

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 last four decades across more than 100 developing countries. It applies systematic regression analysis to five energy sector decarbonization outcomes and 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 decarbonizing developing countries' energy mix, and they more often achieve a negligible or opposite result than intended three years after implementation. Policies that address counterparty risk have the highest immediate effect. Effects of renewable policies on different decarbonization outcomes improve slightly five and seven years after their implementation.

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Highlights:

- First systematic assessment of renewable energy policies' impact in developing countries.
- Policies have minor effects that improve slightly 3-7 years after implementation.
- Policies that address counterparty risk have the highest immediate effect.
- Sustained and credible decarbonization policies are crucial but may not be sufficient.

Keywords: developing countries, energy mix, renewable energy policies, RISE indicators, power sector reform

Word count: 7837

Nomenclature/abbreviations:

2SLS	Two-squared least squares
AI	Attributes of financial and regulatory incentives
BACI	Database for International Trade Analysis
CP	Carbon pricing and monitoring
CPI	Climate Policy Initiative
CR	Counterparty risk
EAP	East Asia & the Pacific
ECA	Europe & Central Asia
EFF	Electricity production from fossil fuel (oil, gas & coal) sources
EOS	Electricity production from oil sources
ESMAP	Energy Sector Management Assistance Program
EU	European Union
FCC	Fossil fuel energy (oil, gas & coal) consumption
IR	Incentives and regulatory support
IRENA	International Renewable Energy Agency
IV	Instrumental Variable
LAC	Latin America & Caribbean
LF	Legal framework
MENA	Middle East and North Africa
NC	Network connection and use
OECD	Organisation of Economic Co-operation and Development
PE	Planning for expansion
REC	Renewable energy consumption
REO	Renewable electricity output
RISE	Regulatory Indicators for Sustainable Energy
SAS	South Asia
SSA	Sub-Saharan Africa
UNGA	United Nations General Assembly
WDI	World Development Indicators

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.

This study offers 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 over a hundred developing countries and four decades. In doing so, this 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 [1].

This work considers five inter-related decarbonization outcome indicators of the energy and electricity mix, all in relative terms as a share of the total. The policy variables are grouped into seven energy policy packages leveraging the World Bank Regulatory Indicators for Sustainable Energy (RISE) data⁴, which includes over 75 policy instruments related to renewable energy, power, and fuel use implemented over the last four decades. The seven energy policy packages include Legal framework (LF); Planning for expansion (PE); Incentives and regulatory support (IR); Attributes of financial and regulatory incentives (AI);

⁴ For a detailed description of the database please refer to its official website: <https://rise.esmap.org/>.

Network connection and use (NC); Counterparty risk (CR); and, Carbon pricing and monitoring (CP).

This research is closely related to two large empirical literature streams. First, it belongs within the broad social science literature that analyzes the effect of individual renewable energy policies and their outcomes.

Peñasco, Anadón, and Verdolini [1] 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. The 211 studies on developed countries suggest that energy policy instruments' effects vary. 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 [2–5]. Another relevant finding is that the existing literature is heavily biased toward the country members of the Organisation for Economic Co-operation and Development (OECD). Instead, this study looks only at non-OECD countries and covers more than 100 developing countries.

Second, this study also engages with and contributes to a large body of economics literature on the reform of energy sector governance (see [6-8] for three excellent surveys of this literature) that began in the 1980s. The research presented in this work is particularly related to a sub-stream of the literature that subjects the supposed benefits of energy (typically, electric power) 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 literature [9–12], like this study, attempts to address endogeneity issues using the instrumental variables (IVs) approach. However, none of the studies using IV approaches have examined climate-related outcomes of power sector reform.

Mallawaarachchi, Nepal, and Ross [13] discuss why it is relevant to study the environmental

outcomes of power sector reforms championed over the previous decades. Importantly, studying the climate-related outcomes of power sector reforms can help coordinate policy agendas with differing economic and environmental objectives.

The most closely related study is Doumbia [14], 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 this study, Doumbia [14] 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 [15]. These include endogeneity resulting from omitted variables related to the country and regional characteristics or due to simultaneity and reverse causality of policy enactment and outcomes, lack of accounting for the depth of reform, and collinearity of policies. This study seeks to engage with each of these challenges systematically. The analysis includes time and country fixed effects to account for the country and temporal omitted variables and estimate instrumental variable (IV) regressions across six regional panels.

The 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, according to international organizations.

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

The research in this study also addresses the difficulties of coding variables to consistently reflect the depth of reform and issues related to the collinearity of many renewable energy policies. Finally, this study provides develops and assesses 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 resulting combinations of indices and models create 18 "base" regression specifications. This study estimates 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 [17], this study applies two-stage least squares (2SLS) country interactions, rendering tens of thousands of first-stage coefficients. When restricting the sample to the IV regressions that plausibly meet the relevance criterion and are theoretically consistent, 540 first-stage regressions constitute the basis for the analysis.

The main results of the 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.

In addition, this analysis considers that the results may differ when considering the impact on modern (non-hydro) renewables instead of all renewables. These and other robustness checks lead largely to the same results.

A host of interrelated factors connected to the difficulty in securing finance could drive the limited impact of these policies in the country sample [20,21]. This explanation regarding difficulties securing finance is in line with additional results of the research presented in this study, which indicate that addressing counterparty risk is associated with increases in renewable deployment in developing countries' energy mix three years after implementation.

The finding on 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.

This study interprets and discusses these results in the context of the Sailing Ship Effect [18,19], wherein incumbent fossil fuel technologies dampen the short-term effects of renewable energy policies. 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. The developed world should at least fulfill its climate finance commitments under the Paris Agreement. Overall, the research presented in this study 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. The analysis 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 [2].

2 METHODS

This study examines 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 (1). As energy sector policies take time to implement, this study assumes that policy implementation does not immediately affect the outcome variable and considers three-year, five-year, and seven-year lags, as is common in policy evaluation literature [22,23]. Each regression equation can be summarized as follows:

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

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 two-way 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 this problem, this study explicitly controls 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. The research in this study attempts to correct endogeneity bias using the instrumental variables (IV) approach. Alternative methods, such as regression

discontinuity design, difference in differences, or causal machine learning, are not appropriate to cross country data with no clearly-defined discontinuities, an absence of parallel trends, and a lack of observations needed for machine learning identification.

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 this 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, discussed in section 3.3.

Following the literature [17,24], the analysis estimates model (1) in the following two stages:

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

$$y_{c,t} = \theta_c + \sum_{c=1}^n \vartheta_c \widehat{x}_{c,t-l} D_c + \sum_{c=1}^n \rho \widehat{x}_{c,t-l} + \mu_t + v_{c,t}, \quad (3)$$

where D is a country dummy variable, \hat{x} is the instrumented policy variable, α , θ , γ , 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 . This study restricts the analysis to the sub-set of the second-stage estimates 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, the analysis keeps the first-stage estimates that are statistically significant and have theoretically consistent signs. Sections 4 and 5 discuss the strength of the IVs.

3 CALCULATION

3.1 DEPENDENT VARIABLES

The research in this study uses the World Bank World Development Indicators (WDI) as a data source for the 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, this study considers five relevant and related dependent variables connected to energy and electricity production and consumption (Table 1). As per their title in the WDI, the variables are: (1) “renewable energy consumption”; (2) “renewable electricity output”; (3) “fossil fuel energy consumption”; (4) “oil, gas, and coal [fossil fuel] energy electricity production”; and, (5) “oil electricity production”. As discussed in the Introduction, there is a broad literature on the effects of renewable energy policies mostly in developed countries; results are mixed but tend towards positive effects on renewable energy deployment. The RISE database claims to document the implementation of policies that support renewable energy. Based on these premises, renewable energy policy packages should negatively affect the first three energy mix measures in Table 1. In contrast, renewable energy policy packages should positively affect the remaining two energy mix measures in Table 1.

