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Sustainable energy deployment in developing countries: the role of composition of energy aid

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Abstract

Increasing the share of renewable energy in the global energy mix requires enormous investments in low-carbon energy infrastructure in developing countries. Energy aid, being an important funding channel, seems to play a pivotal role in augmenting the shift towards cleaner energy sources. This paper presents a panel analysis on the effectiveness of energy aid and its composition on the substitution potential of renewable sources in the power sector. Our findings based on dynamic panel data and panel quantile regression techniques for a sample of 67 developing countries during 2002–2017, in general, reveal the heterogeneous effects of various components of energy aid on renewable deployment. In particular, energy ODA and its components focus on hydropower infrastructure development without targeting non-hydro renewable sources effectively. Findings also reveal that renewable generation, policy, and distribution components of energy aid help augment the share of hydro sources, irrespective of the renewable energy transition stage. However, we did not find any such effects on non-hydro renewable sources. Probable policy implications call for restructuring the composition and geographical distribution of energy aid to support the development of low-carbon energy infrastructure in the developing world. Donors should disburse energy aid in countries with low renewable shares to attract domestic and international private investments, particularly for increasing the share of non-hydro renewable sources.

JEL-Classification: Q01, Q20, Q40, F35

Keywords: Renewable energy deployment, energy aid, aid effectiveness, developing countries, System GMM, Panel quantile regression

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1 Introduction

With the increasing global warming at an unprecedented rate since the mid-20 century, adverse impacts on natural resources, economic growth, and human well-being became inevitable. The rapid increase in greenhouse gas (GHGs) emissions generated through excessive use of fossil fuel is considered to be the predominant cause of global warming (Pachauri et al., 2014). The International Energy Agency report on "global energy and CO_2 status" unveils that energy-related CO_2 emissions represent two-thirds of all GHGs emissions and have touched a historic high in 2018, driven by emission growth in the power sector (IEA, 2018). Since the substantial share of the increased energy demand is expected to originate from developing countries, these economies are also likely to increase energy-related CO_2 emissions[1]. As economic development and environmental issues are closely intertwined with energy usage, the substitution of fossil fuels by renewable energy sources in developing countries appears to be crucial for achieving sustainable development goals (SDGs) and the targets of the Paris agreement (Bruggink, 2012).

Increasing renewable energy (RE) in the global energy mix is one of the targets of the 7th SDGs, which calls for the worldwide commitment to raise affordable and clean energy. Indeed, RE can support two-thirds of the total global energy demand and contribute to reduction of greenhouse gas emissions needed to limit average global surface temperature below 2 degree Celsius (Gielen et al., 2019). Despite enormous RE potential in the developing world, renewable technologies are yet to be exploited fully due to financial, technical, policy, and information barriers. Moreover, existing investment in high carbon-intensive energy infrastructure causes carbon lock-in and holds back renewable investments (Fadly, 2019). Consequently, 81% of the world's total primary energy supply comes from fossil fuels[2]. It calls for the need to overcome these barriers and, hence, accelerate efforts to increase the share of cleaner and sustainable energy sources.

Overcoming these barriers requires enormous public and private investments in clean energy infrastructure. Since RE projects are associated with high upfront costs relative to expected monetary returns and a longer payback period, private investors are reluctant to invest in these

[1] Carbon Emissions Set to Rise Steadily with Fossil Fuel Use; But, IEA Indicates, Ways to Halt Climate Change Do Exist - News – IEA

[2] http://reports.weforum.org/fostering-effective-energy-transition-2019/press-release/

projects at the initial stage (Ragosa and Warren, 2019). Moreover, RE projects require advanced capital-intensive technology imported from the developed world (Kim, 2018). Given these limitations, official development assistance (ODA) in the energy sector could help overcome these barriers and increase the share of renewables in the total energy mix. In particular, concessional funding in the energy sector, technical consultancy, and successful donor-funded projects could help mitigate the risk of introducing new technologies. In addition, co-financing RE projects with private players create an enabling environment for mobilizing private investments in the RE sector (Buntaine and Pizer, 2015; Hašcic et al., 2015). Even International Energy Agency, 2011 projected that, out of around 18 USD billion required for the clean energy transition, about 40% of funding should come from bilateral and multilateral donors till 2030[3]. Given this projected funding requirement for the low-carbon energy deployment, the need for ODA in the energy sector seems inevitable, supporting such pro-environmental change.

Few studies have scrutinized the RE-ODA effectiveness for renewable deployment (Kim, 2018; Yang and Park, 2020). However, these studies have the following shortcomings. **First,** existing studies use absolute measures of RE deployment[4], which do not capture the substitution potential of renewable sources. Such change in the energy mix is essential for mitigating climate change (Bourcet, 2020). **Second**, the existing literature only considers ODA for RE generation (Gualberti et al., 2014; Kim, 2018; Yang and Park, 2020). However, energy ODA comprises funding for energy distribution, policy, and energy generation, targeting renewable and non-renewable sources[5]. Financing for energy policy, distribution, and non-renewable energy generation might affect RE deployment and provide new insights into the effectiveness of different components of energy aid for RE deployment. **Third**, existing studies used the static panel data estimation techniques without adequately addressing endogeneity issues and the path dependency of renewable deployment indicators. Moreover, these studies did not examine the variation in energy aid effectiveness on the conditional distribution of RE deployment. This aspect seems crucial to assess the "catalyst role" that energy ODA is supposed to play in developing countries with a low share of renewables (Buntaine and Pizer, 2015).

[3] Energy for all (iea.org)

[4] Few examples of absolute measures of RE deployment are RE capacity, growth in RE capacity, RE capacity per capita.

[5] As classified by OECD-CRS, https://stats.oecd.org/viewhtml.aspx?datasetcode=CRS1&lang=en

Given this background, the study attempts to contribute to the existing literature by examining the effect of total energy ODA and its composition on the relative measure[6] of renewable deployment[7] in 67 developing countries from 2002 to 2017.As advocated by various studies on aid effectiveness[8], we use the aid disaggregation approach to comprehend the individual and joint impact of sub-components of energy ODA on renewable energy deployment. Specifically, we analyse the role of energy aid on total RE deployment[9]and compare the findings with non-hydro renewable technologies, given that these modern renewable sources are at a nascent stage in most developing countries. The estimation technique includes system GMM and panel quantile regression with non-additive fixed effects to account for distributional heterogeneity (Arellano and Bover, 1995; Blundell and Bond, 1998; Powell, 2016). System GMM addresses endogeneity issues and the path dependency of RE deployment indicators. We also use panel quantile regression techniques to investigate the heterogeneous impact of energy ODA and its components across the conditional distribution of RE deployment. Hence, the study provides a more comprehensive analysis of energy ODA effectiveness with probable policy implications to make energy ODA aligned with climate mitigation objectives.

The paper is structured as follows: Section 2 briefly reviews the relevant literature and derives the central hypotheses; section 3 presents the details of the data and methodologies used. Empirical findings are presented in section 4. Section 5 concludes the paper and provides certain policy implications.

[6] RE deployment as a share in total installed capacity is the relative measure of RE deployment (Bourcet, 2020).

[7] Power sector emits most of the energy-related CO_2 emissions (IEA,2018)

[8] For aid disaggregation approach see: Mavrotas (2005); Bjørnskov (2019).

[9] Total renewable deployment includes both hydro and non-hydro sources.

2 Literature Review

2.1 The role of energy aid in RE deployment

RE deployment confronts various financial, technical, policy, and information barriers, making it less appealing than conventional energy sources (Atteridge and Savvidou, 2019). RE projects have high upfront costs relative to expected monetary returns and a long gestation period, limiting investment by private players, particularly at the initial stage of transition (Brunnschweiler, 2010; Ragosa and Warren, 2019). Murdock. et al. (2019) argued that large-scale renewable deployment also requires complementary infrastructure, such as transportation networks, grid, and ICT infrastructure. The resultant colossal funding requirement for renewable energy deployment necessitates the big push at the initial stage from international public funding sources for strengthening policy, distribution, and generation capacity. Gualberti et al. (2012) demonstrate the instrumental role of international funding organisations in making energy systems in developing countries more affordable, reliable, and sustainable in the long run. Similarly, Tirpak and Adams (2008) analyse the significance of energy ODA for private investment in the renewable sector and argue that energy ODA reduction significantly reduced private investments in renewable energy projects in developing countries during 1990–1997.

Most of the clean energy innovations take place in developed countries and few emerging economies like China[10]. Kim (2018) argues that the technology-intensive nature of clean energy requires extensive public support for importing and disseminating technology in the domestic markets from the developed world. Domestic renewable energy policies are indispensable in incentivizing private investors to invest in clean technologies and have to be effectively crafted by government agencies that require institutional capacity (Wall et al., 2019; Ragosa and Warren, 2019). Stadelmann and Castro (2014) argue that international development funding could influence the adoption of renewable energy policies in developing countries.

Existing literature advocates in favour of energy aid for renewable energy deployment as it could help remove the financial, technical, and institutional barriers mentioned above. Buntaine and Pizer (2015) and Hašcic et al. (2015) argue that energy ODA could overcome these barriers through co-financing RE projects with private players, providing concessional loans and grants for energy generation, and creating an enabling environment by supporting complementary

[10] https://www.iea.org/reports/clean-energy-innovation/global-status-of-clean-energy-innovation-in-2020#abstract

infrastructure and institutional capacity. Notably, there are two channels through which ODA targeted to the energy sector can augment renewable deployment. First, soft funding targeting energy education, training, management, and research could enable domestic governments to enhance their institutional capacity to undertake research and formulate policies to encourage RE deployment. Second, through concessional loans and grants, energy ODA finances RE projects and reduces private investors' risk since these private players may not cope with the new technologies associated with the renewable sector at the initial stage.

2.2 Existing empirical studies on energy aid effectiveness

Although the focus of the literature on aid effectiveness has shifted to sectoral ODA efficacy, studies on energy aid effectiveness seem to scanty (Tirpak and Adams, 2008; Bruggink, 2012; Bjørnskov, 2019; Yang and Park, 2020). Unlike Pohl and Mulder (2013), who analyse the effect of aggregate ODA on the probability of adopting non-hydro renewable electricity sources, Kretschmer et al. (2013), Maruta and Banerjee (2020), Gualberti et al. (2014) focus on sectoral ODA effectiveness. In particular, these studies consider the effects of energy aid commitments and find a positive impact on energy intensity and electricity installed capacity. However, aid commitments could not reveal the actual impact of aid disbursements.

Few studies have also examined the mobilization effect of RE ODA on private investments in renewable energy and find a positive impact of concessional public funding on private investments in the RE sector (Hašcicet al., 2015; Ragosa and Warren, 2019). Kim (2018) demonstrates the positive effect of energy aid with technical cooperation on the growth of non-hydro renewable electricity capacity, particularly in low-income countries. Yang and Park (2020) assert the role of RE policies and political democracy in making energy aid commitments conducive to renewable electricity generation. Buntaine and Pizer (2015), however, find no effect of donor funds on RE projects as the concessional funding is channelized into those countries with already substantial private investments in the RE sector. It creates an adverse impact on the expansion of private investments in developing countries. A complete summary of the existing empirical literature on energy aid effectiveness is presented in Appendix A (Table A1).

However, the studies mentioned above predominantly suffer from the following shortcomings, which we try to address in this exercise. **First**, substituting fossil fuels for renewable sources is necessary for decarbonizing the growth process and achieving sustainable development. However, none of the existing studies considered the effect of energy ODA on the substitution potential that requires using a relative definition of renewable energy deployment (Bourcet, 2020). **Second**, existing studies hardly looked into the effects of the various components of energy aid. However, according to the OECD-Credit Reporting System (CRS) sectoral classification, aid to the energy sector comprises funding for energy policy, distribution, and generation targeting renewable and non-renewable sources. There are wide variations in the composition of energy aid across different income groups of countries[11]. **Third,** from the methodological perspective, existing studies have employed static panel data estimation techniques while analysing the relationship between energy ODA and renewable outcomes (Kim,2018; Yang and Park, 2020). However, these studies hardly consider the issues related to endogeneity and path dependency of RE deployment (Halimanjaya, 2016). Buntaine & Pizer (2015) argue that energy ODA could play a 'catalyst role' in augmenting private investments in clean energy facilities if targeted to countries with fewer RE investments. Therefore, energy ODA funding should be effective in countries with low RE shares as it is challenging to attract private investments in the new and risky sector. However, none of the existing studies analyse the catalyst role of energy ODA in the RE sector.

Given the above shortcomings of the existing studies, we use the relative definition of RE deployment in the form of renewable electricity capacity as a share of total electricity capacity. We also conduct separate analyses for non-hydro renewable share, given our objective to explore the role of ODA on modern renewable sources. We specifically focus on the electricity sector as it is a directly usable form of energy, and most of the increased CO_2 emissions are associated with power generation. Moreover, other areas of renewable energy, which includes transportation and heating, have not received substantial investments in developing countries (IEA,2018). Furthermore, we carry out a disaggregated analysis of energy ODA and investigate the effectiveness of each component of energy ODA separately (generation, distribution, and policy). Besides, we examine the potential complementariness between ODA for renewable generation, policy, and distribution. Methodologically, unlike previous studies in this context, we employ the dynamic panel data estimation technique to our empirical models. We also use the panel quantile regression technique to capture the 'catalyst effect' and test the robustness of our GMM result across the distribution of RE deployment indicators.

[11] See Fig-1.

Given these conjectures, we frame the following hypotheses:

H_1: *ODA targeted to the energy sector contributes to increasing RE deployment*.

H_2: *Various components of energy ODA exert a varied effect on the RE deployment. ODA for renewables, distribution, and policy would increase renewable deployment, whereas ODA for non-renewable energy production would negatively impact renewable deployment. We expect the mutually reinforcing effect of ODA for energy distribution, policy, and renewable generation on the RE deployment.*

H_3: *The impact of energy ODA and its components vary across the conditional distribution of RE deployment with a larger effect in countries with low RE shares (catalyst effect)*.

