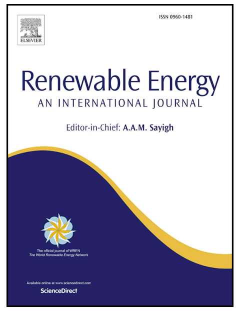

The dynamic impact of renewable energy and institutions on economic output and CO_2 emissions across regions

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PII: S0960-1481(17)30298-7

DOI: 10.1016/j.renene.2017.03.102

Reference: RENE 8703

To appear in: *Renewable Energy*

Received Date: 4 April 2016

Revised Date: 21 November 2016

Accepted Date: 21 March 2017

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Abstract

We provide a comprehensive and robust analysis of the role of renewable energy consumption and institutions on economic growth and in combating CO_2 emissions across the regions and income groups. For our empirical model, we use annual data from 85 developed and developing economies across the world over the period from 1991 to 2012. We employ various econometric techniques from panel estimations to obtain the robust results. Our findings confirm that there is significant heterogeneity across the sub-samples. Overall, results from the system-GMM and fully modified OLS indicate that the growth of renewable energy consumption has a significant positive and negative impact on economic output and CO_2 emissions, respectively. Institutions have a positive influence on economic growth and a reducing effect on CO_2 emissions. Our findings suggest that both renewable energy deployment and institutions are significant in promoting economic growth and reducing CO_2 emissions. Finally, we suggest that institutional alignment is necessary to promote the use of renewable energy across economic activities to ensure sustainable economic development.

JEL Classification: N74, Q42, Q48

Keywords: Renewable energy sources, Institutions, Economic output, CO_2 emissions, Regional analysis

1. Introduction

Environmental degradation is a major concern both at the national and global levels for countries around the world. Existing policies largely focus on the variations in energy use and implications for factors such as economic growth and environmental degradation, among others. Accordingly, a vast literature in empirical energy economics relates energy with economic growth and emissions.[1] As we move towards a cleaner energy era, renewable energy sources (RES) are in center-stage in improving the overall energy-mix, and are now widely accepted pathway towards sustainable growth (e.g., Aguirre & Ibikunle, 2014; Gan, Eskeland, & Kolshus, 2007). Increasing the share of renewable energy usage is an important policy agenda both for developed and developing economies. In most countries, carbon-intensive fossil fuel energy sources face increasingly tight regulation, with the aim of reducing consumption and increasing efficiency. Given the global awareness regarding climate change and associated perils, the target of most nations is to achieve an appropriate balance among three policy objectives: 1) to achieve energy security by increasing the share of renewable energy sources in total energy use, 2) to reduce CO_2 emissions by discouraging fossil fuel energy generation and giving higher priority to clean energy, and 3) to work towards sustainable economic growth. The global renewable energy market has therefore gained momentum over the past couple of decades, as noted during the recent Conference of Parties (COP21) meeting organised by the United Nations Framework Convention Committee and confirmed by the International Renewable Energy Agency (IRENA).[2]

The adoption of renewable energy, however, is not homogenous. For example, Nastasi and Basso (2016) identify problems in linking heat and electricity production during the

[1] Smyth and Narayan (2015) has an excellent review. Amongst many others, a recent study by Dutta and Das (2016) also identify coal as a major source of environmental emissions. There are studies which focus on individual sectors such as residential, transport. Nejat et al. (2016) has a focus on residential sector, while Chung et al. (2013) on transport sector.

[2] http://irenanewsroom.org/category/cop21/

transition process towards the use of renewable sources. The adaptation of renewables depends on scientific causes, investment, infrastructure and institutional framework across countries. As a result, the rate of CO_2 emissions varies significantly between nations. Recent statistics show that the rate of adoption is faster for emerging countries (BNEF, 2015).[3] Renewable energy deployment can be made more efficient by an adequate level of integration of objectives and interests at both the global and local levels.

The role of institutions may also play a significant role in the rate of adoption of renewable technologies and reductions in CO_2 emissions per country. The recent literature has started to explore the drivers of the renewable energy adoption and its effect on CO_2 emissions reduction. The existing literature attempted to explain the adoption of renewable energy by examining various factors, with particular emphasis on factors such as policy choices (see, Jacobsson & Lauber, 2006; Johnstone et al., 2009; Menanteau et al., 2003), and the cost and willingness to pay for adoption (see, e.g., Kobos, Erickson, & Drennen, 2006; Menanteau et al., 2003; Scarpa & Willis, 2010). An issue that has not received much attention in the literature is whether and how the differences in CO_2 emissions and adoption of renewable energy depend on the institutional differences between countries. Does the difference in institutions across countries have any implications for the adoption of renewable energy, and consequently for CO_2 emissions? Does improved institutional arrangement help in reducing CO_2 emissions? The focus of this study lies in answering these questions. We argue that cross-country differences in institutions explain a substantial part of the cross-country differences in the level of CO_2 emissions.

