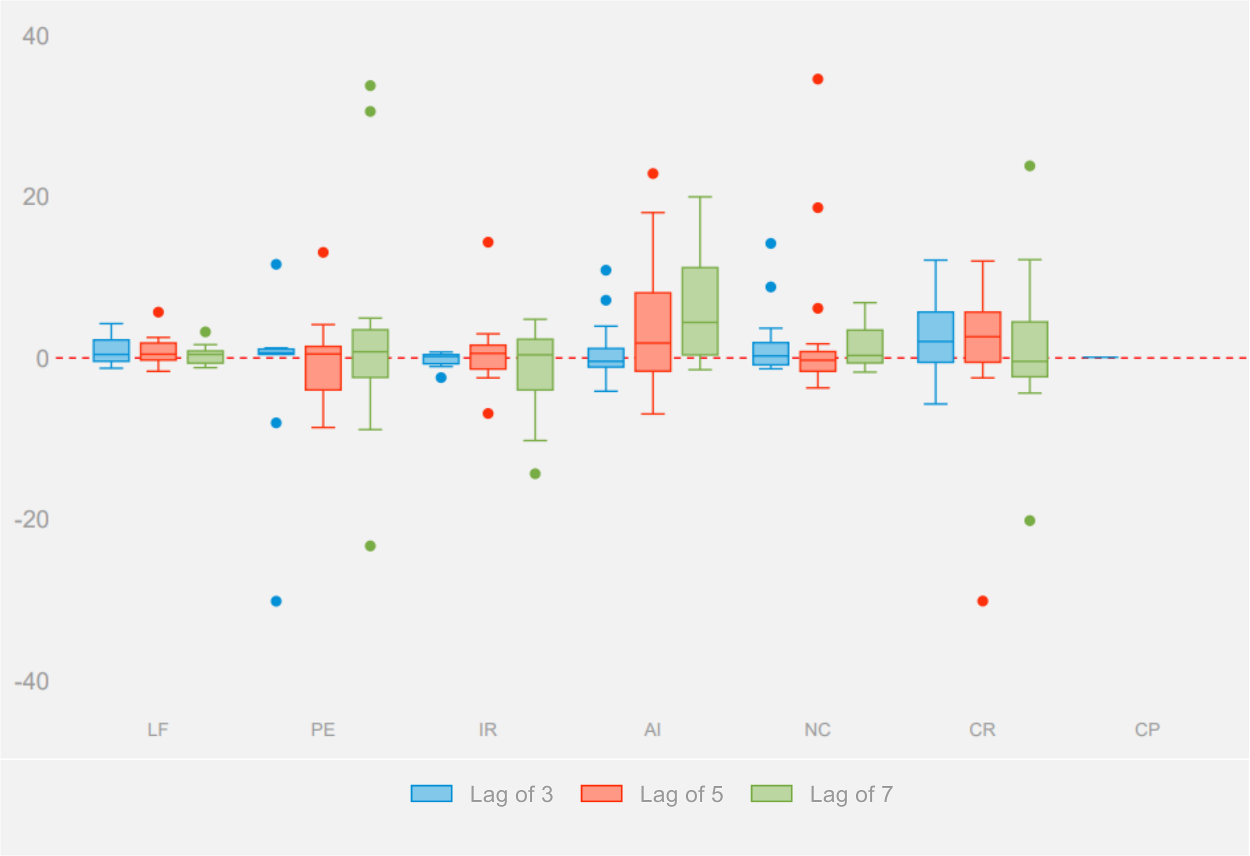


Figure A.8. Boxplot second-stage coefficients by energy policy packages, by the second stage lag; replacing shares of “Renewable energy consumption” and “Renewable electricity output” with shares of “Modern Energy Generation over Total Generation” and “Modern Energy Capacity over Total Installed Capacity” to exclude large hydropower