H_4: *Energy ODA and its components exert varied impacts on total renewable electricity capacity and non-hydro renewable electricity capacity.*

3 Data and methodology

3.1 Dependent variables

Details of the definition and construction of the variables, control variables, empirical models, and estimation techniques are presented in this section. The dependent variable is the proportion of renewable electricity capacity to total electricity installed capacity (REC). The primary reason for using a relative definition of renewable energy deployment is to examine the role of energy aid in fostering the substitution of fossil fuels by renewable sources (Bourcet, 2020).We use electricity capacity[12] instead of electricity generation to encapsulate successful public and private investments in RE sources as electricity capacity is hardly influenced by external factors such as meteorology and domestic demand variability, beyond investor's control (Kim and Park, 2016; Kim, 2018). To account for modern renewable sources' technical and maturity differences, we define another dependent variable, non-hydro renewable electricity capacity, as a proportion of total electricity installed capacity (NHREC). The data for electricity capacity, renewable electricity capacity, and non-hydro renewable electricity capacity in million kilowatts (MKW)is extracted from the US Energy Information Administration (EIA)[13]. Using these data, we construct two dependent variables as follows:

1. REC $=\frac{Renewable\ electricty\ \ capacity}{Total\ electricty\ capacity}$

2. NHREC[14] $= \frac{Non\!-\!hydro\ renewable\ electricty\ capacity}{Total\ electricty\ capaicty}$

3.2 Energy aid and its composition

The primary explanatory variable, per capita energy aid ($EAID_{pc}$)[15], includes all aid disbursements for energy infrastructure from official donors[16] as reported to the organization for economic cooperation and development (OECD) credit reporting system (CRS), in constant 2017 US$. Total

[12] The US Energy Information Administration (EIA) refers to capacity as the maximum amount of electricity that a generator can produce under ideal conditions.

[13] International – U.S. Energy Information Administration (EIA)

[14] Non-hydro renewable sources include biomass, geothermal, ocean, solar, and wind.

[15] Energy aid and energy official development assistance (ODA) is same and simultaneously used in the paper.

[16] Official donors comprise of donors in the development assistance committee (DAC), several non-DAC donors and multilateral organisation.

energy aid comprises aid for energy policy (POLICY), renewable energy generation (REG), non-renewable energy generation (NREG), energy distribution (DIS), and nuclear energy plants (NUCLEAR). These components of total energy aid target distinct aspects of energy infrastructure: generation, policy environment, and infrastructure for energy transmission. As funding for energy policy, distribution, and institutional capacity building are essential for RE deployment, we separately examine the role of different categories of energy aid on cleaner electricity adoption. Values of all the aid variables are standardised and expressed in per capita terms as highly populated, and large countries need more resources to adopt clean electricity technologies.

Figure 1 shows that energy aid has increased in countries of all the income groups with a substantial rise in low and lower-middle-income countries. The increase is attributed to the surge in policy, distribution, and renewable energy generation aid. Across all the income groups, energy aid for electricity generation from non-renewable energy sources has decreased during 2002–2017.

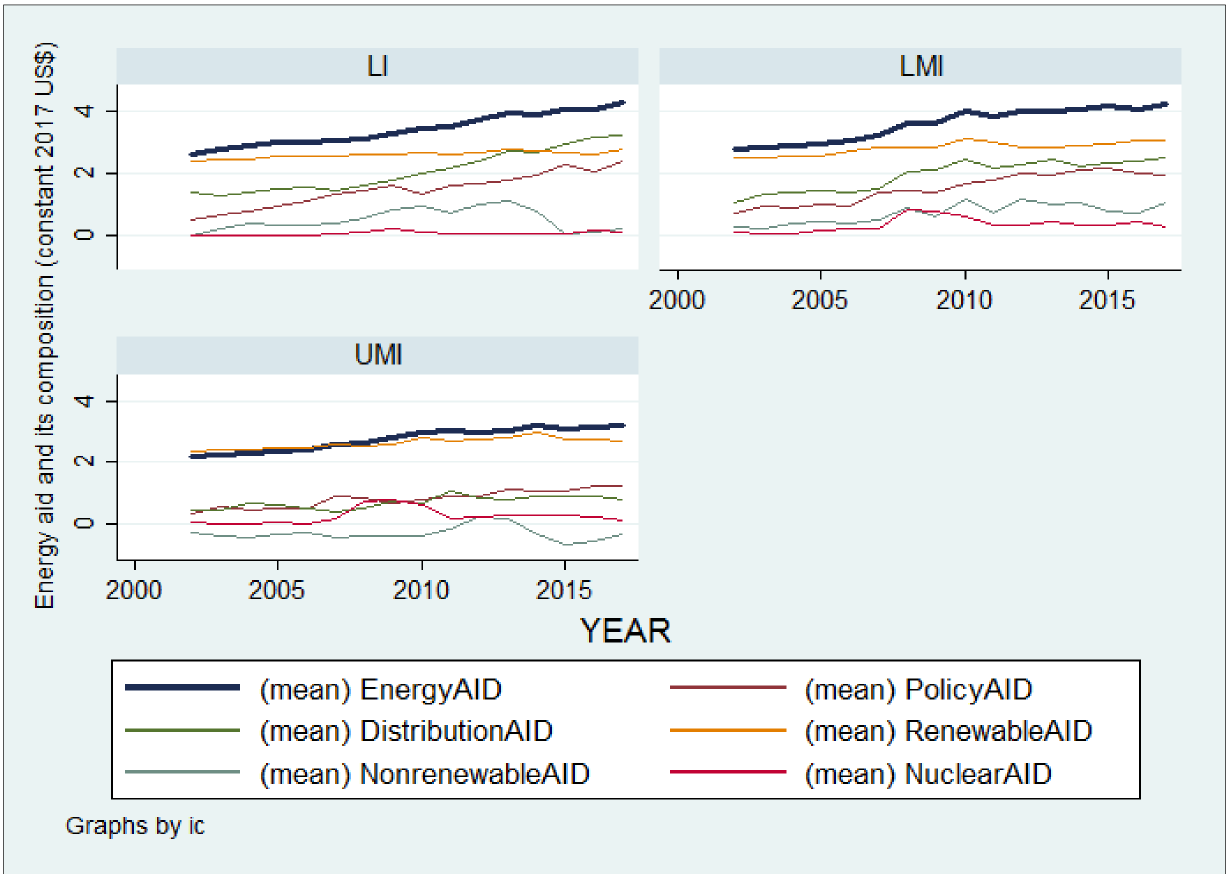

Figure 1: Energy aid and its composition over time, by income groups

The data sample covers the period from 2002 to 2017. We consider post-2001 energy aid data based on OECD recommendations as pre-2001 data are unreliable for sectoral analysis (Kim, 2018). The study uses the amount of disbursed aid in the energy sector rather than commitments in order to measure actual flows in the energy sector, given the argument that commitments are official, written obligations by the donors, which may not end up with actual disbursement due to several exogenous factors (Bulíř and Hamann,2003; Kim, 2018). Therefore, aid disbursement is considered to be the appropriate measure to examine energy aid effectiveness.

3.3 Control Variables

We add several control variables, including electricity net consumption (billion KWH), denoted by EC, total natural resource rent (% of GDP) excluding forest rents (RENT), GDP per capita (GDP_{pc}), domestic credit to the private sector (DCPS), net inflow of foreign direct investments (FDI), per capita CO_2 emissions (CO_2), governance readiness (GOV), democracy level (POLITY) and uncertainty Index (UI). Most of these control variables are commonly used in prior studies related to RE deployment (Aguirre and Ibikunle, 2014; Kim, 2018; Fadly, 2019; Bourcet, 2020). Variable definitions and data sources are presented in Appendix A (Table A2).

An increase in electricity demand captured by EC is likely to increase investment in renewable and non-renewable electricity capacity (Marques et al., 2010). However, there is no consensus on the possible impact of an increase in EC on renewable energy deployment (Bourcet, 2020). Moreover, prior studies hardly scrutinized how increased EC could influence the substitution potential of renewable sources. Fossil fuel dependency in the form of higher fuel rent provides room for powerful lobby groups to oppose investment in renewables (Fadly, 2019). Thus, we include fuel rent (% of GDP), which is expected to impact RE deployment negatively.

GDP per capita as a measure of a country's economic growth is likely to impact renewables deployment by stimulating investment in capital-intensive renewable energy projects and funding other essential renewable policy incentives (Sadorsky, 2009; Chang et al., 2009; Aguirre and Ibikunle, 2014; Bourcet, 2020). Most existing studies show the positive influence of GDP_{pc} on consumption and electricity generation from renewable sources (Bourcet, 2020).

Conversely, few studies have also identified the negative impact of the increase in GDP_{pc} on renewable energy deployment as established fossil fuel sources can quickly meet higher electricity demand following economic expansion and impede investments in renewable sources (Marques and Fuinhas 2011; Cadoret and Padovano, 2016).

Bank credit to renewable and non-renewable electricity projects seems to be crucial, particularly in developing countries where other financing avenues are limited. Brunnschweiler (2010) shows that commercial banks play a significant role in renewable energy production, particularly for modern renewable sources. To account for this, we include domestic credit to the private sector (% of GDP). FDI inflows usually transfer financial capital, technical know-how, managerial expertise, and a diversified skill base. These are fundamental for adopting technologies related to renewable sources and triggers joint clean energy projects under the clean development mechanism (Przychodzen and Przychodzen, 2020). We use FDI to control for the influence of private foreign financial flows on RE deployment. We also include CO_2 emission per capita to address the role of environmental concerns that could incentivize the shift from fossil fuels to renewable (Aguirre and Ibikunle, 2014). However, several studies argue that higher per capita CO_2 emissions indicate fossil fuel dependency and, therefore, provide less incentive to adopt renewable technologies (Fadly, 2019; Przychodzen and Przychodzen, 2020).

Besides these socio-economic and energy-related variables, we add a set of institutional variables in our analyses. Governance readiness (GOV) captures societal stability and institutional quality essential for investment risk reduction. The composite indicator is developed by Notre Dame global adaptation initiative using World Governance Indicators[17] (ND-GAIN, 2018). POLITY variables constructed from the Polity5 dataset ranges from +10 (strongly democratic) to –10 (strongly autocratic). It is widely recognised that democratic regimes are more conducive to incentivizing investment in new and modern renewable technologies (Fadly, 2019). Moreover, Yang and Park (2020) show that a democratic government minimizes public funding misappropriation, such as energy aid to other sectors, and reduces leakages.

[17] Political stability, Non-violence, Control of corruption, Regulatory quality, and Law rule. Higher value of governance readiness indicates higher governance readiness.

Finally, we add an uncertainty index (UI), which captures uncertainty related to political and economic developments for near-term and long-term concerns that could impact renewable energy deployment (Ahir et al., 2018; Bourcet, 2020)[18]. Sweidan (2021) empirically shows the positive effect of geopolitical risk caused by worldwide political and economic uncertainty on RE diffusion as nations try to mitigate risks associated with fossil fuel imports. Table 1 presents the descriptive statistics of all the variables included in the study. Before specifying the model, we undertake a correlation analysis (see Appendix C) among the variables and few tests. We observe the absence of multicollinearity in our dataset as the mean VIF[19] is 2.09. However, we detect high persistence of REC and NHREC; the correlation between their current and past values is 0.99 and 0.94, respectively.

Table 1: Descriptive statistics

Variables	Abbr.	Obs.	Mean	Std.Dev.	Min	Max
Renewable electricity installed capacity as a percentage of total electricity installed capacity	REC	1,216	38.79	31.33	0	100
Non-hydroelectricity installed capacity as a percentage of total electricity installed capacity	NHREC	1,216	3.35	7.58	0	52.38
Per capita disbursement of aid to energy sector (constant US million dollars, 2017)	$EAID_{pc}$	1,216	2.67	5.17	–0.18	63.61
Per capita disbursement of energy aid for energy policy (constant US million dollars, 2017)	$POLICY\text{-}AID_{pc}$	1,216	0.46	1.26	0	14.75
Per capita disbursement of energy aid for renewable energy generation (constant US million dollars, 2017)	$REG\text{-}AID_{pc}$	1,216	0.56	2.28	–0.31	50.20
Per capita disbursement of energy aid for non-renewable energy generation (constant US million dollars, 2017)	$NREG\text{-}AID_{pc}$	1,216	0.42	1.49	–0.008	23.04
Per capita disbursement of energy aid for energy distribution (constant US million dollars, 2017)	$DIS\text{-}AID_{pc}$	1,216	16.30	37.40	–0.14	444.13
Electricity net consumption (billion KWH)	EC	1,216	91.95	452.82	0.2	5935
Total natural resources rent -forest rent (% of GDP)	RENT	1,216	5.67	8.16	0	52.23
GDP per capita PPP (constant 2011 international dollars).	GDP_{pc}	1,216	7487.65	5517.43	545.68	26808.16
Domestic credit to private sector (% of GDP)	DCPS	1,213	38.18	31.04	0.49	160.12
Foreign direct investment, net inflows (% of GDP)	FDI	1,216	4.13	5.04	–37.15	55.07
CO2 emissions (metric tons per capita)	CO_2	1,216	2.29	2.76	0.01	16.09
Governance Readiness	GOV	1,200	0.42	0.10	0.13	0.78
Polity5	POLITY	1,197	3.97	5.19	–10	10
Uncertainty Index	UI	1,096	0.19	0.20	0	1.82

[18] Data – World Uncertainty Index; Higher value means greater uncertainty.

[19] VIF is variance inflation factor.

3.4 Empirical models

3.4.1 System GMM

Our two dependent variables (REC and NHREC) are likely to exhibit path dependency. Past levels of installed capacities can influence current investments in renewable sources (Bourcet, 2020). Besides, $EAID_{pc}$ per capita and its components are disbursed according to the recipient's sustainable energy need. The funding may increase with large-scale sustainable energy use, making aid variables endogenous in the empirical model (Kim, 2019). Considering these facts, we specify the dynamic panel model as follows:

$$\text{In}\,(REC_{it}) = \alpha + \delta \text{In} REC_{it-1} + \beta InEAIDpc^{k}_{i,t-l} + \gamma InX'_{it} + d_t + n_i + \varepsilon_{it} \quad (1)$$

$$\text{In}\,(NHREC_{it}) = \alpha_1 + \delta_1 \text{In} NHREC_{it-1} + \beta_1 InEAIDpc^{k}_{i,t-l} + \gamma_1 InX'_{it} + d_t + n_i + \mu_{it} \quad (2)$$

$REC_{it}\ and\ NHREC_{it}$ are the dependent variables for country i and time t. $REC_{it-1}\ and\ NHREC_{it-1}$ are their respective lag values. δ and δ_1 are the respective coefficients of $REC_{it-1} or\ NHREC_{it-1}$.$\beta$ and γ are the elasticity parameters to be estimated. $EAIDpc^{k}_{i,t-l}$ denotes per capita energy aid from donors to recipient country *i* at the disbursed time *t–l*. *l* is the lag order for energy aid and its sub-components (*l*=1,2,3)[20]. Superscript k indicates different categories of energy aid (POLICY-AID_{pc}, REG-AID_{pc}, NREG-AID_{pc}, and DIS-AID_{pc}). First, we examine the impact of $EAID_{pc}$ (total energy aid) and REG-AID_{pc} (renewable energy generation aid) on REC and NHREC. We estimate the individual and combined effect of POLICY-AID_{pc}, NREG-AID_{pc}, and DIS-AID_{pc} with REG_{pc} on REC and NHREC, respectively. X'_{it} refers to control variables, d_t are the time dummy variables, n_i are the time-invariant, country-specific fixed effects.ε_{it} and μ_{it} are the error terms.