To standardize the estimation results across different specifications, the analysis multiplies 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 in hydro-dominated regions (Latin America). These patterns reinforce estimating the results separately across regions.

Table 1: Dependent Variables

Variable name in WDI	Acronym and WDI variable code	Unit	Expected impact of renewable energy policies
Fossil fuel energy (oil, gas & coal) consumption	FCC, EG.USE.COMM.FO.ZS	Percent of total	Negative
Electricity production from oil, gas & coal [fossil fuel] sources	EFF, EG.ELC.FOSLZS	Percent of total electricity output	Negative
Electricity production from oil sources	EOS, EG.ELC.PETR.ZS	Percent of total electricity output	Negative
Renewable energy consumption	REC, EG.FEC.RNEW.ZS	Percent of total	Positive
Renewable electricity output	REO, EG.ELC.RNEW.ZS	Percent of total electricity output	Positive

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

3.2 INDEPENDENT VARIABLES

The Energy Sector Management Assistance Program (ESMAP) at the World Bank has published the Regulatory Indicators for Sustainable Energy (RISE) renewable energy "traffic light" indicators that since 2010. The independent explanatory variables of this study are based on the disaggregated policy instrument data behind the 2018 version of RISE. The Energy Sector Management Assistance Program (ESMAP) at the World Bank has published Regulatory Indicators for Sustainable Energy (RISE) renewable energy "traffic light" indicators since 2010. The independent explanatory variables of this study are based on the disaggregated policy instrument data behind the 2018 version of RISE. In country and time

coverage and topical depth, the underlying dataset behind RISE's "traffic light" indicators" is comparable to the joint IEA/IRENA Renewable Energy Policies and Measures Database. Nevertheless, ESMAP's RISE database is more suited for an econometric approach because it is can be reorganized into a panel dataset with binary variables that represent the implementation of specific types of policies.

Concretely, the independent variables in this study are indexes that represent seven energy policy packages. Each energy policy package comprises the disaggregated policy instruments tallied in the RISE data. This section describes the primary RISE dataset and the three alternative methods to reduce the dataset's dimensionality and create the independent variable indexes. In the primary RISE dataset, each policy is coded in two variables: one indicating whether the policy exists through a yes/no answer and the second specifying the year of the first instance of the policy, if applicable.⁵ Restructuring the dataset combines the two variables for each policy instrument into one. The value of each variable changes from 0 to 1 when the first policy was put into place, creating the panel dataset needed for the rest of the analysis.

The research in this study addresses at least two further challenges with the structure of the primary dataset for creating the independent variables. First, there are 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 the solution to address each type of discrepancy.

Second, the dataset has occasional continuous variables and variables that cannot be transformed into panel data. These occasional continuous variables disrupt the efforts to

⁵ For instance, "Does a legal framework for renewable energy development exist?" and the year for the first legal framework.

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 1980-2018, as most policies were not implemented before then (see Appendix Table A.4).

Reducing dimensionality

The analysis must reduce the highly dimensional policy instrument data appropriately for regression 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 has clusters (or groups) of policies. The dendrogram in Appendix B shows that policy instruments within the same heading tend to be implemented together. The methods, therefore, use these headings, or energy policy packages, as the 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.esmap.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. The analysis in this study uses 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 aggregate traffic light indicators prevalent 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 equally within groups is part of the motivation to seek alternative methods and to create other indices that serve as independent variables.

An alternative approach is to create an index that sums up the enacted policies at each time. Such a "summation" index has been tried before [9] 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. The analysis uses the summation index as the second option.

A third, the "composite" index, 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. Appendix C describes the details of constructing the composite index. Appendix Table A.5 compares the weights between indexes.

Each independent variable represents an aggregate of renewable energy policies or energy policy packages. To construct the representation of renewable energy policy packages

useful for regression analysis, this study employs three weighting methods: the RISE, the summation, and the composite 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 disregards policy groups provided by RISE and makes use of how policies are related to one another in implementation through a 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 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.

Due to the panel format of the data, each country has three versions of each of the seven independent variables over several decades. There are too many data points across time to illustrate usefully. 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, this work explores the international political economy aspects highlighted in the energy sector governance reform literature, which spans several decades and regions.

This study posits that countries are more likely to implement regulatory energy policies when they display a relatively higher 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, Zelner, and Guillén [25], for example, argue that "international pressures of coercion and emulation strongly influence the domestic adoption of market-oriented reforms."⁶

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 [26], including power sector reform [27]. For example, Imam, Jamasb, and Llorca [28] 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, this work argues that developing countries' governments whose political ideology is closer to major Western donors are more likely to implement renewable energy reforms.

This study considers 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. It pinpoints three measurable ways this rapport may be measured and evidenced over time in the data. Table 3 summarizes the chosen IVs, described and supported in the following sub-sections. Appendix Figures A.4 and A.5 illustrate the temporal path of the three IVs aggregated over regions from 1980 to 2018.

⁶ 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."

Table 3: Summary of Instrumental Variables

Closeness to donors	IV	Supported in
Foreign policy	UN General Assembly (UNGA) voting	Bailey et al. (2017)
Trade	Relative trade value aggregates	Henisz et al. (2005)
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.

The methods consider that it may take time to implement policies following an increase in closeness measured through the IV. Therefore, this analysis uses 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 the analysis also considers the moving average over three years of the IVs.

Foreign Policy Closeness IV

To represent changes in foreign policy preferences, this analysis uses a dyadic dataset behind the Affinity of Nations index by Bailey et al. [16]. 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 participating 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. Instead, 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 the sample changed compared to the five donors over time, the analysis sums the yearly Ideal Point Distance between each country and the donors. Since the goal is a “closeness” rather than a “distance” indicator (i.e., the IV should be positively associated with relative closeness to the donors), the analysis multiplies the summed Ideal Point Distance by the negative one.

International Trade Closeness IV

Henisz, Zelner, and Guillén [25] 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."⁷

To capture changes in closeness through trade, the analysis computes 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) [29]. The analysis also generates a panel dataset on the existence of Trade Agreements with the European Union. The data source is the EU Commission's "current state of play" agreements in place (see Appendix Table A.6). This variable is binary and takes a value of 1 since the trade agreement came into force. If there is no trade agreement, the variable is 0 for the entirety of the time series.

⁷ 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."

4 RESULTS

The methods yield 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 the methods lead to estimating 3,780 regressions, excluding the additional country interactions. As a result, the analysis renders thousands of coefficients that constitute the base for the analysis (Table 4).

Table 4: Estimated empirical specifications

Specification	Options
IV type	<ol style="list-style-type: none"> 1. Affinity through United Nations General Assembly (UNGA) voting 2. Affinity through bilateral trade 3. Affinity through EU trade agreements
IV moving average	<ol style="list-style-type: none"> 1. Five years moving average 2. Three years moving average
Indices	<ol style="list-style-type: none"> 1. RISE 2. Composite 3. Summation
Regions	<ol style="list-style-type: none"> 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	<ol style="list-style-type: none"> 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) 5. Renewable electricity output, % of total electricity output (REO)

Specification	Options
Renewable Energy Policies	<ol style="list-style-type: none"> 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, the methods 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 [24].