Notes: LF=Legal framework; PE=Planning for expansion; IR=Incentives and regulatory support; AI=Attributes of financial and regulatory incentives; NC=Network connection and use; CR=Counterparty risk. To avoid an overpopulated graph, we show one region only. Regression specification: RISE index, UNGA affinity IV with five years moving average. X-axis: energy policy package. Y-axis: outcomes (colors). Clustered outcomes are shown in circles. To correctly view the graph, the axes were cut at -40, leaving out one datapoint at -60 for PE lag of 5. In the boxplot, there is a box from the first quartile to the third quartile, with the 2nd quarter (50% percentile) marked by the internal line of the box. The whiskers extending from the boxes go from each quartile to the minimum or maximum, outliers included.

Table A.12. Average effect of energy policy packages, by the second-stage lag; replacing shares of "Renewable energy consumption" and "Renewable electricity output" with shares of "Modern Energy Generation over Total Generation" and "Modern Energy Capacity over Total Installed Capacity" to exclude large hydropower

Energy policy package	**3**	**5**	**7**
Legal Framework	0.86	0.93	0.43
Planning for expansion	-2.13	-1.49	2.88
Incentives and regulatory support	-0.18	0.84	-1.51
Attributes of financial and regulatory incentives	0.79	4.07	9.18
Network connection and use	1.70	2.19	1.35
Counterparty Risk	2.53	1.66	1.11
Carbon pricing and monitoring	0.09		

Notes: Regression specification: RISE index, UNGA affinity IV with five years moving average.

Table A.13. Average effect of all energy policy packages together on two absolute energy outcomes, by the second-stage lag

Energy outcome	**3**	**5**	**7**
Absolute modern renewable capacity	0.21	0.34	0.49
Absolute modern renewable generation	0.55	1.07	1.48

Notes: Regression specification: RISE index, UNGA affinity IV with five years moving average.

APPENDIX B: DENDROGRAM OF POLICY DATASET

Dendrograms are widely used to find homogeneous groups in observations, or in our case, policy instruments, that differ from each other. They can help the researcher to identify the structure of the data or to group variables based on their similarity. The results of the dendrogram lead us to group policies within the Headings that were provided to us by ESMAP.

To depict how the policies relate to one another, we first create a dissimilarity (1-similarity) matrix based on the Jaccard coefficient. In brief, the Jaccard coefficient (Eq. B.1) is the proportion of occurrences in which both variables (policies) take a value of one in the panel dataset, over the occurrence of all other combinations, except both variables taking a value of zero.

$\text{Jaccard coefficient}=a/(a+b+c)$Jaccard coefficient=a/(a+b+c) *Eq. B.1*

Table Appendix B.1. Variables in the Jaccard coefficient.

	Var1, 1	Var1, 0
Var2, 1	a	b
Var2, 0	c	d

Source: (Jaccard, 1908).

We then systematically merge similar policies into groups, creating an agglomerative hierarchical clustered visualization. In the resulting dendrogram, each policy is placed along the y-axis and is connected to other policies via a horizontal line that ends at their corresponding similarity value. The shorter the lines, the more similar the policies.

The shape of dendrograms changes according to the method of linking groups. The methods pertinent to binary data are single, complete, and average linkages. Each method has its limitations. The single linkage may produce “chaining”, in which several clusters are joined because one of their cases is within proximity of a case from a separate cluster. However, in complete linkage, outlying cases prevent close clusters from merging. We choose the third method, average linkages, as, in theory, it provides a compromise between single and complete linkage (Greenacre & Primicerio, 2013; Yim & Ramdeen, 2015).

In Figure B.1, the three vertical dashed red lines allow the reader to compare dissimilarities visually. In our case, the dendrogram helps further support the idea that policies within Headings are most similar to each other and not most similar to those in other Headings.

Overall, it supports our theoretical rationale to operationalize the independent variables using the structure that was pre-determined by the dataset we acquired.