We estimate Eq. (1) and Eq. (2) by dynamic panel data methodology, as suggested by Bourcet (2020). In particular, we choose two-step System Generalised Method of Moments (GMM) estimators, proposed by Arellano and Bover (1995) and Blundell and Bond (1998) to address the issues of dynamic panel bias, endogeneity of energy aid variables, heteroscedasticity, and autocorrelation within individuals (Roodman, 2009). The method solves the endogeneity issue by instrumenting the lagged dependent variable and other endogenous

[20] We present results with Lag 1 in the main body of the paper.

variables with variables that are uncorrelated with fixed effects (Roodman, 2009). The first step of the estimation procedure is to eliminate country-specific fixed effects through the first difference transformation

$$\Delta \text{In}(REC_{it}) = \delta . \Delta \text{In}REC_{i,t-1} + \beta . \Delta InEAIDpc^{k}_{i,t-l} + \gamma \Delta InX'_{i,t} + \Delta d_t + \Delta \varepsilon_{i,t} \quad (3)$$

$$\Delta \text{In}(NHREC_{it}) = \delta_{1.} \Delta \text{In}NHREC_{i,t-1} + \beta_1 . \Delta InEAIDpc^{k}_{i,t-l} + \gamma_{1.} \Delta InX'_{i,t} + \Delta d_t + \Delta \mu_{i,t} \quad (4)$$

In the second step, the first differenced estimators (Eq.3 and Eq.4) are combined with the estimators in the levels (Eq. 1 and Eq. 2) to form an efficient "system estimator." The predetermined and endogenous variables in the first differenced equations (Eq. 3 and Eq. 4) are instrumented with appropriate lags of the specified variables in levels. The strictly exogenous variables are first differenced for use as instruments in the first differenced equation. For level equations (Eq. 1 and Eq. 2), predetermined and endogenous variables are instrumented with an appropriate lag of their first differences. Simultaneously, the strictly exogenous regressors can directly enter the instrument matrix for use in the levels equation.

The method is considered to be more efficient than the difference GMM as it assumes that the first difference of instruments is uncorrelated with fixed effects, which allows the introduction of more instruments. Also, coefficients of time-invariant regressors, which would disappear in the difference GMM, could be estimated through system GMM. We employ a two-step system GMM instead of one step because they are more robust and efficient to address heteroscedasticity and autocorrelation problems. (Roodman, 2009).

For validity of the instruments, we first, check the second-order serial correlation in the error term. AR (2) reports the p-value for the null-hypothesis of no second-order serial correlations in the first differenced residuals. Secondly, we check whether there is correlation between instruments and error terms using Hansen test of over-identifying restrictions that shows the p-values for the null hypothesis of instrument validity. Thirdly, we report the number of instruments of each model, which should be smaller than or equal to the number of groups in the regression to avoid instrument proliferation (Roodman, 2009).

3.4.2 Panel Quantile Regression

A panel quantile regression model with the *non-additive fixed effects* proposed by Powell (2016) is used in this paper to examine the distributional and heterogeneous impact of energy ODA and its components on REC and NHREC. The method also maintains a non-separable disturbance term associated with quantile estimation. It is claimed to be an improvement over the panel quantile regression estimators with *additive fixed effects* and separate disturbance term, which assumes that only time-varying components of the disturbance term influence the variability of parameters.

The distribution of the outcome variable $Y_{i,t}$ is estimated using quantile panel regression for treatment variables $D_{i,t}$. To keep the non-separable disturbance term, the study employs non-additive fixed effects to model the outcome, expressed as:

$$Y_{i,t} = D'_{i,t}\beta\left(U^*_{i,t}\right), U^*_{i,t} \sim U(0,1) \tag{5}$$

Where $D'_{i,t}\beta(\tau)$ strictly increases in quantile τ. $U^*_{i,t}$ represents the function of the disturbance terms and proneness of the outcome. The structural quantile function for Eq. (5) is expressed as:

$$S_y(\tau/d) = d'\beta(\tau) \quad \tau \in (0,1) \tag{6}$$

The structural quantile function explains the quantile of the latent outcome variable $Y_d = d'\beta(U^*)$ for randomly selected $U^* \sim U(0,1)$ and a fixed potential value of the treatment effect d. Following above algorithm, we specify the panel quantile regression as follows, where REC/NHREC are our outcome variables and $EAIDpc^k_{it-1}$ is the primary treatment variable.

$$(REC/NHREC)_{it}(\tau/\, \alpha_i\,, \delta_t, X_{it}) = \alpha_i + \delta_t + \beta_{1,\tau} InEAIDpc^k_{it-l} + \beta_{2,\tau} InX'_{it} \tag{7}$$

Where α_i denotes the non-additive fixed-effects, $InEAIDpc^k_{it-l}$ denotes lagged value of energy aid (*l*=1,2,3) and its components, k indicates different categories of energy aid, X'_{it} denotes the matrix of control variables at individual country i and time t. The model is estimated using the Markov Chain Monte Carlo optimization method.

4 Results and discussion

4.1 System GMM results

Table 2 below shows the estimated effect of $EAID_{pc}$ (Model 1, 2) and $REG\text{-}AID_{pc}$ (Model 3, 4) on REC and NHREC, respectively. We first present our findings based on $REG\text{-}AID_{pc}$ out of all the components of energy aid as it is directly related to RE deployment. We observe positive and significant effect of $EAID_{pc}$ and $REG\text{-}AID_{pc}$ on RE deployment; the magnitude is greater for $REG\text{-}AID_{pc}$ than $EAID_{pc}$, which indicates that other components of $EAID_{pc}$ might be counter-productive for increasing RE shares. Lagged values of both the dependent variables are positive, less than one, and highly significant, verifying the persistence effect and validating the use of dynamic panel data models. Across models, the coefficient of FDI is positive and significant, showing the importance of private funding channel for fostering substitution of fossils by RE sources. Positive and significant coefficient of domestic credit (DCPS) implies that the share of modern renewable increases with expansion of credit to the private sector (Model 2, 4). EC and GDP_{pc} exert significant and positive effects in few models while explaining RE share. The Coefficient of CO_2 is negative and significant in Model 2 and 3, which indicates that fossil fuel dependency lowers RE deployment. This finding is consistent with those in previous studies (Fadly, 2019; Przychodzen and Przychodzen, 2020). The UI coefficient is positive and significant with REC and negative and significant with NHREC only in Model 1 and 2. It indicates that economic and political uncertainty worldwide deters investment in modern renewable technologies (non-hydro). Countries might shift from fossil fuels to hydroelectricity sources during global uncertainty to reduce the risk of fossil fuel price and quantity volatility.

Contrary to our expectations, the coefficient of governance readiness (GOV) variable is mostly negative and significant in few models which indicates that government institutions may not be efficient to support the diffusion of RE sources in developing countries. Table 3 and 4 present the findings based on our second hypothesis by analysing the effects of different components of $EAID_{pc}$ on REC and NHREC, respectively.

Table 2: Estimated effect of total and renewable energy aid on RE deployment

MODEL VARIABLES	(1) REC-EAID$_{pc}$	(2) NHREC-EAID$_{pc}$	(3) REC-REGAID$_{pc}$	(4) NHREC-REGAID$_{pc}$
L1. REC	0.90*** (0.02)		0.97*** (0.02)	
L1. NHREC		0.84*** (0.02)		0.96*** (0.01)
L1. EAID$_{pc}$	0.06* (0.03)	0.02** (0.01)		
L1. REG-AID$_{pc}$			3.66*** (0.49)	0.78*** (0.22)
EC	0.03* (0.01)	–0.03 (0.03)	0.02 (0.02)	0.01*** (0.00)
RENT	0.00 (0.01)	–0.00 (0.01)	0.00 (0.00)	–0.00 (0.00)
GDP$_{pc}$	0.01 (0.05)	0.60*** (0.15)	0.19*** (0.06)	–0.00 (0.01)
DCPS	–0.02 (0.02)	0.06** (0.02)	–0.02 (0.03)	0.02** (0.01)
FDI	0.18*** (0.02)	0.16*** (0.02)	0.21*** (0.01)	0.14*** (0.01)
CO_2	–0.03 (0.03)	–0.26*** (0.07)	–0.12*** (0.03)	–0.00 (0.01)
GOV	0.06 (0.09)	–0.35** (0.14)	–0.18** (0.08)	–0.01 (0.03)
POLITY	0.07** (0.03)	0.02 (0.03)	0.00 (0.03)	0.01 (0.01)
UNI	0.07* (0.03)	–0.07** (0.03)	0.01 (0.02)	–0.00 (0.05)
Time dummies	Yes	Yes	Yes	Yes
Observations	995	995	995	995
No. of countries	67	67	67	67
No. of instruments	44	64	60	52
Hansen J (Chi^2) P-value [a]	14.45 (0.56)	37.57 (0.39)	37.52 (0.23)	30.74 (0.16)
Arellano bond test of zero autocorrelation AR(1) AR(2) p-value[b]	–2.10** –1.59 (0.11)	–2.16** 1.42 (0.15)	–2.22** –1.56 (0.11)	–2.21** 1.41 (0.15)

Notes: All variables are in logarithmic form, and consequently, the estimates coefficients are elasticities.[a]The Hansen test p-value for overidentifying restrictions, where H_0: over-identifying restrictions are valid;[b]the Arellano bond test p-value for serial correlation of order 2 in the first difference residuals, where H0:no autocorrelations. Columns in the table report the estimated coefficient of each model with the two-step system GMM. Standard errors in the parentheses. *, **, *** significant at 10, 5, and 1 percent respectively. L1 (lag operator) represents the first lag.

Table 3: Estimated effect of different components of energy aid on REC

MODEL Dependent Variable-REC	(1) NREG	(2) NREG	(3) POLICY	(4) POLICY	(5) DISTRI	(6) DISTRI
L1. REC	0.94^{***} (0.02)	0.77^{***} (0.04)	0.92^{***} (0.03)	0.86^{***} (0.01)	0.98^{***} (0.01)	0.94^{***} (0.01)
L1. $REG\text{-}AID_{pc}$	0.98^{*} (0.53)	1.37^{***} (0.51)	0.52^{*} (0.28)	1.47^{***} (0.37)	1.24^{**} (0.49)	0.97^{***} (0.32)
L1. $NREG\text{-}AID_{PC}$	0.00 (0.01)	–0.83 (0.57)				
L1. ($REG\text{-}AID_{pc}$* $NREG\text{-}AID_{PC}$)		0.25 (0.16)				
L1. $POLICY\text{-}AID_{pc}$			$–0.05^{**}$ (0.02)	$–4.07^{***}$ (1.54)		
L1. ($REG\text{-}AID_{pc}$* $POLICY\text{-}AID_{pc}$)				1.169^{**} (0.44)		
L1. $DIS\text{-}AID_{pc}$					–0.01 (0.01)	1.182^{*} (0.50)
L1. ($REG\text{-}AID_{pc}$* $DIS\text{-}AID_{pc}$)						$–0.34^{**}$ (0.13)
EC	–0.01 (0.03)	0.03 (0.04)	0.04 (0.04)	0.08^{***} (0.03)	–0.00 (0.03)	–0.01 (0.02)
RENT	0.00 (0.01)	0.00 (0.01)	–0.00 (0.01)	$–0.03^{***}$ (0.01)	0.00 (0.00)	–0.00 (0.00)
GDP_{pc}	0.01 (0.09)	0.29^{*} (0.15)	0.05 (0.13)	–0.05 (0.05)	–0.01 (0.05)	0.05 (0.05)
DCPS	0.00 (0.03)	–0.03 (0.07)	–0.03 (0.04)	$–0.07^{**}$ (0.03)	0.01 (0.02)	0.00 (0.02)
FDI	0.17^{***} (0.01)	0.27^{***} (0.02)	0.24^{***} (0.02)	0.22^{***} (0.01)	0.14^{***} (0.01)	0.18^{***} (0.01)
CO_2	0.01 (0.05)	–0.15 (0.10)	–0.06 (0.06)	–0.02 (0.03)	0.01 (0.02)	–0.01 (0.02)
GOV	0.04 (0.11)	–0.05 (0.17)	0.10 (0.15)	0.09 (0.07)	–0.04 (0.07)	–0.04 (0.07)
POLITY	–0.00 (0.03)	0.12^{***} (0.04)	0.03 (0.03)	0.05 (0.03)	0.03 (0.02)	0.01 (0.01)
UNI	0.02 (0.02)	0.04 (0.03)	0.02 (0.02)	0.08^{***} (0.02)	0.01 (0.02)	0.05^{***} (0.01)
Time dummies	Yes	Yes	Yes	Yes	Yes	Yes
Observations	995	995	995	995	995	995
No. of countries	67	67	67	67	67	67
No. of instruments	54	66	54	65	54	61
Hansen J (Chi^2)[a] P-value	24.17 (0.51)	30.82 (0.60)	30.89 (0.13)	46.97 (0.10)	26.98 (0.35)	32.06 (0.41)
Arellano bond test of zero autocorrelation AR(1) AR(2) p-value[b]	$–2.12^{**}$ –1.02 (0.30)	$–2.13^{**}$ –0.96 (0.33)	$–2.04^{**}$ –0.72 (0.47)	$–2.14^{**}$ –1.03 (0.30)	$–2.15^{**}$ –1.04 (0.29)	$–2.15^{**}$ –1.26 (0.20)

Notes: Same as table 2.