Undeniably, policy plays a significant role in the adoption of renewables, and as noted in the Renewables Global Status Report (2015), renewable energy developments are predominantly led by government action policies (REN21, 2015). For instance, in 2015 alone,

[3] http://global-climatescope.org/en/

164 countries have adopted renewable energy targets, and an estimated 145 countries had renewable energy support policies in place. Accordingly, policy options such as feed-in tariffs, Tradeable Green Certificates (TGCs), Renewable Green Certificates (RECs), tenders, and tax incentives or credits, among others, have been implemented in various regions for deployment purposes. These policy instruments differ across countries in the extent to which regulators can manage the rate and volume of the renewable energy deployment. In developing countries, implementation faces additional policy changes and uncertainties, creating various barriers to adoption.

Barriers to renewable energy deployment may also arise due to infrastructure issues, and institutional and administrative arrangements. The existence of these barriers can either prevent deployment altogether or may lead to higher than anticipated costs. Therefore, overcoming these obstacles is crucial to renewable energy deployment. The existing debate has focused on the role of policy in overcoming such structural barriers. In this study, we seek to contribute to the discourse by providing a perspective regarding the role of institutions.

Our purpose is, therefore, to analyse the role of institutions in economic growth processes and CO_2 emissions reduction by increasing the share of renewable energy sources in total energy use. In particular, we examine the role of institutions in mitigating environmental degradation and promoting economic growth for a selected panel of countries. Consistent with Acemoglu et al. (2005), we will show that institutions are of primary importance to economic outcomes, including such factors as renewable energy, which promotes economic growth in a sustainable way. In particular, free market institutions protect property rights (by enforcing contracts and appropriate legal systems). This in turn supports freedom of choice and voluntary exchange and enables governments to implement desired and desirable policies. We contend that the effectiveness of renewable energy policies largely depends on effective institutions, without which governments' ability to enforce policies may be undermined. Thus, institutions are particularly relevant to the speed of renewable energy adoption, and differences in institutions across countries can, therefore, explain differences in the rate of adoption.

Furthermore, within a single country, groups and individuals typically benefit differently from economic institutions. There is conflict over social choices, given that individuals have different ideas of what is good for society (Acemoglu et al., 2015). Ultimately, conflicts of choice are often resolved in favour of groups with greater political power. Institutional changes may, therefore, affect groups and individuals differently and can influence political power in changing the energy mix.

We present empirical evidence of the policy objectives noted above by examining the role of institutions in promoting the same. Specifically, we provide evidence of the role of institutions in promoting economic output and reducing CO_2 emissions. For this purpose, this study uses annual data from 1991 to 2012 for 85 developed and developing economies around the world. Additionally, we make use of several robust panel econometric models in establishing our major hypotheses.

This study is the first attempt which investigates the role of the institutions in explaining the combined policy objectives of economic growth and CO_2 emissions reduction. Understanding the role of institutions is important, as it presents a new perspective on the current debate that seeks to understand why the levels of environmental degradation vary so significantly between countries. Various countries consistently receive support from the international organisations to promote the adoption of renewable energy. Countries are often compared for the purpose of such funding. Therefore, the results from this study may assist in the judgement of key determinants across countries for this purpose.

In comparing countries, existing studies predominantly considered conventional factors related to growth and energy policies (see, e.g., Apergis & Payne, 2010; Jacobsson et al., 2009; Kitzing, Mitchell, & Morthorst, 2012; Ozaki, 2011; Scarpa & Willis, 2010). In addition to these factors, our study primarily highlights the role of institutions, which has been the subject of recent increased attention between countries in energy policy context. Secondly, the results of this study could be used to guide policy advisers and investors in understanding the environment in which countries perform regarding renewable energy deployment, and help them to tailor investments towards renewable sources. Thirdly, we divide our sample of 85 countries into eight groups to identify the heterogeneity across our findings. Six sub-sample groups (i.e., HIC, M&LIC, MENA, SSA, ECA and SA&EAP) are classified based on income divisions and geographical regions. The remaining two sub-sample groups (ANNEX 1 and NON-ANNEX 1) are classified based on the United Nations Framework Convention on Climate Change. Our study, therefore, provides evidence on the role of institutions across all possible country and region groupings used in the development and energy-related literature.

The rest of the paper is organised as follows. Section 2 briefly touches on literature with an emphasis on our major hypotheses. Section 3 discusses the model, data and estimation techniques. In Section 4, we discuss empirical findings. In Section 5, we list our major conclusions and provide some policy suggestions.

2. Literature review and related hypotheses

In this section, we provide a brief of overview of the existing literature providing the motivation for our study and for developing the relevant hypotheses.