Additionally, the methods 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). As a result of 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, the analysis leads to additional robustness tests to confirm 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" [30] p.118.

Due to the uniqueness of the empirical approach, it is possible to conduct a formal test for differences in the second-stage estimates resulting from different instrumental variables. The analysis involves regressing 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. The results yield statistically significant differences only 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 increase the confidence that the second stage estimates reflect the causal outcome of renewable energy policy reforms.

Table 5: Specification regression test for instrumental variable exogeneity

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

Notes: *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$. FCC: Fossil fuel energy consumption. EFF: Electricity production from fossil fuels. EOS: Electricity production from oil sources. REC: Renewable energy consumption. REO: Renewable electricity output.

Kruskal-Wallis H test helps 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. This test is impervious to the normality assumption, which will likely 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 the IVs (Table 6, third column).

Table 6: Summary results of Kruskal-Wallis H tests

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

Notes: 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, the analysis continues 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. The

size of the subsample of results available to review shows that limiting this study to a more recent time frame during which climate concerns gained importance in energy policy decisions would have severely restricted the analysis.

A mere 4.8 percent (or 26 coefficients) of the estimated second-stage regressions are positive and statistically significant. In other words, 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 Europe and Central Asia and Sub-Saharan Africa, 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, renewable energy policies' significance and effectiveness 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: Share of significant second-stage coefficients as a percentage of total eligible first-stage regressions by regions (top) and income levels (bottom), 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%

	Group	Total eligible first-stage regressions*	Share with significant second-stage coefficients**	Share with positive and significant second-stage coefficients**
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 average. 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. *F-stat > 10, P-value < 0.05 and positive coefficients. ** P-values < 0.1.*

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 the 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, this study considers the possibility that the effect of each energy policy package changes with time and analyzes the effect of policies over 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, the analysis keeps only one outcome coefficient at random by energy policy package and country in subsequent analysis. As there is no theoretical reason to prefer any outcome variable over another, and because this results section has shown that results tend to cluster across outcomes, it is possible to simply pick 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, it is useful to take a moment to consider that of the 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 considers the possibility that lumping gas in with other fossil fuels could theoretically be driving the pessimistic results regarding the impact of energy policy packages on the decarbonization of the energy mix. As 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 the 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).

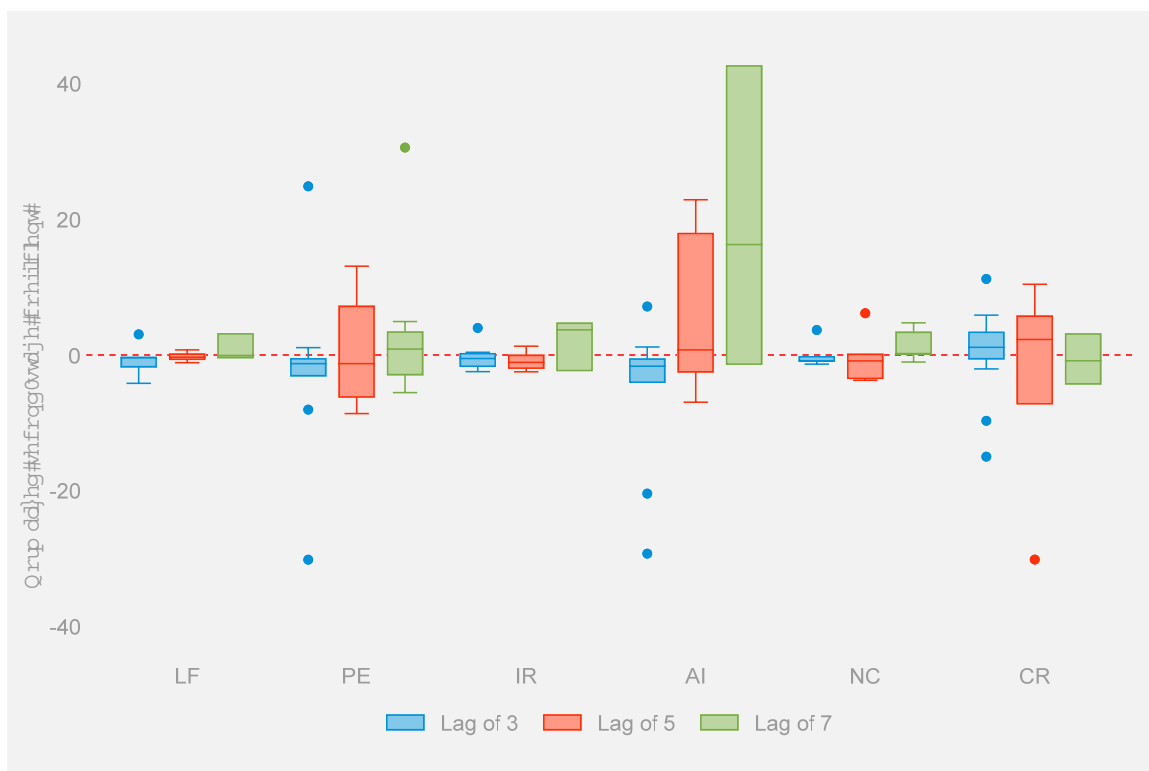


Figure 1: Boxplot of normalized second-stage coefficients by an energy policy package

Notes: Y-axis= normalized percentage change of renewable energy penetration due to the enactment of renewable energy policy. Colors= lags in years. 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. Boxplots represent the first quartile, median, third quartile, and minimum and maximums; outliers are represented by dots. Includes S2 coefficients with P-values < 0.1.

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

Energy policy package	Lags in years		
	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 average. Includes S2 coefficients with P-values < 0.1.

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 other means. One interpretation is that mitigating counterparty risk could have comparatively immediate effects. Another interpretation of the result is that addressing counterparty risk positively influences outcomes while supporting other energy policy packages that take more time to achieve 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, the analysis challenges the results in three ways and arrives at similar conclusions.

5 DISCUSSION

5.1 ROBUSTNESS CHECKS

Limiting the country sample

An 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 the 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, it is necessary to challenge the results by narrowing the comparison 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 the analysis 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 without 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

The analysis acknowledges that the introduction of large hydropower instead of modern renewables may obscure the effects of the energy policy packages. Therefore, for robustness, the analysis re-estimates 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.

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 the dependent

variables removes large hydropower. The text refers 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.13 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, 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. However, 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 goes down over time.

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

Considering absolute instead of relative changes in modern renewables

The analysis considers 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.

The analysis, therefore, re-estimates 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.

The number of coefficients for these two outcome variables individually is too low to visualize by the energy policy package. The analysis, therefore, aggregates the results into boxplots that represent the three time lags. The immediate effects of policies are small and close to zero; temporal results also echo the results of previous analyses (Appendix Tables A.11 and A.12, Figures A.7 and A.8).