Table 4: Estimated effect of different components of energy aid on NHREC

MODEL Dependent Variable NHREC	(1) NREG	(2) NREG	(3) POLICY	(4) POLICY	(5) DISTRI	(6) DISTRI
L1. NHREC	0.79*** (0.02)	0.78*** (0.02)	0.81*** (0.03)	0.85*** (0.02)	0.68*** (0.05)	0.70*** (0.01)
L1. REG-AID$_{pc}$	0.16 (0.37)	0.94* (0.50)	–1.03 (0.63)	0.12 (0.53)	2.11** (0.86)	0.08 (0.78)
L1. NREG-AID$_{PC}$	–0.03*** (0.01)	–1.53*** (0.39)				
L1. (REG-AID$_{pc}$* NREG-AID$_{PC}$)		0.44** (0.11)				
L1. POLICY-AID$_{pc}$			–0.39*** (0.05)	10.94* (6.17)		
L1. (REG-AID$_{pc}$* POLICY-AID$_{pc}$)				–3.14* (1.77)		
L1. DISTRIBUTION-AID$_{pc}$					–0.11** (0.02)	1.10* (0.57)
L1. (REG-AID$_{pc}$* DISTRIBUTION-AID$_{pc}$)						–0.33** (0.16)
EC	0.05 (0.04)	0.02 (0.02)	–0.02 (0.04)	–0.02 (0.02)	–0.12 (0.08)	0.08 (0.07)
RENT	–0.01 (0.01)	–0.01 (0.01)	–0.05*** (0.01)	–0.02 (0.01)	–0.00 (0.03)	–0.03 (0.03)
GDP$_{pc}$	0.48*** (0.09)	0.43*** (0.06)	0.15 (0.15)	0.25*** (0.09)	0.03 (0.21)	0.56*** (0.14)
DCPS	0.02 (0.04)	0.06** (0.02)	0.08** (0.03)	0.07*** (0.02)	0.19** (0.07)	0.03 (0.07)
FDI	0.17*** (0.02)	0.12*** (0.01)	0.19*** (0.03)	0.15*** (0.01)	0.11* (0.06)	0.04** (0.02)
CO_2	–0.26*** (0.04)	–0.22*** (0.03)	–0.02 (0.07)	–0.10* (0.05)	0.04 (0.10)	–0.29*** (0.04)
GOV	–0.29** (0.13)	–0.20** (0.08)	–0.04 (0.13)	–0.09 (0.07)	–0.13 (0.25)	0.29 (0.24)
POLITY	0.08** (0.03)	0.06** (0.03)	0.08** (0.03)	0.06*** (0.02)	–0.00 (0.07)	0.12* (0.07)
UNI	–0.10*** (0.03)	–0.08*** (0.03)	–0.15*** (0.05)	–0.07* (0.03)	0.02 (0.07)	–0.01 (0.05)
Time dummies	Yes	Yes	Yes	Yes	Yes	Yes
Observations	995	995	995	995	995	995
No. of countries	67	67	67	67	67	67
No. of instruments	64	65	65	65	59	61
Hansen J (Chi^2)[a] P-value	36.63 (0.39)	44.94 (0.12)	41.37 (0.24)	44.99 (0.12)	32.87 (0.32)	32.12 (0.41)
Arellano bond test of zero autocorrelation AR(1) AR(2) p-value[b]	 –2.23** 1.40 (0.16)	 –2.21** 1.35 (0.17)	 –2.26** 1.30 (0.19)	 –2.42** 1.38 (0.16)	 –2.70*** 1.03 (0.30)	 –2.21 1.43 (0.15)

Notes: Same as Table 2.

Specifically, we examine the combined effects of various components of energy aid on RE shares: REG-AID$_{pc}$ with NREG-AID$_{pc}$, REG-AID$_{pc}$ with POLICY-AID$_{pc}$, and REG-AID$_{pc}$ with DIS-AID$_{pc}$ in Model 2, 4, and 6, respectively. The effect of REG-AID$_{pc}$ is positive and significant for REC across models (Table 3), whereas it is significant for NHREC in few models (Table 4). For REC in Table 3, the REG-AID$_{pc}$ coefficient becomes insignificant when interacted with NREG-AID$_{pc}$ (Model-2), remains positive and significant when interacted with POLICY-AID$_{pc}$ (Model-4), and become negative and significant when interacted with DIS-AID$_{pc}$ (Model-6). It indicates that only POLICY-AID$_{pc}$ complements with REG-AID$_{pc}$ for increasing the share of renewable electricity capacity in total electricity capacity (REC).

For NHREC in table 4, magnitude of the coefficient of REG-AID$_{pc}$ drops from 0.94 to 0.44, when interacted with NREG-AID$_{pc}$, albeit positive and significant (Model 2). However, we observe negative and significant effects of REG-AID$_{pc}$, when interacted with POLICY-AID$_{pc}$ and DIS-AID$_{pc}$ respectively. It appears that none of the components of energy aid complements with REG-AID$_{pc}$ for increasing modern renewable shares at lag 1. Findings related to the control variables are consistent with previous results (Table 2), with certain variations in significance levels.

4.2 Panel quantile regression results

The results of the panel quantile regression estimator are presented in Tables 5–8. The results are reported for the 10th, 20th…….,80th, and 95th percentiles of the conditional distribution of REC (Table 5 and 7). For NHREC, we report the findings based on the 30th percentile and above because of very small and insignificant coefficients in the case of lower percentiles (Table 6 and 8). The results in Table 5 reveal that EAID$_{pc}$ homogenously increases REC, the magnitude of which is greater at lower quantiles. Contrarily, EAID$_{pc}$ increases NHREC at quantile 95 and decreases NHREC at lower quantiles, as presented in Table 6. It indicates that EAID$_{pc}$ effectively increases the share of modern renewable technologies in countries that have already adopted them on a large scale.

Table 5: Estimated effect of total energy aid on REC with quantile regression

MODEL VARIABLES	(1) Q.10	(2) Q.20	(3) Q.30	(4) Q.40	(5) Q.50	(6) Q.60	(7) Q.70	(8) Q.80	(9) Q.95
L1. $EAID_{pc}$	–0.00 (0.00)	0.05*** (0.00)	0.03*** (0.00)	0.05*** (0.00)	0.01*** (0.00)	0.00 (0.00)	0.00*** (0.00)	0.01*** (0.00)	0.00*** (9.87e-05)
EC	0.44*** (0.00)	0.46*** (0.00)	0.43*** (0.00)	0.22*** (0.00)	0.13*** (0.0)	0.05*** (0.00)	0.04*** (0.00)	0.04*** (0.00)	0.00*** (6.51e-05)
RENT	0.03*** (0.00)	–0.08*** (0.01)	–0.02*** (0.00)	–0.03*** (0.00)	–0.09*** (0.00)	–0.06*** (0.00)	–0.07*** (0.00)	–0.11*** (0.00)	–0.06*** (9.69e-05)
GDP_{pc}	2.51*** (0.01)	2.23*** (0.01)	1.92*** (0.02)	1.01*** (0.00)	0.56*** (0.01)	0.44*** (0.00)	0.23*** (0.01)	0.23*** (0.00)	–0.02*** (0.00)
DCPS	–0.04*** (0.00)	–0.08*** (0.01)	–0.14*** (0.01)	–0.19*** (0.00)	–0.09*** (0.00)	0.03*** (0.00)	0.00 (0.00)	–0.07*** (0.00)	–0.05*** (0.00)
FDI	1.09*** (0.08)	2.38*** (0.04)	2.86*** (0.03)	1.28*** (0.03)	0.70*** (0.06)	0.64*** (0.00)	0.78*** (0.00)	0.81*** (0.01)	0.38*** (0.00)
CO_2	–1.71*** (0.01)	–1.74*** (0.01)	–1.75*** (0.01)	–1.07*** (0.00)	–0.75*** (0.01)	–0.63*** (0.00)	–0.46*** (0.00)	–0.36*** (0.00)	–0.05*** (0.00)
GOV	–0.55*** (0.02)	–0.12*** (0.02)	0.45*** (0.05)	0.63*** (0.00)	0.88*** (0.03)	0.55*** (0.01)	0.52*** (0.01)	0.10*** (0.00)	–0.14*** (0.00)
POLITY	1.11*** (0.02)	0.95*** (0.01)	0.65*** (0.02)	0.19*** (0.00)	0.06*** (0.01)	0.03*** (0.00)	0.08*** (0.00)	0.13*** (0.00)	0.20*** (0.00)
UI	0.19*** (0.07)	0.08** (0.03)	0.14*** (0.04)	0.18*** (0.02)	0.06** (0.02)	0.08*** (0.01)	0.39*** (0.01)	0.45*** (0.00)	0.11*** (0.00)
Obs.	995	995	995	995	995	995	995	995	995
No. of countries	67	67	67	67	67	67	67	67	67

Notes: All variables are in logarithmic form, and consequently, the estimates coefficients are elasticities.Standard errors in the parentheses. *, **, *** significant at 10, 5, and 1 percent respectively. L1 (lag operator) represents the first lag.

EC is consistently positive and significant for REC and NHREC till the 80th quantile.EC starts negatively affecting NHREC at higher quantile (Q.95). It indicates that once countries have achieved substantial RE deployment through modern renewable sources, they shift to hydro or fossil fuels to meet further increase in energy demand. The coefficient of RENT is homogenously negative and significant for both REC and NHREC. The coefficient of GDP_{pc} is uniformly positive and significant for NHREC. However, at higher quantiles, its effect is negative on REC, supporting the argument that economic expansion and the resultant higher electricity demand again shift the production capacity favouring conventional fuels that are easy to produce and have a well-established market (Marques and Fuinhas 2011; Cadoret and Padovano, 2016). Coefficients of domestic credit (DCPS)are negative and significant for REC across the entire distribution and until the 50th quantile for NHREC. At higher quantiles (from Q 60 to 95), DCPS increases NHREC (Table-6). It indicates that financial intermediation in these bank-based developing countries becomes conducive for modern RE deployment once these countries have attained a substantial share of modern renewable in total electricity capacity. FDI is homogenously positive and significant for REC. For NHREC, FDI gains significance at 95th quantile. It suggests the need for domestic and international public funding at the initial stages of modern RE deployment as private cross-border investments are effective when the share of modern renewable in the total electricity capacity is high. Similar to system GMM results, the coefficient of CO_2 is homogenously negative and significant for both REC and NHREC.

With regard to institutional variables, we find the heterogeneous effect of governance indicators on RE deployment. We observe the positive impact of governance indicator only at the middle of the distribution for REC (30th to 80th quantiles) and at lower quantiles (30th to 50th quantiles), in case of NHREC. It indicates that higher governance readiness supports fossil fuel sources in countries with low and higher RE shares. The probable reason might be that countries with very low and high RE shares need to tap fossil fuels sources due to shallow penetration of RE technologies and limited RE capacity to meet the country's expanding economic need with RE technologies, respectively. The democratic regime is significantly conducive for the adoption of both REC and NHREC across the entire distribution. Similar to system GMM findings, UI has a homogenous positive and significant effect on REC. In contrast, it exerts mostly negative and significant effects on NHREC, particularly at lower and higher quantiles.

Table 6: Estimated effect of total energy aid on NHREC with quantile regression

MODEL VARIABLES	(1) Q.30	(2) Q.40	(3) Q.50	(4) Q.60	(5) Q.70	(6) Q.80	(7) Q.95
L1. $EAID_{pc}$	0.00 (0.00)	–0.03*** (0.00)	–0.01*** (0.00)	0.02 (0.02)	0.00 (0.02)	–0.01 (0.03)	0.06*** (0.00)
EC	0.12*** (0.00)	0.26*** (0.00)	0.30*** (0.00)	0.15*** (0.00)	0.22*** (0.01)	0.08*** (0.01)	–0.11*** (0.00)
RENT	–0.00*** (0.00)	–0.01*** (0.00)	–0.05*** (0.00)	–0.08*** (0.00)	–0.16*** (0.00)	–0.29*** (0.02)	–0.54*** (0.00)
GDP_{pc}	0.08*** (0.00)	0.07*** (0.00)	0.08*** (0.02)	0.53*** (0.04)	0.64*** (0.04)	1.03*** (0.17)	0.56*** (0.02)
DCPS	–0.03*** (0.00)	–0.09*** (0.00)	–0.21*** (0.00)	0.16*** (0.02)	0.27*** (0.03)	0.52*** (0.02)	0.94*** (0.03)
FDI	–0.31*** (0.01)	–0.54*** (0.01)	–0.52*** (0.02)	–0.28*** (0.10)	–0.00 (0.05)	–0.08 (0.22)	0.54*** (0.03)
CO_2	–0.05*** (0.00)	–0.08*** (0.00)	0.07*** (0.01)	–0.19*** (0.00)	–0.26*** (0.03)	–0.45*** (0.14)	–0.32*** (0.02)
GOV	0.10*** (0.01)	0.29*** (0.02)	0.25*** (0.03)	–0.26*** (0.04)	–0.05*** (0.01)	–0.70*** (0.14)	–1.62*** (0.04)
POLITY	0.13*** (0.00)	0.14*** (0.01)	0.36*** (0.00)	0.37*** (0.01)	0.33*** (0.01)	0.69*** (0.02)	0.65*** (0.01)
UI	–0.02*** (0.00)	–0.03*** (0.01)	–0.08*** (0.01)	0.17*** (0.04)	0.35*** (0.02)	–0.38*** (0.05)	–0.45*** (0.05)
Obs.	995	995	995	995	995	995	995
No. of countries	67	67	67	67	67	67	67

Notes: Same as table 5.

The estimated results of different categories of energy aid on REC and NHREC are presented in tables 7 and 8, respectively. The effect of REG-AID_{pc} on REC is homogenously positive from 20th to 95th quantiles, whereas its effect on NHREC is heterogeneous, mainly positive, and significant for middle quantiles (50th to 70th quantiles, Table 9). The reason might be that implementing new and modern renewable sources requires minimum resources and recipients' willingness to follow RE deployment. Even a limited substitution for cleaner electricity sources gives donors the signal about the recipient's inclination to adopt modern renewable energy sources. REG-AID_{pc} is counterproductive at the higher share of NHREC, which indicates that concessional funding for renewable energy generation might crowds out private RE investments in countries with a higher share of modern renewables and thereby halts NHREC expansion.