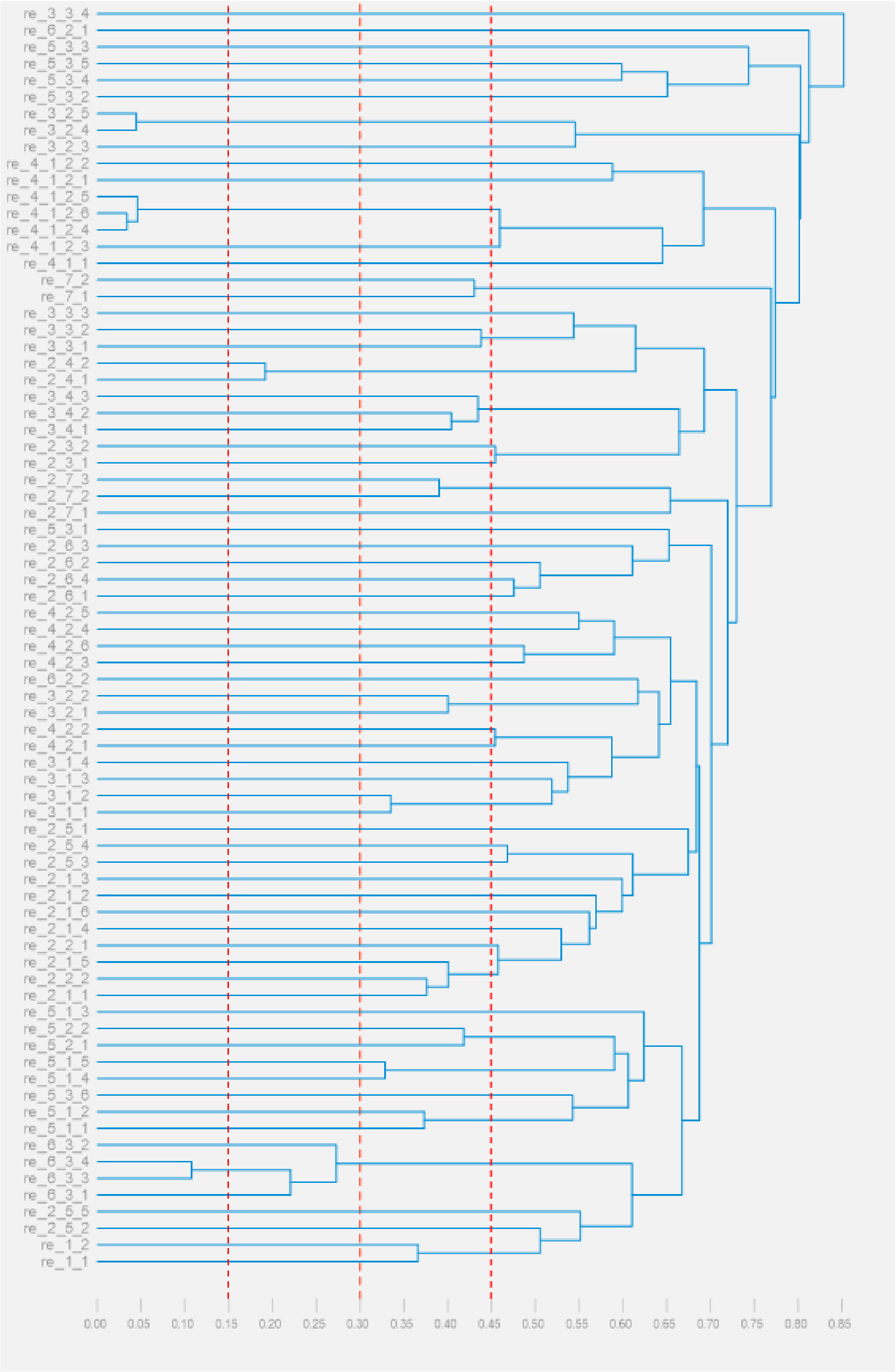


Figure B.1: Dendrogram cluster visualization of policies in the RISE dataset.