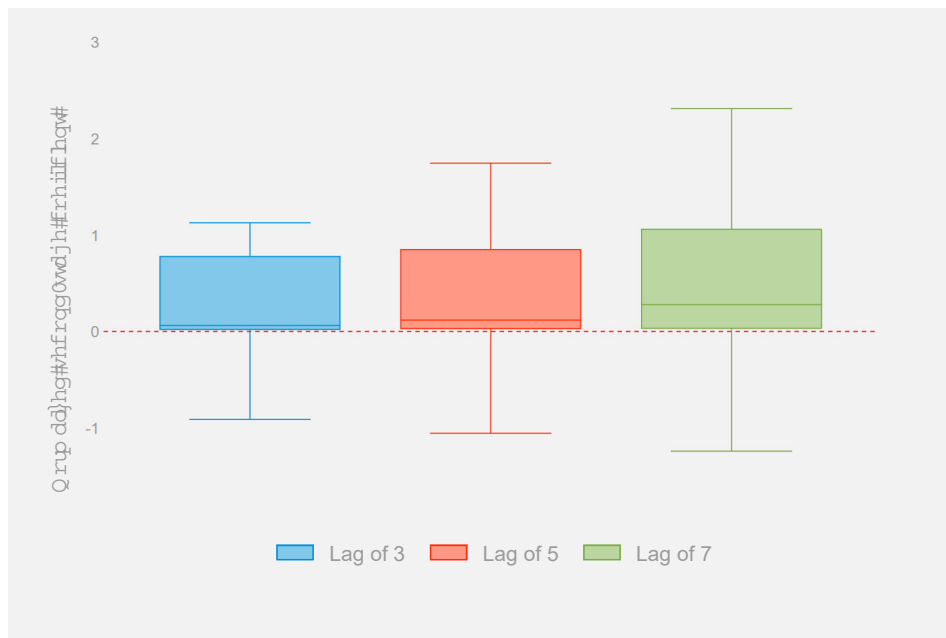


Figure 2: Boxplot of normalized second-stage coefficients for only the absolute modern renewable capacity outcome

Notes: Y-axis= normalized percentage change of renewable energy penetration due to the enactment of renewable energy policy. Colors= lags in years. Regression specification: RISE index, UNGA affinity IV with five years moving average. Boxplots represent the first quartile, median, third quartile, and minimum and maximums (excludes outliers). Includes S2 coefficients with P-values < 0.1.

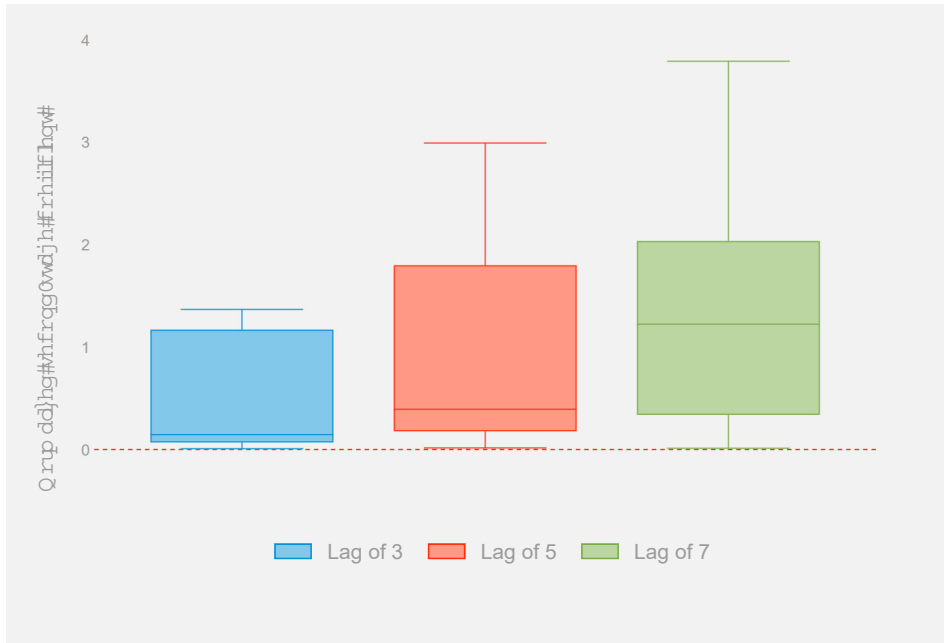


Figure 3: Boxplot of normalized second-stage coefficients for only the absolute modern renewable generation outcome

Notes: Y-axis= normalized percentage change of renewable energy penetration due to the enactment of renewable energy policy. Colors= lags in years. Regression specification: RISE index, UNGA affinity IV with five years moving average. Boxplots represent the first quartile, median, third quartile, and minimum and maximums (excludes outliers). Includes S2 coefficients with P-values < 0.1.

5.2 POLICY IMPLICATIONS

Achieving climate goals worldwide requires a sound understanding of how effective different decarbonization policies are, including in developing countries that are relatively understudied.

The research in this study addresses the following questions: How do the effects of seven major energy policy packages on the deployment of clean energy technologies compare in developing countries? Additionally, how do such effects change from the short to medium term after implementation by policy category?

Peñasco, Anadón, and Verdolini [1]’s relevant systematic review of policies in developed countries finds mixed results and can help guide expectations on the country

sample of this study. The systematic 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 the energy policy packages in this study, do not affect renewable deployment. Results of studies on GHG trading schemes, which lie within the energy policy packages on carbon pricing and monitoring, are also mixed. Fifty-three percent report no impact, and eight 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 the 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 the energy policy package on attributes of financial and regulatory incentives in this study). 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 design elements are crucial to success.

Consistent with the literature on the energy sector reform in developing countries [6–8], this study's main results and robustness checks point to very low effectiveness across energy policy packages to achieve the decarbonization of the energy mix.

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

A host of interrelated issues in developing countries could drive the results. The institutional capacity in this study's countries is weaker than those covered by the policy evaluation literature [8], where the impact on energy mixes and renewable energy technology deployment seems 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 connected to macroeconomic conditions and a lack of infrastructure [20,21], although finance plays a crucial role in decarbonization [31–34].

The importance of securing finance is in line with the 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 the review by Peñasco, Anadón, and Verdolini [1], “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. The Sailing Ship Effect [18,19], 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 efforts to identify the causal relationship between energy policy packages and decarbonization, the analysis is limited by the extent to which the methods, through IVs and controls, can address other patterns shaping the energy sector in the country sample. These include, for example, changes in enforcement capabilities over

time, which static country fixed effects cannot control. Further focus on enforcement capabilities could be an excellent project for the future research; nevertheless, it would also require metrics beyond RISE, with careful external validation of each indicator. Good rule of law or good governance indicators may not necessarily mean effective enforcement of energy regulations as those could be litigated or later watered down by lobbyists.

While this study establishes the limited effectiveness of the renewable energy policies in achieving decarbonization in the country sample, the validity of the exclusion restriction of the IVs could be a potential source of error affecting the results. 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, alternative instruments and data that covered the breadth of geography, power sector policy, and outcomes that the research questions entailed are not readily available. Further research may be able to consider other instruments or methods, especially if the analysis is narrower in scope.

Last, this Discussion has considered that the interrelation between energy policy packages could help improve our understanding of the dynamics between policies and explain the finding of more positive effects over time. The evolving interdisciplinary analytical framework of policy mixes spearheaded by Rogge and Reichardt [35] is a descriptive conceptual framework about the policy-making process and is appropriate for social science research questions in multiple fields. The limited relevant empirical work in energy includes Schmidt and Sewerin [36], who analyze policy mixes in nine developed countries, although that study does not consider policy interactions.

6 CONCLUSION

Achieving decarbonization worldwide requires a robust understanding of how effective different renewable energy and climate policies are in various 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.

The research presented in this study relies on the background data behind the RISE indicators published by the ESMAP at the World Bank. The methods 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. The analysis estimates 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.