Table 7: Estimated effects of different components of energy aid on REC with quantile regression

MODELS VARIABLES	(1) Q.10	(2) Q.20	(3) Q.30	(4) Q.40	(5) Q.50	(6) Q.60	(7) Q.70	(8) Q.80	(9) Q.95
L1. REG-AID_{pc}	-0.43^{***} (0.08)	1.30^{***} (0.19)	1.57^{***} (0.11)	1.41^{***} (0.12)	0.44^{***} (0.03)	0.93^{***} (0.005)	0.48^{***} (0.05)	0.23^{***} (0.03)	0.23^{***} (0.04)
L1. NREG-$AID_{pc\_}$	-0.04^{***} (0.00)	-0.05^{***} (0.00)	-0.02^{***} (0.00)	-0.07^{***} (0.00)	-0.06^{***} (0.00)	-0.05^{***} (0.00)	-0.02^{***} (0.00)	-0.03^{***} (0.00)	-0.01^{***} (0.00)
L1. POLICY-AID_{pc}	0.04^{***} (0.01)	0.13^{***} (0.02)	0.40^{***} (0.01)	0.05 (0.07)	0.13^{***} (0.00)	0.04^{***} (0.00)	-0.06^{**} (0.02)	-0.07^{***} (0.01)	-0.05^{***} (0.00)
L1. DIS-AID_{pc}	0.04^{***} (0.00)	0.05^{***} (0.00)	0.02^{***} (0.00)	–0.00 (0.00)	0.00^{***} (0.00)	0.01^{***} (0.00)	0.01 (0.00)	0.04^{***} (0.00)	0.01^{***} (0.00)
EC	0.43^{***} (0.00)	0.45^{***} (0.00)	0.46^{***} (0.00)	0.15^{***} (0.02)	0.09^{***} (0.00)	0.06^{***} (0.00)	0.05^{***} (0.00)	0.04^{***} (0.00)	0.01^{***} (0.00)
RENT	0.06^{***} (0.00)	-0.01^{***} (0.00)	0.02^{***} (0.00)	-0.08^{***} (0.02)	-0.10^{***} (0.00)	-0.08^{***} (0.00)	-0.09^{***} (0.00)	-0.13^{***} (0.00)	-0.06^{***} (0.00)
GDP_{pc}	2.54^{***} (0.01)	2.14^{***} (0.01)	1.94^{***} (0.01)	1.01^{***} (0.00)	0.58^{***} (0.00)	0.40^{***} (0.00)	0.13^{***} (0.04)	0.10^{***} (0.01)	-0.05^{***} (0.00)
DCPS	-0.01^{***} (0.00)	-0.11^{***} (0.00)	-0.19^{***} (0.00)	-0.05^{*} (0.02)	-0.07^{***} (0.00)	-0.01^{***} (0.00)	–0.00 (0.01)	-0.09^{***} (0.00)	-0.08^{***} (0.00)
FDI	1.08^{***} (0.01)	1.87^{***} (0.02)	2.72^{***} (0.03)	1.68^{***} (0.12)	0.86^{***} (0.02)	0.61^{***} (0.00)	0.73^{***} (0.01)	0.84^{***} (0.01)	0.45^{***} (0.00)
CO_2	-1.70^{***} (0.01)	-1.64^{***} (0.00)	-1.73^{***} (0.01)	-1.073^{***} (0.01)	-0.77^{***} (0.00)	-0.62^{***} (0.00)	-0.39^{***} (0.02)	-0.22^{***} (0.01)	-0.04^{***} (0.00)
GOV	-0.55^{***} (0.02)	0.20^{***} (0.01)	0.33^{***} (0.02)	0.16 (0.15)	0.70^{***} (0.02)	0.73^{***} (0.00)	0.41^{***} (0.01)	0.07^{***} (0.02)	-0.11^{***} (0.00)
POLITY	1.22^{***} (0.00)	0.94^{***} (0.01)	0.62^{***} (0.01)	0.00 (0.01)	-0.04^{***} (0.01)	-0.06^{***} (0.00)	0.16^{***} (0.01)	0.18^{***} (0.02)	0.21^{***} (0.00)
UI	0.09^{***} (0.01)	0.10^{***} (0.03)	0.15^{***} (0.014)	0.07 (0.09)	0.08^{***} (0.03)	0.08^{***} (0.00)	0.29^{***} (0.09)	0.23^{***} (0.01)	-0.03^{***} (0.00)
Obs.	995	995	995	995	995	995	995	995	995
No. of countries	67	67	67	67	67	67	67	67	67

Notes: Same as table 5.

As expected, the effect of NREG-AID$_{pc}$ on REC is homogenously negative and significant. In contrast, we find a negative and significant impact of NREG-AID$_{pc}$ on NHREC only at higher quantiles (60th to 95th), when renewable technologies become competent for larger-scale commercial use, thereby become competitive with fossil fuels. POLICY-AID$_{pc}$ and DIS-AID$_{pc}$ are homogenously positive and significant till 60th and 95th quantile, respectively, for REC. Contrary to these findings, we find that POLICY-AID$_{pc}$ and DIS-AID$_{pc}$ are homogenously unfavourable for NHREC, except for EDIS$_{pc}$ at 95th quantile. The results for all the control variables are consistent with the aggregate energy aid analysis, except for UI for NHREC (Table 8), which is uniformly positive till 70th quantile and turned negative after that. We may conjecture that economic and political uncertainty increases NHREC at the initial stage of transition. It only impedes the sustainable substitution process at a later stage when private investments take centre stage.

Table 8: Estimate effects of different components of energy aid on NHREC with quantile regression

MODELS VARIABLES	(1) Q.30	(2) Q.40	(3) Q.50	(4) Q.60	(5) Q.70	(6) Q.80	(7) Q.95
L1. REG-AID$_{pc}$	–0.17*** (0.04)	–0.62*** (0.01)	0.96** (0.43)	2.41*** (0.15)	1.66*** (0.03)	–3.12*** (0.52)	0.60 (0.46)
L1. NREG-AID$_{pc_}$	0.00** (0.00)	0.01** (0.00)	0.01** (0.00)	–0.00*** (0.00)	–0.01*** (0.00)	–0.03*** (0.00)	–0.01 (0.00)
L1. POLICY-AID$_{pc}$	–0.02*** (0.00)	–0.07*** (0.00)	0.02 (0.06)	–0.19*** (0.01)	–0.27*** (0.00)	–0.25*** (0.02)	0.06 (0.04)
L1. DIS-AID$_{pc}$	–0.01*** (0.00)	–0.03*** (0.00)	–0.04*** (0.00)	–0.01*** (0.00)	–0.02*** (0.00)	–0.01*** (0.00)	0.02** (0.01)
EC	0.12*** (0.00)	0.24*** (0.00)	0.22*** (0.00)	0.17*** (0.00)	0.15*** (0.00)	0.07*** (0.00)	–0.12*** (0.01)
RENT	–0.00*** (0.00)	–0.02*** (0.00)	–0.11*** (0.01)	–0.11*** (0.00)	–0.17*** (0.00)	–0.28*** (0.00)	–0.51*** (0.03)
GDP$_{pc}$	0.04*** (0.00)	0.13*** (0.00)	0.28*** (0.05)	0.47*** (0.03)	0.50*** (0.00)	0.86*** (0.04)	0.53*** (0.02)
DCPS	0.00 (0.00)	–0.01*** (0.00)	–0.10** (0.04)	0.18*** (0.00)	0.24*** (0.00)	0.48*** (0.02)	0.94*** (0.03)
FDI	–0.25*** (0.01)	–0.43*** (0.01)	–0.48*** (0.06)	–0.46*** (0.02)	0.06*** (0.01)	0.16** (0.07)	0.50*** (0.07)
CO_2	–0.05*** (0.00)	–0.12*** (0.00)	–0.14*** (0.02)	–0.18*** (0.01)	–0.15*** (0.00)	–0.30*** (0.02)	–0.29*** (0.01)
GOV	0.08*** (0.00)	0.16*** (0.00)	0.22*** (0.00)	–0.09*** (0.02)	–0.10*** (0.00)	–0.91*** (0.06)	–1.58*** (0.05)
POLITY	0.12*** (0.00)	0.24*** (0.00)	0.21*** (0.02)	0.33*** (0.01)	0.43*** (0.00)	0.78*** (0.01)	0.62*** (0.02)
UI	0.03*** (0.00)	0.02*** (0.00)	0.11*** (0.02)	0.21*** (0.03)	0.21*** (0.00)	–0.20*** (0.05)	–0.57*** (0.05)
Obs.	995	995	995	995	995	995	995
No. of countries	67	67	67	67	67	67	67

Notes: Same as table 5.

4.3 Robustness check

In order to test the robustness of our main findings, we re-estimate all the regression models with a second and third lag of ODA variables, given that it might take a longer time for concessional funding to impact RE deployment (all the results are presented in Appendix B). The results with system GMM are almost similar to our main findings (See Table B1–B3). The coefficients of REG_{pc} are positive, significant, and greater than those of $EAID_{pc}$ (Table B1). For disaggregate analysis (Table B2, B3), NREG-AID_{pc} coefficients are negative as before. However, the coefficient appears to be statistically insignificant with subsequent lags. POLICY-AID_{pc} and DIS-AID_{pc} coefficients are negative and significant for both REC and NHREC.

Contrary to our main findings of interaction effects on RE deployment, we find that DIS_{pc} complements REG_{pc} in augmenting REC and NHREC with the time lag (Table B2, B3). However, $POLICY_{pc}$ does not complement with REG_{pc} for increasing the share of modern renewable technologies. The findings with quantile regressions are presented in Tables B4 to B11. All the results are, by large consistent with our main findings.

5 Conclusion and policy implications

5.1 Conclusion

The paper has examined the effectiveness of energy ODA and its composition on the substitution potential of RE sources in developing countries by employing relative definitions of RE deployment. For this purpose, we first use dynamic panel data estimation techniques. Then, we analyze the same with panel quantile regression techniques to investigate the effectiveness of energy aid and its components at the different levels of the RE shares.

The results with panel data estimation show that the RE generation component of total energy ODA significantly increases the proportion of RE capacity in the total electricity capacity. However, the magnitude and significance of the positive effect reduces with non-hydro renewable shares. In contrast, ODA for fossil fuels energy generation significantly hampers the diffusion of modern renewable sources and reduces RE generation ODA's effectiveness for RE deployment. Distribution aid compliments renewable electricity generation aid (REG_{pc}) for RE deployment with substantial time lags. Policy aid compliments REG_{pc} only when hydro sources are part of total renewable capacity.

The findings based on panel quantile regression technique demonstrate the positive and significant effect of energy ODA on REC in countries with lower proportions of renewable capacity in total electricity capacity. The same effect is obtained for non-hydro renewables at upper quantiles. Thus, energy ODA does not seem to play a "catalyst role" in adopting modern renewable technologies. $REG\text{-}AID_{pc}$ homogenously increases the share of total renewable capacity. In contrast, it has a heterogeneous effect on modern renewable technologies. ODA for electricity generation from fossil fuels obstructs transition to both hydro and non-hydro RE sources. Energy policy and distribution ODA encourage hydro RE mainly in countries with a low share of renewables and are not beneficial for non-hydro RE sources across the entire distribution.

5.2 Policy implications

Based on the above results, we draw the following policy implications related to the efficacy of energy sector ODA, relevant to decarbonising energy infrastructure and promoting climate change mitigation. First, Donors need to pay more attention to energy ODA's composition while expanding the concessional funding for building low-carbon energy infrastructure. There should be limited support to carbon-intensive energy generation projects in developing countries, at the earliest. RE generation projects should diversify their targets from already developed RE sources like hydropower to modern renewable sources that require extensive external support at the initial stage of adoption and commercial penetration of technologies.

Second, donors should continue to provide support to energy policy and distribution with renewable energy projects catering to the specific needs of hydro and non-hydro renewable sources separately. Separate funding for strengthening policy environment and transmission networks may lead to unfavourable outcomes. Therefore donors need to provide financing for RE projects collaborating with concessional funds for supporting energy policy and transmission networks. The focus should be on creating an enabling environment for large-scale acceptance of modern renewable technologies in those developing nations that initiated diversifying their energy mix with new and contemporary renewable sources (Solar, Wind, Geothermal). Third, recipients need to build up domestic institutions and promote movement towards a democratic regime to achieve sustainable energy goals. Global political and economic uncertainty through increasing geopolitical risks accelerates the shift from fossil to hydro sources. It deters investments in modern renewable sources in countries with a high share of modern renewables. Therefore, continuous support from the national government and local private players appear to be fundamental for increasing the modern RE shares. Fourth, recipients should attract private investments in the renewable sector once the industry experiences successful implementation of certain projects through donor funding. It makes domestic and foreign private investments more effective for RE deployment.

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Appendix

Appendix A Snapshot of existing studies, data description, and sources

Table A1: Summary of existing literature on energy ODA effectiveness

Author (s)	Coverage / Scope	Method /technique	Dependent variable	Independent variables	Findings
Pohl and Mulder (2013)	Developing countries	Two-part model and Two step selection model	Electricity generation from biomass, geothermal, solar, and wind (Kilowatt-hour per capita)	Net ODA as a percentage of GNI	ODA reduces the probability of non-hydro renewable electricity generation.
Kretschmer et al. (2013)	Low-income, lower middle income, and upper-middle-income countries	Dynamic GMM and Least square dummy variable.	Energy intensity and emission intensity	Total aid, energy aid commitments, Industry aid commitments	Aid is effective in reducing the energy intensity of GDP and not carbon intensity.
Gualberti et al. (2014)	Sub-Saharan Africa, low and lower-middle-income countries, low electricity access countries.	Fixed effects, Random effect, pooled regression	Installed capacity of electricity generation	Development finance committed to the energy sector:	Official development finance enhances for electricity production enhances Installed Capacity.
Buntaine and Pizer (2015).	Developing countries	Descriptive statistics, pooled and fixed effects	The number of Private renewable projects in solar and wind technologies.	Projects financed with domestic public resources and Net aid	Donors are not channelizing the finance in countries where private investment is limited. No positive effect of donor funds on private RE projects
Hašcicet al. (2015)	Developing countries	Heckman selection model (Type – II, Tobit)	Private finance in renewable energy generation sectors	Bilateral public flows (Debt and Equity), ODA loans, and grants through RIO marker	Public finance (domestic. Bilateral, and multilateral) positively affects private financial flows in the RE sector.
Kim (2018)	Developing countries	Fixed effect estimator	New electricity capacity from non-hydro renewable energy	Foreign aid disbursement for non-hydro renewable energy projects	Energy aid with technical cooperation has a more substantial effect on renewable energy capacity, particularly in low-income countries.
Kim (2019)	Developing countries	Heckman selection model	Foreign aid in the energy sector (Renewable, non-renewable, policy, and transmission)	Recipient's energy needs and donor interest	Donors respond to the recipient's sustainable energy needs, particularly with energy policy aid.
Ragosa and Warren (2019)	Developing countries	Linear and logistic fixed effects model	1. Foreign private investment flows in the renewable energy sector 2. Foreign Private Investment (binary)	Financial flows from multilateral and national development banks	Provision of international public finance, regulatory support measures, political stability is strong drivers of cross-border investment in RE.
Yang and Park (2020)	Developing countries	Fixed effect estimator	On-grid renewable electricity generation (kWh) is sourced from hydroelectricity, geothermal, solar, tide / wave, fuel cells, wind, biomass, and waste.	ODA committed to energy generation from renewable sources.	RE financial incentive policy and degree of political democracy conditioned the effectiveness of RE ODA.
Maruta and Banerjee (2020)	Developing countries	Two-stage least squares	Energy efficiency measured as GDP per unit of energy use at constant 2011PPP$ per Kg of oil equivalent.	Per capital energy aid commitments.	Energy aid has a significant positive effect on energy efficiency.