Source: RISE dataset and authors' elaboration based on methods described in this chapter.

APPENDIX C: CORRELATION ANALYSIS

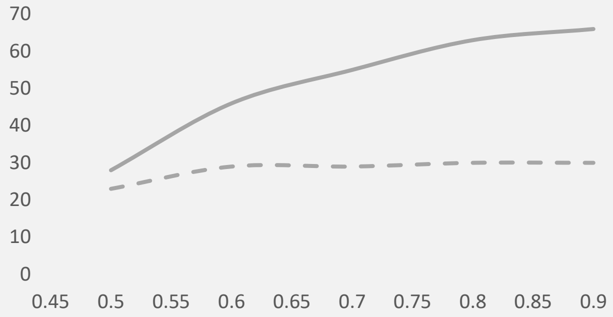
Our first option in correlation analysis is to apply a "survival" method, which keeps only uncorrelated variables. We start the exercise at the most disaggregated group level and then pit any 'surviving' variables against remaining variables at higher aggregation levels, first the more aggregate group, stopping then the heading level. We use the ϕ statistic, which is suitable for truly dichotomous variables. It is equivalent to Pearson's $\rho = \sqrt{\chi^2/N}$ and in a 2x2 contingency table, the output is equivalent to Cramer's V, Spearman's ρ, and Pearson's correlation (Warner, 2007).

In the "survival" method, we assume that keeping one of two highly correlated variables retains enough information to represent both. We also assume transitivity. In other words, we assume that pitting surviving sub-group variables against variables in higher levels of aggregation would give similar outcomes than doing the same analysis with the ones that were removed from the pool. This allows us to compare pairs and keep only one variable of the pair when the correlation is above a predetermined threshold.

An alternative is to use group averages. We first obtain ϕ statistics for all pairs within a heading and compute the average ϕ statistic for that heading if the p value<0.05. When the average ϕ statistic is higher than a predetermined cutoff, then we keep the average of the heading as a new variable that summarizes the heading and move on to the next heading. However, if it is not, we repeat the exercise by group and sub-group.

Additionally, we must choose the ϕ statistic cut-off point for what should be considered "high" enough correlations, but the parameter to use is not immediately evident. The trade-off here is between retaining information or producing a manageable number of independent variables, each needing separate regressions.

We run the analysis at several cut-off levels for both methods to discover whether there is an embedded tipping point in the data that minimizes cutting data and maximizes information (Figure C.1). Figure C.1 suggests the higher the cut-off, the more variables we keep, which is expected. However, there does not seem to be a unilaterally optimal cut-off point at the aggregate level. This would have occurred if each increasing the cut-off point did not significantly alter the aggregate number of variables retained by the analysis.



Cut-off	Survival method	Average method
0.5	28	23
0.6	46	29
0.7	55	29
0.8	63	30
0.9	66	30

Figure C.1: Number of variables/groups/headings remaining (y-axis), by cut-off point (x-axis), survival method (dashed), average method (solid)

Source: ESMAP RISE dataset and authors' elaboration based on dataset described in this paper.

The survival method retains fewer independent variables than the average method. While averaging retains more information than the survival method, it may obscure underlying disparities in the averaged variables. Specifically, using group averages fails to identify policies that are different from others in their group.

Both methods may mask and compound errors. At the p=0.05 level, five out of every 100 correlations fail to reject the null hypothesis. If these variables are carried into the subsequent rounds, then the possibility of rejecting the null hypothesis is carried with them.

The most glaring shortcoming to using only correlation methods is that the dimensionality is not considerably reduced. Using the minimal cut-off of 0.5, we are left with at least 23 variables. Therefore, the second step, summation, creates our final "Composite index" that is comparable to the default RISE and the Summation index described in the text.