The discussion of the results credibly evaluates the robustness of indicators' measurement, the quality of instrumental variables used, and the significance and direction of estimated energy policy package coefficients. Notably, this study finds no major measurement differences when aggregating policy instruments in different ways, showing that the World Bank aggregation method is robust to potential under- and overweighting problems. The research in this study also finds 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 the identification approach.

The findings of this research on 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 the 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 policy implications. 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 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. The results also point to a possible role for additional South-South interactions to build on experiences related to policy design, enforcement, and monitoring.

Some findings lend a basis for optimism. The effectiveness of renewable energy policies improves over time and could be 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.

The results of this study 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, and more. There are several venues for future research, however. New research can embark on further improving the causal mechanism explaining the results and the relation between policies. Studies that utilize more granular data at the

industry level could 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 & FIGURE

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

Source: ESMAP RISE dataset.

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



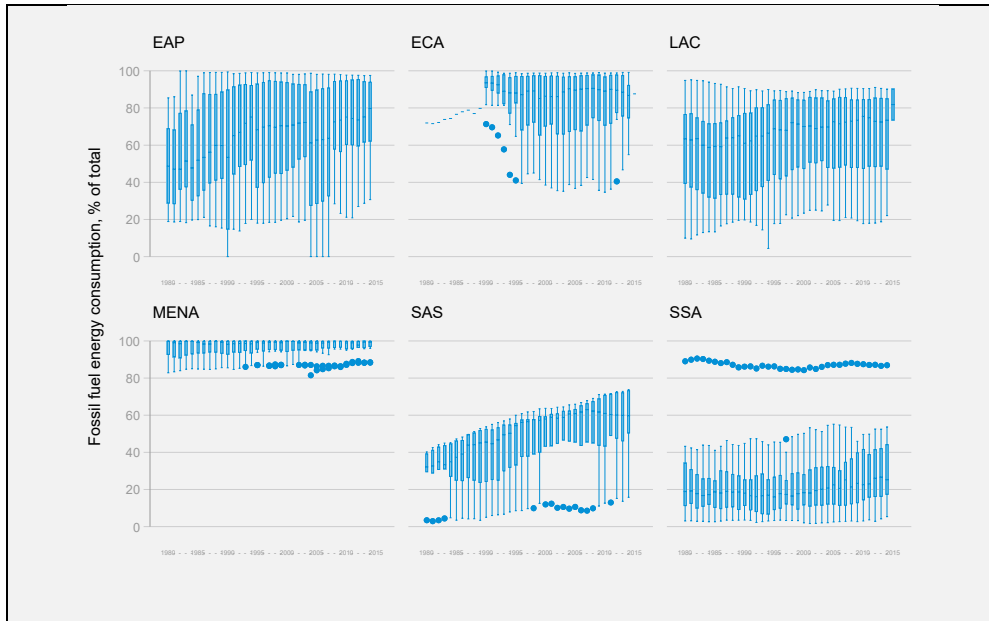


Figure A.1: Dependent variables negatively affected by renewable energy policies
(distribution by regions)

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.
The exact year is unimportant; the trend and differences between the regions is key.



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.
The exact year is unimportant; the trend and differences between the regions is key.

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 the analysis assumes 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"	Cannot use a year if it is not available.
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. Without a year, the analysis cannot count them in a panel, however.
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. Without a year, the analysis cannot count them in a panel, however.
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), but the dataset gets 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 the analysis assumes 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. Since the analysis treats missing dummy columns as "NA", it favors 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	Study 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	Study 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	Study 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 renewable energy policy dataset

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, by region, for 2015

Source: Y-axis= index. ESMAP RISE dataset and authors' elaboration based on the methods described in this paper.

Table A.5: The weights of RISE index versus composite index that were used to create the explanatory variables in the "type" column

Type	Study ID	Composite index weight	RISE index weight	Type	Study 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	Study ID	Composite index weight	RISE index weight	Type	Study 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.

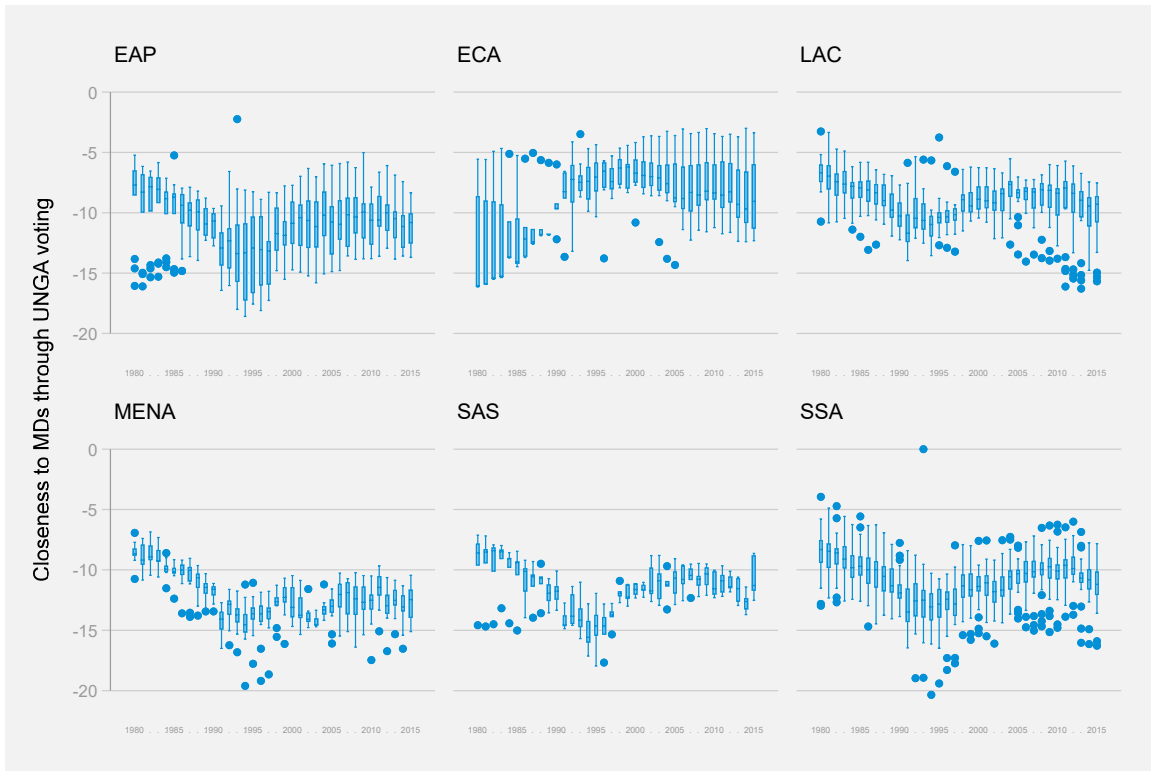


Figure A.4: Closeness to major donors through UNGA voting (distribution by regions)

Source: Author's elaboration based on Bailey et al. (2017). The exact year is unimportant; the trend and differences between the regions is key.