Table A2: Data definitions and sources

Variable	Definition	Source	Exp Sign
Dependent Variables			
Renewable electricity installed capacity as a percentage of total electricity installed capacity (REC)	Renewable electricity installed capacity is the maximum output of electricity that a generator can produce from renewable sources, including hydro, biomass, geothermal, ocean, solar, and wind. Total electricity installed capacity is the maximum amount of electricity a generator can produce from all sources	International energy statistics, US-EIA	
Non-hydroelectricity installed capacity as a percentage of total electricity installed capacity (NHREC)	Non-hydroelectricity installed capacity is the maximum amount of electricity that a generator can produce from all renewable sources, excluding hydro.	International energy statistics, US-EIA	
Independent Variables.			
Per capita disbursement of aid to the energy sector (constant US million dollars, 2017) ($EAID_{pc}$)	Per capita Official development assistance (ODA)/aid is defined as those flows in the energy sector to countries and territories on the DAC List of ODA Recipients provided by official donors (Bilateral plus multilateral), divided by the total population. Each transaction of which: a) is administered with the promotion of the economic development and welfare of developing countries as its main objective; and b) is concessional in character and conveys a grant element of at least 25% (calculated at a discount rate of 10 percent).	OECD-Credit Reporting System.	Positive
Per capita disbursement of energy aid for energy policy (constant US million dollars, 2017) ($POLICY\text{-}AID_{pc}$)	Aid for energy policy targets Energy policy and administrative management, Energy Education/training, Energy research, energy conservation, and demand-side efficiency, divided by the total population.	OECD-Credit Reporting System.	Positive
Per capita disbursement of energy aid for renewable energy generation (constant US million dollars, 2017) ($REG\text{-}AID_{pc}$)	Aid for renewable energy generation targets multiple renewable technologies, including hydro, solar, wind marine, geothermal, and biofuel, divided by the total population	OECD-Credit Reporting System.	Positive
Per capita disbursement of energy aid for non-renewable energy generation (constant US million dollars, 2017) ($NREG\text{-}AID_{pc}$)	Aid for renewable energy generation targets all fossil fuel sources, including Coal, oil, and natural gas, divided by the total population	OECD-Credit Reporting System.	Negative
Per capita disbursement of energy aid for energy distribution (constant US million dollars, 2017) ($DIS\text{-}AID_{pc}$)	Aid for energy distribution targets electric power transmission and distribution for the centralized grid and isolated mini-grids, retailed gas distribution, liquid, and solid fossil fuels, divided by the total population.	OECD-Credit Reporting System	Positive/ Negative
Electricity net consumption (billion KWH) (**EC**)	Electricity net consumption = total net electricity generation + electricity imports – electricity exports – electricity transmission and distribution losses. Net consumption excludes the energy consumed by the generating units.	International energy statistics, US-EIA	Positive/ Negative
Total natural resources-forest rent (% of GDP)	Total natural resources rents are the sum of oil rents, natural gas rents, coal rents (hard and soft), mineral rents, and forest rents. Forest rents are roundwood harvest times the product of average prices and a region-specific rental rate.	WDI	Negative
GDP per capita PPP (constant 2011 international dollars).	PPP GDP is gross domestic product converted to international dollars using purchasing power parity rates. An international dollar has the same purchasing power over GDP as the US dollar has in the United States. GDP at purchaser's prices is the sum of gross value added by all resident producers in the economy plus any product taxes and minus any subsidies not included in the value of the products. Data are in constant 2011 international dollars.	WDI	Positive/ Negative
Domestic credit to private sector (% of GDP)	Domestic credit to the private sector refers to financial resources provided to the private sector by financial corporations, such as through loans, purchases of nonequity securities, trade credits, and other accounts receivable that establish a claim for repayment.	WDI	Positive
Foreign direct investment, net inflows (% of GDP)	Foreign direct investments are the net inflows of investment to acquire a lasting management interest (10 percent or more of voting stock) in an enterprise operating in an economy other than that of the investor. It is the sum of equity capital, reinvestment of earnings, other long-term capital, and short-term capital, as shown in the balance of payments. This series shows net inflows (new investment inflows less disinvestment) in the reporting economy from foreign investors and is divided by GDP.	WDI	Positive

Table A2 (continued)

Variable	Definition	Source	Exp Sign
Independent Variables.			
CO_2 emissions (metric tons per capita)	Carbon dioxide emissions are those stemming from the burning of fossil fuels and the manufacture of cement. They include carbon dioxide produced during the consumption of solid, liquid, and gas fuels and gas flaring.	WDI	Positive/ Negative
Governance Readiness	The stability of the society and institutional arrangements that contribute to the investment risks. A stable country with a high governance capacity reassures investors that the invested capital could grow under the help of responsive public services and without significant interruption.	ND-GAIN	Positive
Polity5	The POLITY score is computed by subtracting the AUTOC score from the DEMOC score; the resulting unified polity scale ranges from +10 (strongly democratic) to 10 (strongly autocratic).	Marshall and Gurr, 2020. Centre for Systemic Peace	Positive
Uncertainty Index	The index captures uncertainty related to economic and political developments, regarding both near-term (e.g., the uncertainty created by the United Kingdom's referendum vote in favour of Brexit) and long-term concerns (e.g., uncertainty engendered by the impending withdrawal of international forces in Afghanistan, or tensions between North and South Korea), using Economist Intelligence Unit (EIU) country reports.	(Ahir et al., 2018)	Negative

Appendix B Results of the robustness tests

Table B1: Estimated effect of total and renewable energy aid on renewable energy deployment with system GMM

MODEL VARIABLES	(1) REC-EAID$_{pc}$	(2) NHREC-EAID$_{pc}$	(3) REC-REGAID$_{pc}$	(4) NHREC-REGAID$_{pc}$
Results with lag 2				
L1. REC	0.97*** (0.02)		0.93*** (0.01)	0.97*** (0.12)
L1. NHREC		0.87*** (0.01)		
L2. EAID$_{pc}$	0.06*** (0.01)	0.01* (0.00)		
L2. REG-AID$_{pc}$			1.58*** (0.34)	2.10 (2.57)
Results with lag 3				
L1. REC	0.92*** (0.03)	0.81*** (0.02)	0.98*** (0.01)	0.75*** (0.02)
L1. NHREC				
L3. EAID$_{pc}$	0.10*** (0.02)	0.07*** (0.01)		
L3. REG-AID$_{pc}$			0.48*** (0.12)	0.60*** (0.12)

Notes: We replicate the estimation procedure of Table-3 with lagged values of aid covariates. L2represents the second lag, and L3 represents the third lag**.** Columns in the table report the estimated coefficient of each model with the two-step system GMM. Standard errors in the parentheses. *, **, *** significant at 10, 5, and 1 percent respectively.

Table B2: Estimated effect of different components of energy aid on REC with system GMM

MODEL Dependent Variable-REC	(1) NREG	(2) NREG	(3) POLICY	(4) POLICY	(5) DISTRI	(6) DISTRI
Results with lag 2						
L1. REC	0.88*** (0.02)	0.86*** (0.02)	0.97*** (0.06)	0.93*** (0.01)	0.86*** (0.03)	0.96*** (0.01)
L2. REG-AID$_{pc}$	1.59*** (0.52)	2.90*** (0.46)	1.30** (0.65)	0.30 (1.15)	1.18*** (0.48)	3.50*** (0.50)
L2. NREG-AID$_{PC}$	–0.03*** (0.00)	–2.61*** (0.45)				
L2. (REG-AID$_{pc}$* NREG-AID$_{PC}$)		0.74*** (0.13)				
L2. POLICY-AID$_{pc}$			–0.36*** (0.10)	–8.88* (5.29)		
L2. (REG-AID$_{pc}$* POLICY-AID$_{pc}$)				2.51 (1.50)		
L2. DIS-AID$_{pc}$					–0.04*** (0.01)	–4.37*** (0.61)
L2. (REG-AID$_{pc}$* DIS-AID$_{pc}$)						1.25*** (0.17)

Table B2 (continued)

MODEL Dependent Variable-REC	(1) NREG	(2) NREG	(3) POLICY	(4) POLICY	(5) DISTRI	(6) DISTRI
Results with lag 3						
L1. REC	0.90*** (0.02)	0.68*** (0.08)	0.95*** (0.02)	0.88*** (0.01)	0.96*** (0.02)	0.94*** (0.03)
L3. REG-AID$_{pc}$	0.30 (1.11)	4.81 (3.06)	0.78 (1.57)	0.88** (0.43)	0.10 (1.55)	2.33 (2.76)
L3. NREG-AID$_{PC}$	(0.00) (0.02)	–0.53 (1.66)				
L3. (REG-AID$_{pc}$* NREG-AID$_{PC}$)		0.16 (0.47)				
L3. POLICY-AID$_{pc}$			–0.11* (0.06)	–3.73*** (1.43)		
L3. (REG-AID$_{pc}$* POLICY-AID$_{pc}$)				1.11*** (0.41)		
L3. DIS-AID$_{pc}$					–0.01 (0.03)	–2.61 (3.96)
L3. (REG-AID$_{pc}$* DIS-AID$_{pc}$)						0.73 (1.13)

Notes: We replicate the estimation procedure of Table-4 with lagged values of aid covariates. L2represents the second lag, and L3 represents the third lag**.** Columns in the table report the estimated coefficient of each model with the two-step system GMM. Standard errors in the parentheses. *, **, *** significant at 10, 5, and 1 percent respectively.

Table B3: Estimated effect of different components of energy aid on NHREC with system GMM

MODEL Dependent Variable-NHREC	(1) NREG	(2) NREG	(3) POLICY	(4) POLICY	(5) DISTRI	(6) DISTRI
Results with lag 2						
L1. NHREC	0.82*** (0.13)	0.54*** (0.07)	0.85*** (0.07)	0.89*** (0.04)	0.62*** (0.05)	0.54*** (0.03)
L2. REG-AID$_{pc}$	0.20 (2.97)	1.10 (1.08)	–0.94 (0.94)	–1.36 (0.90)	0.18 (0.45)	3.40*** (0.82)
L2. NREG-AID$_{PC}$	–0.01 (0.04)	–0.58 (1.39)				
L2. (REG-AID$_{pc}$* NREG-AID$_{PC}$)		0.16 (0.40)				
L2. POLICY-AID$_{pc}$			–0.44*** (0.12)	4.55 (6.93)		
L2. (REG-AID$_{pc}$* POLICY-AID$_{pc}$)				–1.36 (1.99)		
L2. DIS-AID$_{pc}$					–0.08*** (0.02)	–3.32*** (0.96)
L2. (REG-AID$_{pc}$* DIS-AID$_{pc}$)						0.92*** (0.27)

Table B3 (continued)

MODEL Dependent Variable-NHREC	(1) NREG	(2) NREG	(3) POLICY	(4) POLICY	(5) DISTRI	(6) DISTRI
Results with lag 3						
L1. NHREC	0.76*** (0.11)	0.73*** (0.09)	0.93*** (0.05)	0.69*** (0.07)	0.77*** (0.08)	0.40*** (0.04)
L3.REG-AID$_{pc}$	–1.76 (2.30)	0.99 (1.10)	–1.45 (1.12)	1.38 (0.93)	0.59 (0.53)	6.74 (4.55)
L3. NREG-AID$_{PC}$	–0.03 (0.03)	–0.52 (0.74)				
L3. (REG-AID$_{pc}$* NREG-AID$_{PC}$)		0.14 (0.21)				
L3. POLICY-AID$_{pc}$			–0.16 (0.18)	26.31** (3.47)		
L3. (REG-AID$_{pc}$* POLICY-AID$_{pc}$)				–7.59 (3.47)**		
L3. DIS-AID$_{pc}$					–0.04* (0.02)	–4.32 (3.98)
L3. (REG-AID$_{pc}$* DIS-AID$_{pc}$)						1.15 (1.14)

Notes: We replicate the estimation procedure of Table-5 with lagged values of aid covariates. L2represents the second lag, and L3 represents the third lag**.** Columns in the table report the estimated coefficient of each model with the two-step system GMM. Standard errors in the parentheses. *, **, *** significant at 10, 5, and 1 percent respectively.