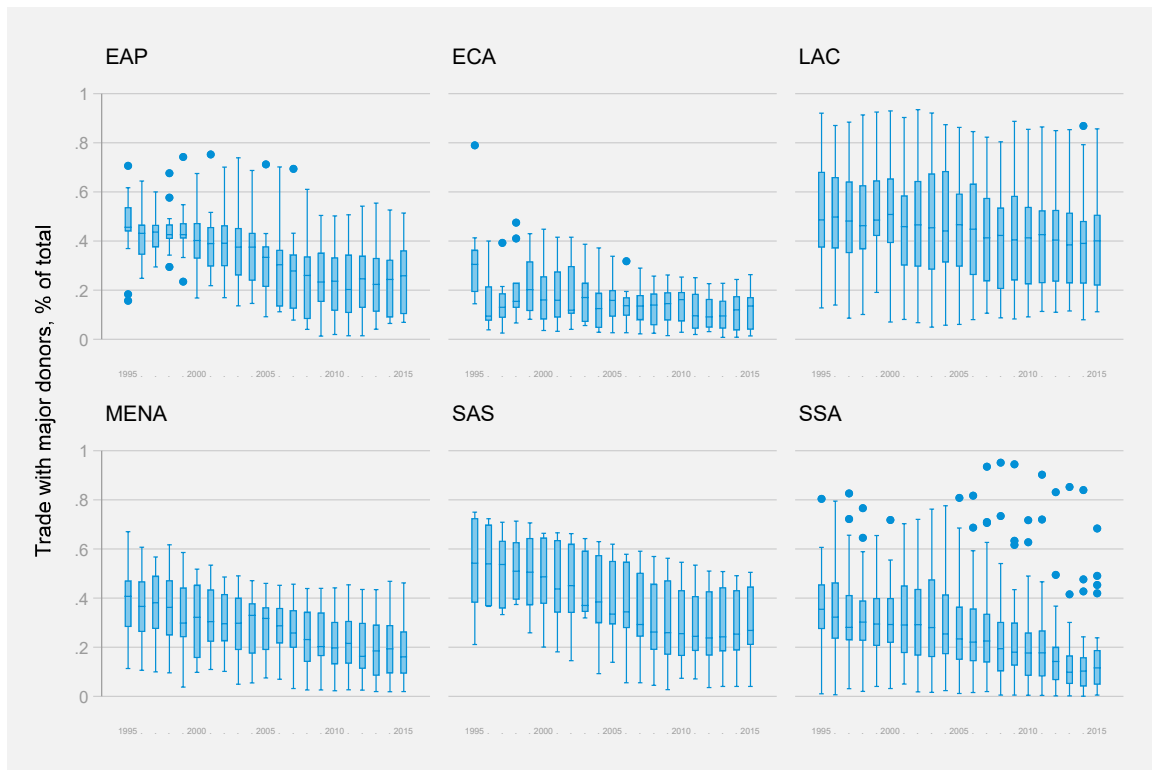


Figure A.5: Closeness with major donors through trade, 1995-2015, % of total (distribution by regions)

Source: UN Comtrade via the CEPII BACI dataset. Years are from 1995-2015. The exact year is unimportant; the trend and differences between the regions is key.

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	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	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
Turkey	1995	1
Ukraine	2016	1
South Africa	2016	1
Zimbabwe	2012	1

Source: EU Commission.

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 the analysis had 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

Notes: Regression specification: RISE index, UNGA affinity IV with five years moving average. Includes S2 coefficients with P-values < 0.1.

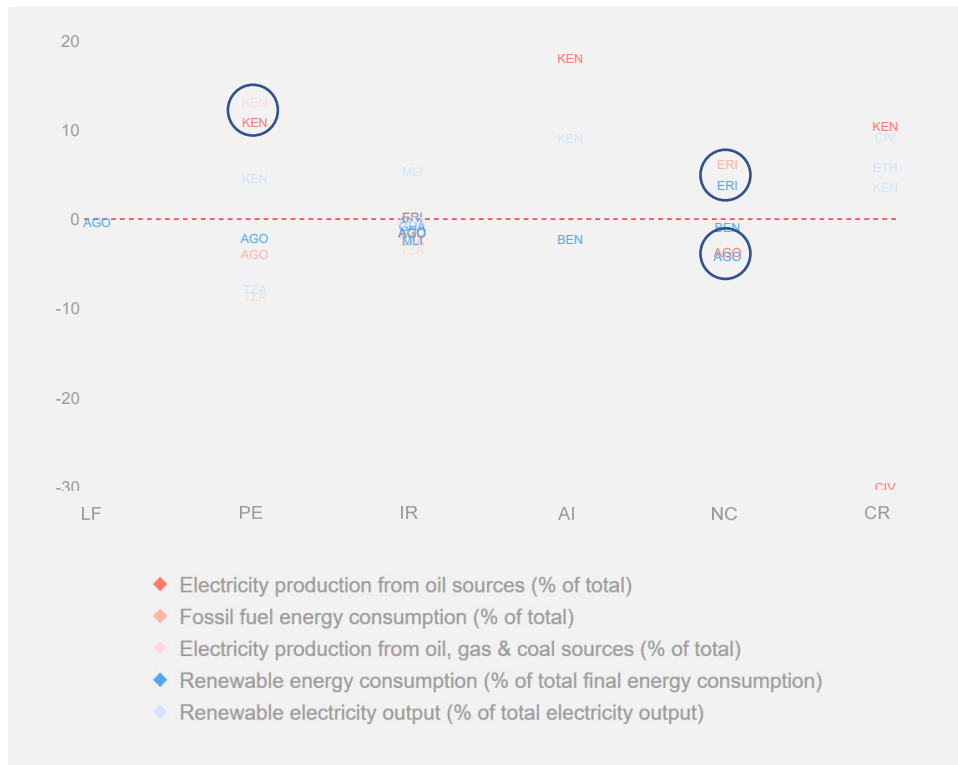


Figure A.6: Scatter plot of S2 coefficients for the SSA region showing that outcomes for the same country tend to cluster together, lag of 5

Notes: Y-axis= normalized percentage change of renewable energy outcome due to the enactment of renewable energy policy. Colors= outcomes. X-axis= Energy policy package. 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, this graph shows one region only. Regression specification: RISE index, UNGA affinity IV with five years moving average. Clustered outcomes are shown in circles. Includes S2 coefficients with P-values < 0.1.

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 refers to normalized percentage change in renewable energy penetration because of the enactment of renewable energy policy. 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. Includes S2 coefficients with P-values < 0.1.

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: Data refers to normalized percentage change in renewable energy penetration because of the enactment of renewable energy policy. Includes S2 coefficients with P-values < 0.1.

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: *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$. FFC: Fossil fuel energy consumption. EFF: Electricity production from fossil fuels. EOS: Electricity production from oil sources. REC: Renewable energy consumption. REO: Renewable electricity output.

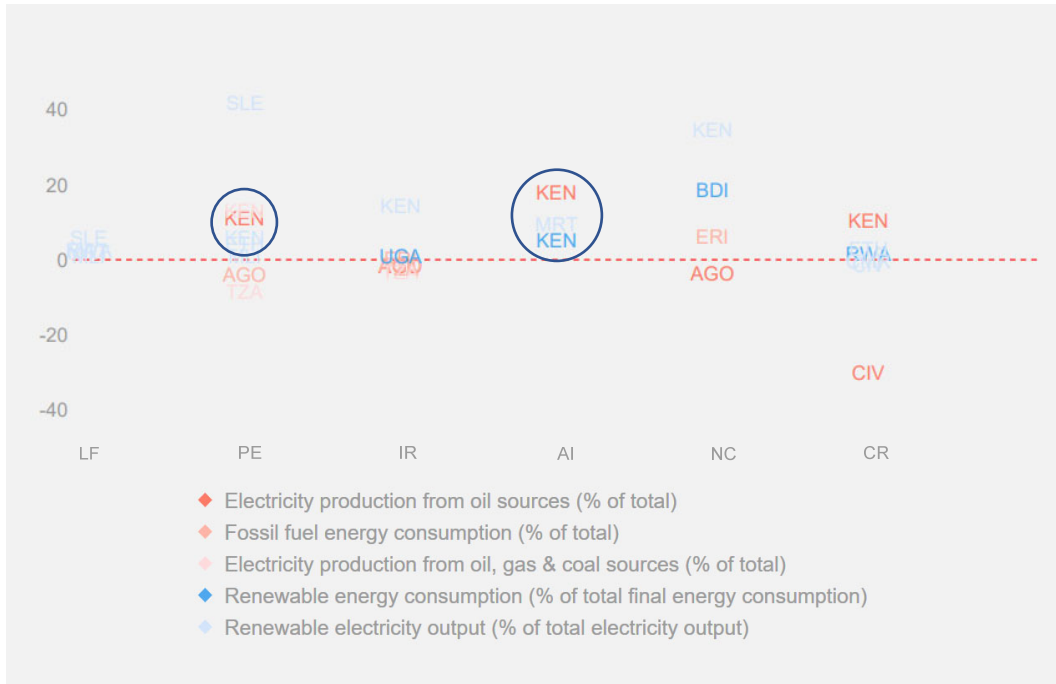


Figure A.7: Scatter plot of S2 coefficients for the SSA region, showing that outcomes for the same country tend to cluster together, replacing shares of “Renewable energy consumption” and “Renewable electricity output” with shares of “Modern Energy Generation over Total Generation” and “Modern Energy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

Notes: Y-axis= normalized percentage change of renewable energy outcome due to the enactment of renewable energy policy. Colors= outcomes. X-axis= Energy policy package. 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, this graph shows one region only. Regression specification: RISE index, UNGA affinity IV with five years moving average. Clustered outcomes are shown in circles. Includes S2 coefficients with P-values < 0.1.

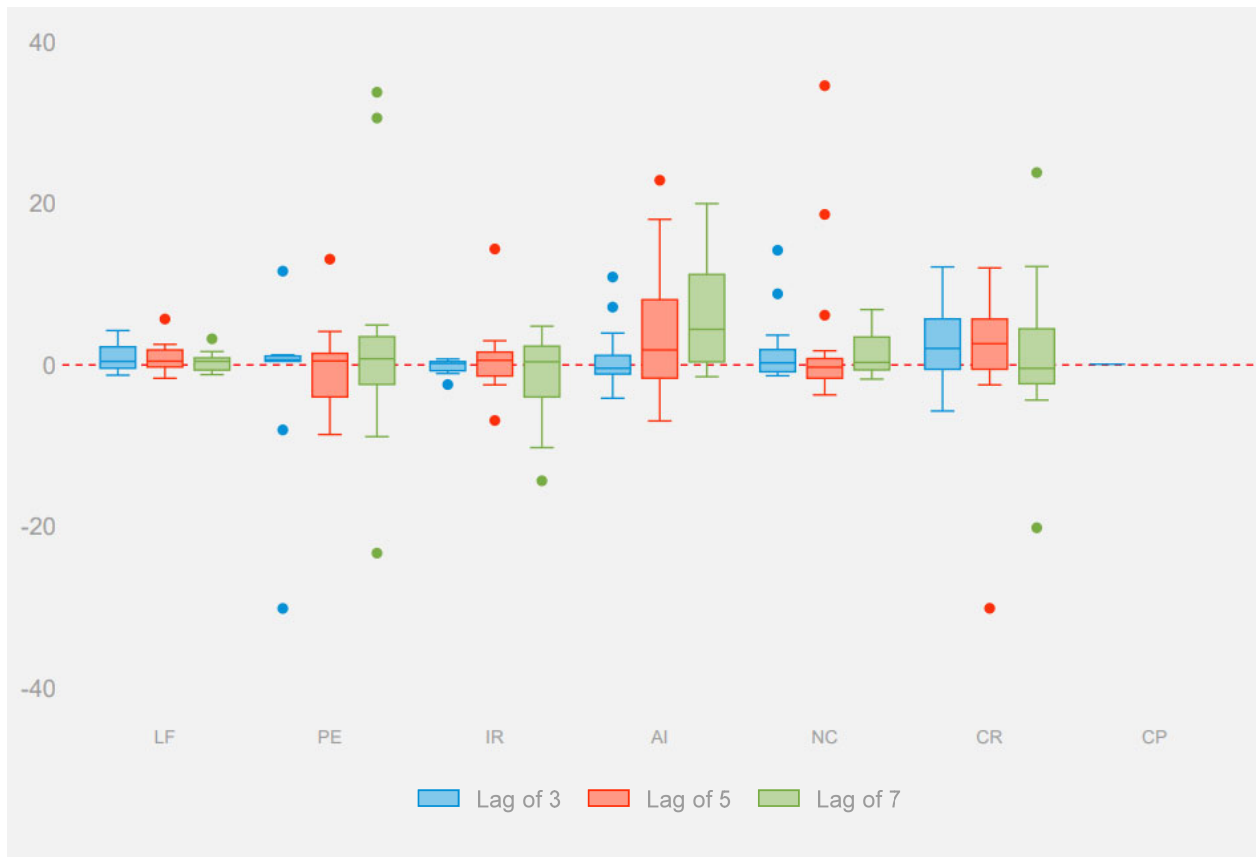


Figure A.8. Boxplot second-stage coefficients by energy policy packages replacing shares of “Renewable energy consumption” and “Renewable electricity output” with shares of “Modern Energy Generation over Total Generation” and “Modern Energy Capacity over Total Installed Capacity” to exclude large hydropower

Notes: Y-axis= normalized percentage change of renewable energy outcome due to the enactment of renewable energy policy. Colors= lags in years. X-axis= Energy policy package. 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, this graph shows one region only. Regression specification: RISE index, UNGA affinity IV with five years moving average. X-axis: energy policy package. To correctly view the graph, the axes were cut at -40, leaving out one datapoint at -60 for PE lag of 5. Includes S2 coefficients with P-values < 0.1.

Table A.12. Average effect of energy policy packages, by the second-stage lag

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: Data refers to normalized percentage change in renewable energy penetration because of the enactment of renewable energy policy. Includes S2 coefficients with P-values < 0.1.

APPENDIX B: DENDROGRAM OF POLICY IMPLEMENTATION

Dendrograms are widely used to find homogeneous groups in observations, or in this case, policy instruments, that differ from each other. They can help clarify the structure of the data or to group variables based on their similarity. The results of the dendrogram support continuing to group policies within the default ESMAP headings in subsequent steps of the analysis.

To depict how the policies relate to one another in implementation, the dendrogram analysis first creates 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.

$$\text{Jaccard coefficient} = \frac{a}{a+b+c} \quad \text{Jaccard coefficient} = \frac{a}{a+b+c} \quad \text{Eq. B.1}$$

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

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

Source: Jaccard (1908).

The method then then systematically merges 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 linking groups. The methods pertinent to binary data are single, complete, and average linkages. Each method has its limitations. 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. In complete linkage, outlying cases prevent close clusters from merging, however. A third method, average linkages, theoretically provides a compromise between single and complete linkage [38,39].