Table B4: Estimated effect of second lag of total energy aid on REC with quantile regression

MODEL VARIABLES	(1) Q.10	(2) Q.20	(3) Q.30	(4) Q.40	(5) Q.50	(6) Q.60	(7) Q.70	(8) Q.80	(9) Q.95
L2. EAID$_{pc}$	0.01*** (0.002)	0.02*** (0.00397)	0.06*** (0.00308)	0.01*** (0.00485)	0.00 (0.00)	–0.00 (0.00)	0.00* (0.00)	–0.00 (0.00)	0.02*** (0.00)
EC	0.43*** (0.00)	0.42*** (0.00)	0.42*** (0.02)	0.21*** (0.00)	0.09*** (0.00)	0.03*** (0.00)	0.05*** (0.00)	0.02*** (0.00)	0.03*** (0.00)
RENT	0.05*** (0.00)	–0.06*** (0.00)	–0.00 (0.00)	–0.06*** (0.00)	–0.10*** (0.00)	–0.04*** (0.00)	–0.06*** (0.00)	–0.10*** (0.00)	–0.11*** (0.00)
GDP$_{pc}$	2.57*** (0.01)	2.26*** (0.01)	1.89*** (0.03)	0.98*** (0.01)	0.55*** (0.01)	0.38*** (0.00)	0.26*** (0.01)	0.26*** (0.00)	–0.07*** (0.00)
DCPS	0.02*** (0.00)	–0.08*** (0.01)	–0.11*** (0.02)	–0.11*** (0.01)	–0.10*** (0.00)	0.02*** (0.00)	0.02*** (0.00)	–0.03*** (0.00)	–0.12*** (0.00)
FDI	1.10*** (0.02)	1.38*** (0.07)	2.38*** (0.04)	1.53*** (0.03)	1.06*** (0.03)	0.60*** (0.01)	0.71*** (0.01)	0.85*** (0.00)	0.55*** (0.01)
CO_2	–1.76*** (0.02)	–1.71*** (0.00)	–1.75*** (0.02)	–1.08*** (0.01)	–0.72*** (0.00)	–0.56*** (0.01)	–0.49*** (0.00)	–0.39*** (0.00)	–0.07*** (0.00)
GOV	–0.53*** (0.01)	0.16*** (0.02)	0.45*** (0.12)	0.62*** (0.04)	0.80*** (0.01)	0.52*** (0.01)	0.51*** (0.01)	0.19*** (0.01)	–0.06*** (0.00)
POLITY	1.13*** (0.01)	1.00*** (0.01)	0.60*** (0.03)	0.21*** (0.02)	0.05*** (0.00)	0.08*** (0.01)	0.09*** (0.007)	0.13*** (0.00)	0.31*** (0.00)
UNI	0.31*** (0.07)	0.23*** (0.03)	0.39*** (0.08)	0.29*** (0.04)	–0.07*** (0.01)	–0.02** (0.01)	0.46*** (0.02)	0.26*** (0.02)	0.11*** (0.00)
Observations	929	929	929	929	929	929	929	929	929
No. of countries	67	67	67	67	67	67	67	67	67

Notes: All variables are in logarithmic form, and consequently, the estimates coefficients are elasticities. Standard errors in the parentheses. *, **, *** significant at 10, 5, and 1 percent respectively. L2 (lag operator) represents second lag.

Table B5: Estimated effect of third lag of total energy aid on REC with quantile regression

MODEL VARIABLES	(1) Q.10	(2) Q.20	(3) Q.30	(4) Q.40	(5) Q.50	(6) Q.60	(7) Q.70	(8) Q.80	(9) Q.95
L3. $EAID_{pc}$	0.06*** (0.00)	0.05*** (0.00)	0.07*** (0.00)	0.03*** (0.00)	–0.00 (0.00)	0.00*** (0.00)	0.00 (0.00)	0.00*** (0.00)	–0.00 (0.00)
EC	0.49*** (0.00)	0.41*** (0.00)	0.36*** (0.00)	0.21*** (0.00)	0.09*** (0.00)	0.04*** (0.00)	0.06*** (0.00)	0.06*** (0.00)	0.03*** (0.00)
RENT	0.01 (0.00)	–0.05*** (0.00)	0.06*** (0.00)	–0.03*** (0.00)	–0.08*** (0.00)	–0.06*** (0.002)	–0.08*** (0.00)	–0.07*** (0.00)	–0.10*** (0.00)
GDP_{pc}	2.36*** (0.02)	2.16*** (0.02)	2.09*** (0.0228)	0.96*** (0.01)	0.54*** (0.00)	0.41*** (0.00)	0.19*** (0.00)	0.15*** (0.0124)	–0.07*** (0.00)
DCPS	–0.10*** (0.02)	–0.06*** (0.01)	–0.13*** (0.00)	–0.07*** (0.01)	–0.11*** (0.00)	0.08*** (0.00)	0.00 (0.02)	–0.11*** (0.00)	–0.13*** (0.00)
FDI	1.23*** (0.05)	1.08*** (0.04)	2.62*** (0.02)	1.44*** (0.02)	0.84*** (0.01)	0.69*** (0.00)	0.76*** (0.03)	0.62*** (0.01)	0.45*** (0.02)
CO_2	–1.65*** (0.01)	–1.71*** (0.01)	–1.78*** (0.01)	–1.03*** (0.01)	–0.72*** (0.00)	–0.63*** (0.00)	–0.44*** (0.01)	–0.36*** (0.01)	–0.08*** (0.00)
GOV	–0.36*** (0.05)	0.39*** (0.04)	0.11*** (0.03)	0.59*** (0.04)	0.89*** (0.01)	0.62*** (0.00)	0.67*** (0.02)	0.47*** (0.02)	0.14** (0.06)
POLITY	1.10*** (0.01)	0.91*** (0.01)	0.57*** (0.02)	0.20*** (0.01)	0.12*** (0.00)	0.03*** (0.00)	0.17*** (0.01)	0.14*** (0.01)	0.31*** (0.02)
UNI	0.26*** (0.03)	0.40*** (0.07)	0.48*** (0.02)	0.30*** (0.03)	–0.02** (0.01)	0.18*** (0.01)	0.53*** (0.04)	0.38*** (0.03)	0.10* (0.05)
Observations	863	863	863	863	863	863	863	863	863
Number of countries	67	67	67	67	67	67	67	67	67

Notes: All variables are in logarithmic form, and consequently, the estimates coefficients are elasticities. Standard errors in the parentheses. *, **, *** significant at 10, 5, and 1 percent respectively. L3 (lag operator) represents the third lag.

Table B6: Estimated effect of second lag of total energy aid on NHREC with quantile regression

MODEL VARIABLES	(1) Q.30	(2) Q.40	(3) Q.50	(4) Q.60	(5) Q.70	(6) Q.80	(7) Q.95
L2. $EAID_{pc}$	–0.007** (0.00)	–0.00 (0.01)	–0.05*** (0.00)	–0.01*** (0.00411)	–0.01 (0.01)	–0.05*** (0.01)	0.03** (0.00)
EC	0.13*** (0.00)	0.25*** (0.00)	0.25*** (0.00)	0.18*** (0.00)	0.19*** (0.01)	0.07*** (0.01)	–0.13*** (0.00)
RENT	–0.01*** (0.00)	–0.01*** (0.00)	–0.07*** (0.00)	–0.12*** (0.00)	–0.21*** (0.00)	–0.29*** (0.01)	–0.55*** (0.00)
GDP_{pc}	0.14*** (0.03)	0.18*** (0.01)	–0.00 (0.00)	0.42*** (0.00)	0.66*** (0.04)	1.08*** (0.12)	0.56*** (0.00)
DCPS	–0.04*** (0.00)	–0.07*** (0.01)	0.06*** (0.00)	0.12*** (0.00)	0.19*** (0.02)	0.53*** (0.01)	0.87*** (0.00)
FDI	–0.04 (0.10)	–0.51*** (0.04)	–0.56*** (0.02)	–0.68*** (0.02)	0.13 (0.08)	0.27*** (0.03)	0.51*** (0.01)
CO_2	–0.08*** (0.01)	–0.14*** (0.00)	–0.03*** (0.00)	–0.10*** (0.00)	–0.22*** (0.02)	–0.51*** (0.10)	–0.32*** (0.00)
GOV	–0.01 (0.04)	0.33*** (0.03)	0.41*** (0.01)	–0.12*** (0.01)	–0.09*** (0.01)	–1.12*** (0.07)	–1.21*** (0.07)
POLITY	0.09*** (0.01)	0.07* (0.04)	0.37*** (0.00)	0.43*** (0.00)	0.61*** (0.03)	0.84*** (0.03)	0.59*** (0.01)
UNI	–0.04* (0.02)	–0.18*** (0.03)	–0.0107 (0.01)	0.25*** (0.01)	0.30*** (0.04)	–0.49*** (0.11)	–0.51*** (0.03)
Observations	929	929	929	929	929	929	929
Number of countries	67	67	67	67	67	67	67

Notes: All variables are in logarithmic form, and consequently, the estimates coefficients are elasticities. Standard errors in the parentheses. *, **, *** significant at 10, 5, and 1 percent respectively. L2 (lag operator) represents second lag.

Table B7: Estimated effect of third lag of total energy aid on NHREC with quantile regression

MODEL VARIABLES	(1) Q.30	(2) Q.40	(3) Q.50	(4) Q.60	(5) Q.70	(6) Q.80	(7) Q.95
L3. $EAID_{pc}$	-0.01^{***} (0.00)	-0.00 (0.02)	-0.02 (0.02)	-0.02^{**} (0.00)	-0.02^{***} (0.00)	-0.02^{***} (0.00)	0.05^{***} (0.01)
EC	0.14^{***} (0.00)	0.30^{***} (0.00)	0.23^{***} (0.00)	0.21^{***} (0.00)	0.23^{***} (0.00)	0.10^{***} (0.00)	-0.07^{***} (0.00)
RENT	-0.02^{***} (0.00)	-0.00 (0.01)	-0.03^{***} (0.00)	-0.12^{***} (0.00)	-0.23^{***} (0.00)	-0.32^{***} (0.01)	-0.55^{***} (0.01)
GDP_{pc}	0.11^{***} (0.00)	0.13^{**} (0.05)	0.14^{***} (0.00)	0.47^{***} (0.01)	0.63^{***} (0.02)	0.69^{***} (0.01)	0.63^{***} (0.01)
DCPS	-0.09^{***} (0.00)	-0.08^{**} (0.03)	0.00 (0.03)	0.20^{***} (0.01)	0.29^{***} (0.00)	0.50^{***} (0.00)	0.86^{***} (0.02)
FDI	-0.10^{***} (0.02)	-0.68^{***} (0.10)	-0.80^{***} (0.06)	-0.51^{***} (0.02)	-0.20^{***} (0.03)	0.12^{**} (0.04)	0.46^{***} (0.05)
CO_2	-0.07^{***} (0.00)	-0.11^{***} (0.02)	-0.05^{***} (0.00)	-0.19^{***} (0.00)	-0.26^{***} (0.01)	-0.20^{***} (0.01)	-0.40^{***} (0.02)
GOV	0.12^{***} (0.01)	0.29^{***} (0.05)	-0.17 (0.16)	-0.18^{***} (0.03)	-0.21^{***} (0.02)	-0.73^{***} (0.06)	-1.35^{***} (0.12)
POLITY	0.10^{***} (0.00)	0.22^{***} (0.02)	0.25^{***} (0.04)	0.49^{***} (0.00)	0.54^{***} (0.00)	0.85^{***} (0.02)	0.51^{***} (0.05)
UNI	-0.05^{**} (0.02)	0.10 (0.07)	-0.02 (0.15)	-0.09^{***} (0.02)	-0.00 (0.01)	-0.47^{***} (0.07)	-0.41^{***} (0.04)
Observations	863	863	863	863	863	863	863
Number of countries	67	67	67	67	67	67	67

Notes: All variables are in logarithmic form, and consequently, the estimates coefficients are elasticities. Standard errors in the parentheses. *, **, *** significant at 10, 5, and 1 percent respectively. L3 (lag operator) represents the third lag.

Table B8: Estimated effect of second lag of different components of energy aid on REC with quantile regression

Model VARIABLES	(1) Q.10	(2) Q.20	(3) Q.30	(4) Q.40	(5) Q.50	(6) Q.60	(7) Q.70	(8) Q.80	(9) Q.95
L2. REG-AID_{pc}	-0.16^{**} (0.07)	0.29^{**} (0.13)	1.39^{***} (0.11)	1.91^{***} (0.03)	0.29 (0.33)	0.90^{***} (0.04)	1.00^{***} (0.09)	0.64^{***} (0.01)	0.51^{***} (0.06)
L2. NREG-$AID_{pc\_}$	-0.00 (0.00)	-0.02^{***} (0.00)	-0.02^{***} (0.00)	-0.04^{***} (0.00)	-0.06^{***} (0.00)	-0.03^{***} (0.00)	-0.02^{***} (0.00)	-0.01^{***} (0.00)	-0.02^{***} (0.00)
L2. POLICY-AID_{pc}	0.07^{*} (0.04)	0.31^{***} (0.01)	0.46^{***} (0.02)	0.24^{***} (0.00)	0.07^{***} (0.01)	0.11^{***} (0.00)	0.07^{***} (0.00)	-0.08^{***} (0.00)	-0.02^{***} (0.00)
L2. DIS-AID_{pc}	0.02^{***} (0.00)	0.07^{***} (0.00)	0.00^{***} (0.00)	-0.01^{***} (0.00)	0.01^{***} (0.00)	-0.00^{**} (0.00)	0.00^{***} (0.00)	0.03^{***} (0.00)	0.01^{***} (0.00)
EC	0.44^{***} (0.00)	0.47^{***} (0.00)	0.43^{***} (0.00)	0.21^{***} (0.00)	0.11^{***} (0.00)	0.07^{***} (0.00)	0.05^{***} (0.00)	0.04^{***} (0.00)	0.00^{**} (0.00)
RENT	0.05^{***} (0.00)	0.00 (0.01)	0.01^{***} (0.00)	-0.02^{***} (0.00)	-0.06^{***} (0.00)	-0.05^{***} (0.00)	-0.07^{***} (0.00)	-0.11^{***} (0.00)	-0.04^{***} (0.00)
GDP_{pc}	2.45^{***} (0.01)	2.26^{***} (0.01)	1.94^{***} (0.01)	0.92^{***} (0.00)	0.47^{***} (0.04)	0.41^{***} (0.01)	0.22^{***} (0.00)	0.07^{***} (0.00)	0.02^{***} (0.00)
DCPS	-0.06^{**} (0.02)	-0.11^{***} (0.03)	-0.09^{***} (0.01)	-0.13^{***} (0.00)	-0.05^{***} (0.01)	0.02^{***} (0.00)	0.02^{***} (0.00)	-0.10^{***} (0.00)	-0.05^{***} (0.00)
FDI	1.17^{***} (0.06)	1.50^{***} (0.08)	2.82^{***} (0.03)	1.38^{***} (0.00)	1.01^{***} (0.07)	0.68^{***} (0.00)	0.768^{***} (0.0136)	0.905^{***} (0.00395)	0.54^{***} (0.00)
CO_2	-1.67^{***} (0.01)	-1.76^{***} (0.00)	-1.77^{***} (0.00)	-1.04^{***} (0.00)	-0.70^{***} (0.02)	-0.66^{***} (0.00)	-0.47^{***} (0.00)	-0.20^{***} (0.00)	-0.07^{***} (0.00)
GOV	-0.52^{***} (0.03)	0.39^{***} (0.04)	0.31^{***} (0.01)	0.59^{***} (0.00)	0.74^{***} (0.02)	0.62^{***} (0.00)	0.48^{***} (0.01)	0.07^{***} (0.00)	-0.30^{***} (0.01)
POLITY1	1.04^{***} (0.02)	0.88^{***} (0.00)	0.69^{***} (0.01)	0.07^{***} (0.00)	0.10^{*} (0.05)	-0.02^{***} (0.00)	0.11^{***} (0.01)	0.25^{***} (0.00)	0.25^{***} (0.00)
UNI	0.33^{***} (0.06)	0.23^{***} (0.05)	0.18^{***} (0.02)	0.25^{***} (0.01)	0.10^{***} (0.01)	0.02^{**} (0.00)	0.52^{***} (0.01)	0.37^{***} (0.00)	0.02^{**} (0.01)
Observations	929	929	929	929	929	929	929	929	929
Number of countries	67	67	67	67	67	67	67	67	67

Notes: All variables are in logarithmic form, and consequently, the estimates coefficients are elasticities. Standard errors in the parentheses. *, ** ,*** significant at 10, 5, and 1 percent respectively. L2 (lag operator) represents second lag.