In Figure B.1, the three vertical lines dashed red lines allow the reader to visually compare dissimilarities. In this case, the dendrogram helps further support the idea that policies within headings are most alike to each other, and not most alike to policies in other headings. Overall, it supports the theoretical rationale to operationalize the independent variables using the structure that was pre-determined by ESMAP’s default RISE dataset.

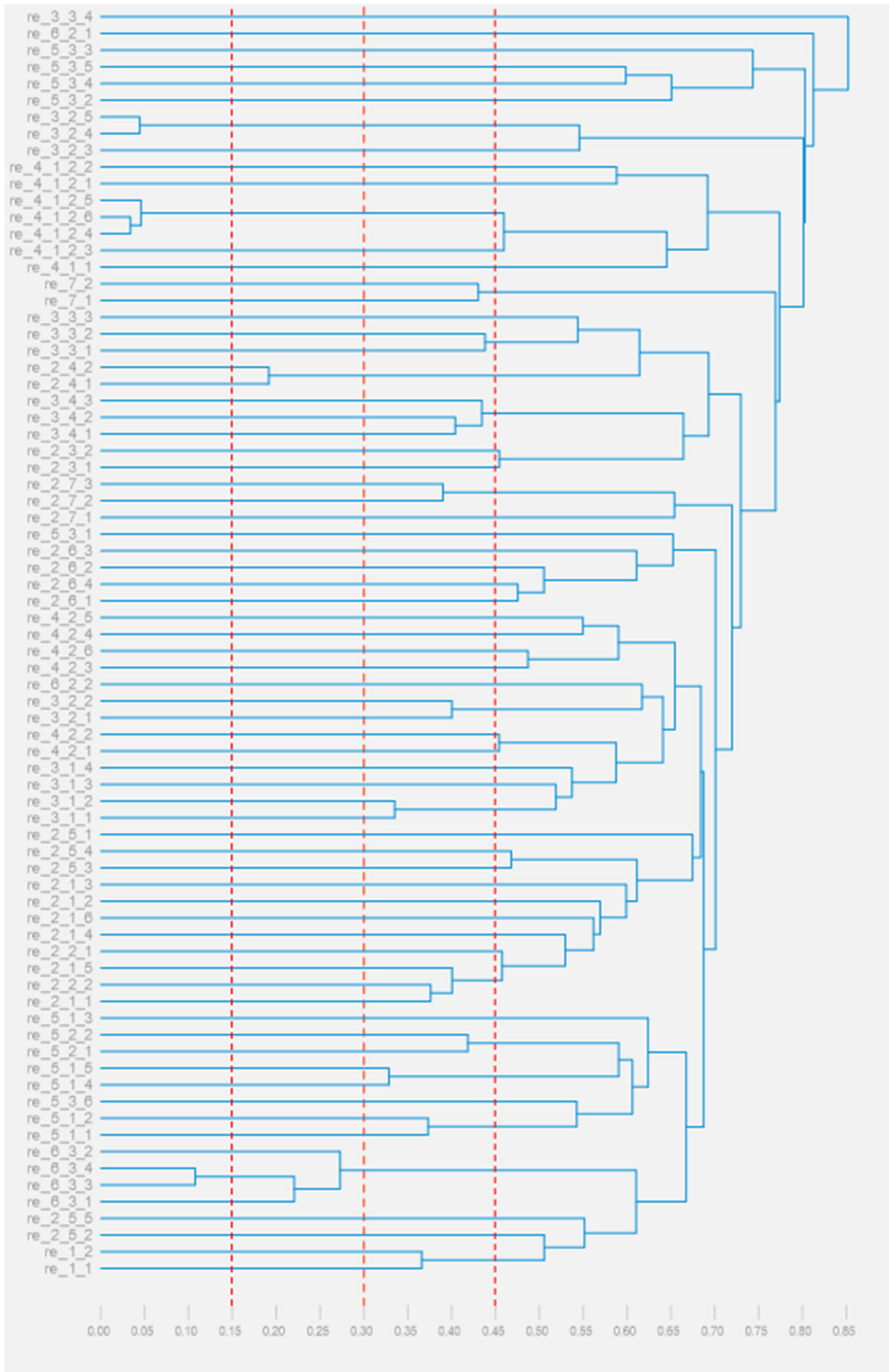


Figure B.1: Dendrogram cluster visualization of policies in the RISE dataset.

Source: RISE dataset and authors' elaboration based on methods described in this chapter. X-axis= Average-linked Jaccard Dissimilarity coefficient. Y-axis= The policy ID used in this study, see Table A.3. for a description of each policy ID.

APPENDIX C: CORRELATION ANALYSIS USED IN THE “COMPOSITE INDEX”

The first option in correlation analysis is to apply a "survival" method, which keeps only uncorrelated variables. The exercise begins at the most disaggregated group level and then pits any 'surviving' variables against remaining variables at higher aggregation levels, stopping then the heading level. The ϕ statistic, 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 [40].

In the "survival" method, the analysis assumes that keeping one of two highly correlated variables retains enough information to represent both. The method also assumes transitivity. In other words, pitting surviving sub-group variables against variables in higher levels of aggregation would give similar outcomes than performing the same analysis with the ones that were removed from the pool. This assumption allows for the comparison of pairs by keeping only one variable of the pair when the correlation is sufficiently high (above a predetermined threshold, as discussed below).

An alternative is to use group averages. The method consists of obtaining 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 the analysis keeps the average of the heading as a new variable that summarizes the heading and move on to the next heading. Otherwise, the analysis repeats the exercise by group and sub-group.

Additionally, it is necessary to choose the ϕ statistic cut-off point for what should be considered "high" correlations. The trade-off here is between retaining information or

producing a manageable number of independent variables, which will each need separate regressions.

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

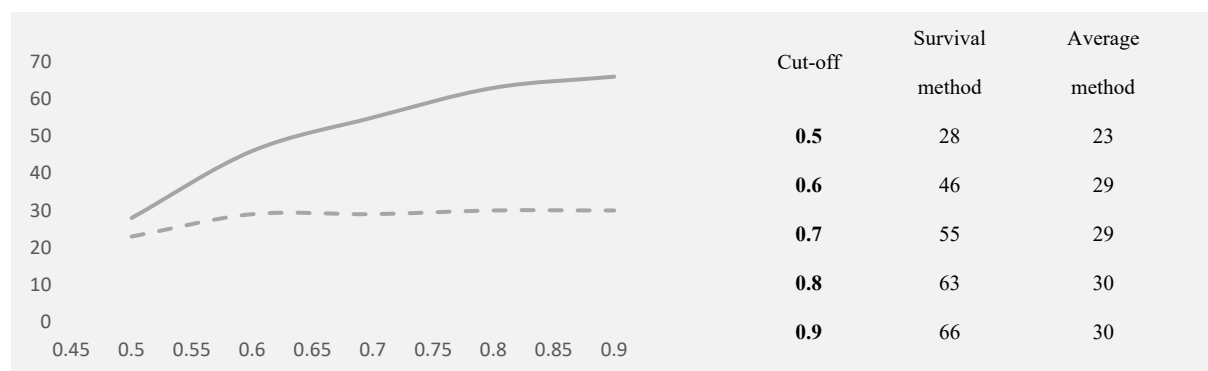


Figure C.1: Number of variables/groups/headings remaining (y-axis), by cut-off point (x-axis), survival method (dashed), average method (solid)

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, the analysis renders at least 23 variables. Therefore, the second step, summation, creates the final “composite” index that is comparable to the default RISE and the summation indexes described in the text.