Table B9: Estimated effect of third lag of different components of energy aid on REC with quantile regression

MODELS VARIABLES	(1) Q.10	(2) Q.20	(3) Q.30	(4) Q.40	(5) Q.50	(6) Q.60	(7) Q.70	(8) Q.80	(9) Q.95
L3. REG-AID$_{pc}$	0.55*** (0.09)	0.68*** (0.187)	1.20*** (0.09)	0.90*** (0.06)	0.39*** (0.07)	0.35*** (0.02)	0.17*** (0.01)	0.06** (0.03)	–0.21*** (0.01)
L3. NREG-AID$_{pc_}$	0.00*** (0.00)	–0.01*** (0.00)	–0.01 (0.00)	–0.04*** (0.00)	–0.06*** (0.00)	–0.03*** (0.00)	–0.01*** (0.00)	–0.00 (0.00)	–0.00 (0.00)
L3. POLICY-AID$_{pc}$	0.54*** (0.01)	0.62*** (0.01	0.74*** (0.03)	0.38*** (0.01)	0.25*** (0.00)	0.11*** (0.00)	0.06*** (0.00)	–0.05*** (0.00)	–0.03*** (0.00)
L3. DIS-AID$_{pc}$	–0.01*** (0.00)	0.02*** (0.00)	0.01** (0.00)	0.01*** (0.00)	0.00*** (0.00)	0.00*** (0.00)	0.01*** (0.00)	0.01*** (0.00)	0.00*** (0.00)
EC	0.44*** (0.00)	0.41*** (0.00)	0.44*** (0.00)	0.20*** (0.00)	0.09*** (0.00)	0.06*** (0.00)	0.04*** (0.00)	0.05*** (0.00)	–0.00*** (0.00)
RENT	0.07*** (0.00)	–0.01 (0.01)	–0.02** (0.01)	–0.01*** (0.00)	–0.09*** (0.00)	–0.07*** (0.00)	–0.07*** (0.00)	–0.13*** (0.00)	–0.04*** (0.00)
GDP$_{pc}$	2.64*** (0.01)	2.39** (0.01)	2.12*** (0.02)	1.02*** (0.01)	0.60*** (0.00)	0.38*** (0.00)	0.21*** (0.00)	–0.02** (0.00)	0.03*** (0.00)
DCPS	0.04*** (0.01)	0.00 (0.03)	–0.08*** (0.01)	–0.06*** (0.00)	–0.07*** (0.00)	0.04*** (0.00)	0.06*** (0.00)	–0.09*** (0.00)	–0.04*** (0.001)
FDI	1.09*** (0.00)	0.91*** (0.02)	2.79*** (0.02)	1.47*** (0.02)	0.61*** (0.01)	0.64*** (0.01)	0.77*** (0.00)	0.93*** (0.00)	0.40*** (0.00)
CO_2	–1.81*** (0.01)	–1.79*** (0.02)	–1.86*** (0.02)	–1.11*** (0.00)	–0.80*** (0.00)	–0.63*** (0.00)	–0.48*** (0.00)	–0.17*** (0.00)	–0.06*** (0.00)
GOV	–0.72*** (0.04)	0.08*** (0.02)	0.18*** (0.05)	0.58*** (0.01)	0.92*** (0.01)	0.71*** (0.00)	0.57*** (0.00)	0.05** (0.02)	–0.26*** (0.00)
POLITY	1.03*** (0.00)	0.88*** (0.01)	0.76*** (0.00)	0.14*** (0.00	–0.05*** (0.00)	0.00 (0.00)	0.09*** (0.00)	0.33*** (0.00)	0.26*** (0.00)
UNI	0.19*** (0.02)	0.18*** (0.02)	0.33*** (0.03)	0.37*** (0.01)	0.08*** (0.02)	0.19*** (0.01)	0.52*** (0.01)	0.33*** (0.01)	0.03*** (0.00)
Observations	863	863	863	863	863	863	863	863	863
Number of countries	67	67	67	67	67	67	67	67	67

Notes: All variables are in logarithmic form, and consequently, the estimates coefficients are elasticities. Standard errors in the parentheses. *, **, *** significant at 10, 5, and 1 percent respectively. L3 (lag operator) represents the third lag.

Table B10: Estimated effect of second lag of different components of energy aid on NHREC with quantile regression

MODEL VARIABLES	(3) Q.30	(4) Q.40	(5) Q.50	(6) Q.60	(7) Q.70	(8) Q.80	(9) Q.95
L2. REG-AID$_{pc}$	–0.22*** (0.00)	–0.08 (0.07)	1.01*** (0.06)	2.58*** (0.10)	1.43*** (0.29)	–0.81*** (0.13)	0.75*** (0.10)
L2. NREG-AID$_{pc_}$	0.00*** (0.00)	0.02*** (0.00)	0.02*** (0.00)	–0.01*** (0.00)	–0.00*** (0.00)	–0.01*** (0.00)	–0.02*** (0.00)
L2. POLICY-AID$_{pc}$	–0.02*** (0.00)	–0.08*** (0.00)	0.01 (0.01)	–0.26*** (0.01)	–0.30*** (0.01)	–0.23*** (0.01)	–0.08*** (0.00)
L2. DIS-AID$_{pc}$	–0.00*** (0.00)	–0.03*** (0.00)	–0.06*** (0.00)	–0.02*** (0.00)	–0.02*** (0.00)	–0.02*** (0.00)	0.00 (0.00)
EC	0.14*** (0.00)	0.26*** (0.00)	0.28*** (0.00)	0.20*** (0.00)	0.15*** (0.00)	–0.01*** (0.00)	–0.15*** (0.00)
RENT	–0.00*** (0.00)	–0.04*** (0.00)	–0.07*** (0.00)	–0.17*** (0.00)	–0.18*** (0.00)	–0.45*** (0.00)	–0.47*** (0.00)
GDP$_{pc}$	0.04*** (0.00)	0.12*** (0.00)	0.11*** (0.00)	0.40*** (0.00)	0.41*** (0.01)	0.76*** (0.00)	0.48*** (0.00)
DCPS	–0.00* (0.00)	–0.00** (0.00)	–0.00 (0.00)	–0.02* (0.01)	0.30*** (0.00)	0.76*** (0.00)	1.09*** (0.01)
FDI	–0.14*** (0.00)	–0.46*** (0.00)	–0.27*** (0.0217)	–0.22*** (0.02)	–0.29*** (0.01)	0.31*** (0.01)	0.55*** (0.01)
CO_2	–0.067*** (0.00)	–0.11*** (0.003)	–0.141*** (0.00)	–0.12*** (0.00207)	–0.12*** (0.00)	–0.23*** (0.00)	–0.36*** (0.00)
GOV	0.06*** (0.00)	0.12*** (0.00)	0.30*** (0.01)	0.164*** (0.04)	–0.17*** (0.01)	–1.63*** (0.01)	–1.32*** (0.03)
POLITY1	0.14*** (0.00)	0.26*** (0.00)	0.40*** (0.01)	0.27*** (0.00)	0.43*** (0.01)	0.71*** (0.00)	0.71*** (0.005)
UNI	–0.00 (0.01)	–0.09*** (0.01)	0.06*** (0.01)	0.26*** (0.02)	0.17*** (0.03)	–0.26*** (0.01)	–0.50*** (0.01)
Observations	929	929	929	929	929	929	929
Number of countries	67	67	67	67	67	67	67

Notes: All variables are in logarithmic form, and consequently, the estimates coefficients are elasticities. Standard errors in the parentheses. *, **, *** significant at 10, 5, and 1 percent respectively. L2 (lag operator) represents the third lag.

Table B11: Estimated effect of third lag of different components of energy aid on NHREC with quantile regression

MODEL VARIABLES	(3) Q.30	(4) Q.40	(5) Q.50	(6) Q.60	(7) Q.70	(8) Q.80	(9) Q.95
L3. REG-AID$_{pc}$	0.19* (0.11)	0.38 (0.25)	2.85*** (0.10)	3.03*** (0.14)	2.08*** (0.06)	0.91*** (0.34)	1.40*** (0.21)
L3. NREG-AID$_{pc_}$	0.00*** (0.00)	0.02*** (0.00)	0.00*** (0.00)	–0.01*** (0.00)	–0.02*** (0.00)	–0.04** (0.01)	–0.01*** (0.00)
L3. POLICY-AID$_{pc}$	–0.03*** (0.00)	–0.09*** (0.00)	–0.16*** (0.01)	–0.31*** (0.00)	–0.35*** (0.01)	–0.06 (0.10)	0.12*** (0.01)
L3. DIS-AID$_{pc}$	–0.01*** (0.00)	–0.03*** (0.00)	–0.03*** (0.00)	–0.03*** (0.00)	–0.02*** (0.00)	–0.03*** (0.00)	–0.05*** (0.00)
EC	0.18*** (0.00)	0.30*** (0.00)	0.25*** (0.00)	0.21*** (0.00)	0.15*** (0.00)	0.05*** (0.01)	–0.11*** (0.00)
RENT	–0.01*** (0.00)	–0.02*** (0.00)	–0.04*** (0.00)	–0.11*** (0.01)	–0.18*** (0.00)	–0.46*** (0.00)	–0.42*** (0.00)
GDP$_{pc}$	0.15*** (0.01)	0.16*** (0.03)	0.19*** (0.01)	0.34*** (0.00)	0.48*** (0.00)	0.73*** (0.03)	0.45*** (0.01)
DCPS	–0.02*** (0.00)	–0.05*** (0.00)	–0.01 (0.01)	0.17*** (0.00)	0.25*** (0.00)	0.59*** (0.06)	0.99*** (0.01)
FDI	–0.32*** (0.03)	–0.23*** (0.03)	–0.64*** (0.01)	–0.32*** (0.02)	–0.38*** (0.01)	0.25*** (0.02)	0.57*** (0.02)
CO_2	–0.11*** (0.00)	–0.16*** (0.02)	–0.09*** (0.00)	–0.13*** (0.00)	–0.13*** (0.00)	–0.23*** (0.01)	–0.46*** (0.00)
GOV	0.16*** (0.02)	0.15*** (0.02)	0.14*** (0.03)	–0.04 (0.03)	–0.09*** (0.01)	–1.10*** (0.27)	–0.98*** (0.04)
POLITY1	0.15*** (0.01)	0.28*** (0.00)	0.30*** (0.01)	0.39*** (0.01)	0.38*** (0.00)	0.33* (0.17)	0.59*** (0.01)
LUNI	0.011* (0.00)	0.08*** (0.01)	0.06** (0.02)	–0.07* (0.03)	0.09*** (0.02)	–0.26*** (0.027)	–0.46*** (0.06)
Observations	863	863	863	863	863	863	863
Number of countries	67	67	67	67	67	67	67

Notes: All variables are in logarithmic form, and consequently, the estimates coefficients are elasticities. Standard errors in the parentheses. *, **, *** significant at 10, 5, and 1 percent respectively. L3 (lag operator) represents the third lag.

Appendix C Correlation matrix

Table C1: Correlation matrix

Variables	REC	NHREC	EAID	EPOLICY	REG	NREG	EDIS	EC	RENT	GDP_{pc}	DCPS	FDI	CO_2	GOV	POLITY	UI
REC	1															
NHREC	0.07*	1														
$EAID_{pc}$	0.08*	0.01	1													
$EPOLICY_{pc}$	0.01	–0.01	0.49*	1												
REG_{pc}	0.02	0.04	0.50*	**0.07***	1											
$NREG_{pc}$	–0.09*	–0.01	0.45*	**0.07***	0.08*	1										
$EDIS_{pc}$	0.17*	–0.03	0.69*	**0.27***	0.07*	0.22*	1									
EC	–0.05*	0.08*	–0.07	**–0.05**	–0.03	–0.03	–0.06*	1								
RENT	–0.16	–0.16	0.02	0.02	–0.04	0.10*	–0.01	–0.03	1							
GDP_{pc}	–0.19*	0.12*	0.02	–0.04	0.14*	0.03	–0.08*	0.11*	0.08*	1						
DCPS	–0.22*	0.13*	0.08*	–0.02	0.13*	0.04	–0.00	0.37*	–0.09*	0.47*	1					
FDI	–0.00	–0.06*	0.11*	0.11*	0.01	0.06*	0.12*	–0.04	0.20*	0.02	0.01	1				
CO_2	–0.23*	–0.07*	0.01	0.02	0.03	0.02	–0.04	0.20*	0.21*	0.58*	0.39*	0.14*	1			
GOV	0.03	0.11*	0.17*	0.03	0.20*	0.02	0.08*	0.01	–0.08*	0.55*	0.41*	0.07*	0.19*	1		
POLITY	0.11*	0.20*	–0.00	–0.00	0.07*	–0.08*	0.00	–0.18*	–0.17*	0.16*	–0.02	–0.10*	–0.04	0.34*	1	
UI	0.08*	0.02	0.06*	–0.00	–0.01	0.01	0.11*	–0.042	–0.03	0.07	0.04	0.01	0.05	0.00	0.16*	1

(*) represents significance at 5%. Bold represents the correlation coefficients between different components of energy aid.