2.1. Renewable energy, institutions and economic growth

Hypothesis 1: Renewable energy consumption promotes economic growth

The literature on the relationship between renewable energy consumption and economic growth recently increased. For instance, Sadorsky (2009) investigated the determinants of renewable energy for 18 emerging countries and showed that per capita GDP plays a significant role in explaining the dynamics of per capita renewable energy consumption. A similar conclusion was reported by Salim and Rafiq (2012) for a panel of six major emerging economies. Bowden and Payne (2010) established a causal relationship between renewable and non-renewable energy consumption and economic growth at the sectoral level for the US. A positive influence was established of renewable energy consumption on real GDP for the residential sector. Menegaki (2011) established neutrality for European countries; Apergis and Payne (2012) reported bi-directional causality for Central America; Salim and Rafiq (2012) established renewables as a primary source for improving economic growth and pollution reduction in emerging countries, and the findings of Tugcu et al. (2012) varied across G-7 countries. Manzano-Agugliaro et al. (2013) presented an excellent review of the scientific research on renewables worldwide. Their research concluded that renewable energy research is highly concentrated in a few countries.

Alper and Oguz (2016) establish a causal relationship from economic growth to renewable energy consumption for Bulgaria, Estonia, Poland and Slovenia. Considering new EU members, they suggest heterogeneous findings in using renewable sources. Destek (2016) confirms, in a sample of newly industrialising countries that renewable energy-growth nexus depends on economic conditions. Jebli et al. (2016) and Kahia et al. (2016) further emphasise that trade and renewable energy uses are efficient strategies towards sustainable development. Bhattacharya et al. (2016) summarise the literature in this respect. Establishing a causal relationship between economic growth and renewable energy consumption was shown to vary. While reviewing existing studies, we conclude that the varied results are due to the differences in estimation techniques, stages of economic development of sample countries, changes in tax or credit structure for renewable deployment, and the different periods of analysis considered in each study. In this study, we extend the existing research including the role of institutions and renewable uses in explaining economic growth across different regions.

Hypothesis 2: Better institutions lead to improved economic growth

Institutions are critical to determining long-run economic growth (Hall and Jones, 1999; Rodrik et al. 2004; Easterly and Levine, 2003; and Bhattacharyya, 2009). In general, the literature on economic freedom shows that free market institutions protect property rights, facilitate policies enabling trade and voluntary exchange, and are instrumental in achieving higher economic growth. Economic freedom comprises a number of separable factors relating to the institutions and policies which govern the economy of any particular country. Moreover, economic freedom is designed to affect the incentive structure within which policies operate. Therefore, this may affect economic growth and the choice of input mix contributing to production and consumption decisions. Following Gwartney and Lawson (2004, 2007) economic freedom comprises five dimensions: size of the government (government spending, taxes and government enterprises); property rights and legal structure; effective monetary and fiscal policies; and trade policies and regulation of business (including labour and credit markets). In the case of renewables, viable investments require effective policy regimes and social acceptance from public, political and regulatory stakeholders. Effective institutional arrangements prevent market failure and help to sustain growth momentum, mitigating CO_2 emissions in the long-run.

2.2. Renewable consumption, institutions and CO_2 emissions

Hypothesis 3: Renewable energy reduces CO_2 emissions

Degradation of the environment creates social costs. A high level of CO_2 emissions may lead to the quest for a cleaner environment and thus encourages the use of renewable energy. Using a panel of 64 countries, Omri et al. (2015) established CO_2 emissions and trade as major drivers of per capita renewable energy consumption. Most of the previous studies (e.g., Sadorsky, 2009; Menegaki, 2011; Salim and Rafiq, 2012) emphasise a reduction in CO_2 emissions due to the shift towards renewable energy. Similarly, a recent study by Paramati et al. (2016) suggests that per capita GDP and clean energy consumption play a significant role in reducing per capita CO_2 emissions in 20 emerging market economies. Considering global concern over greenhouse gas emissions, it is expected that CO_2 emissions will have a significant indirectly effect on renewable energy adoption.

Hypothesis 4: Better institutions lead to fewer CO_2 emissions

According to a growing body of literature, different institutional circumstances may create varying incentives for the establishment of energy policies. For instance, more open and responsive democratic regimes may perform better than comparatively autocratic countries in implementing environmental policies (Bernauer & Koubi, 2009), although others have been more sceptical of this claim (Shearman & Smith, 2007; Ward, 2008). Furthermore, better institutional arrangements and better quality institutions enable governments to internalise externalities due to pollution. Better government and political situations are also able to implement suitable tax rates, subsidies and related policies in the energy sector to reduce CO_2 emissions. To our knowledge, no empirical study has examined the role of institutions in renewable energy deployment and the resulting reduction of CO_2 emissions. However, studies such as Painuly (2001) do provide a framework for identifying barriers to renewable energy penetration, where lack of institutional mechanism, legal and regulatory frameworks and financial incentives are identified as institutional barriers.

Hypothesis 5: Higher per capita income increases CO_2 emissions

The Environmental Kuznets' Curve (EKC) hypothesis postulates an inverted U-shaped relationship between the level of CO_2 emissions (an indicator of environmental degradation) and per capita income. CO_2 emissions increase with per capita income during the early stages of economic development due to industrialisation and begin to decline as the per capita income continues to increase past a threshold point. This is due to improvements in technology, a developing energy mix and various combinations of policies which may assist in reducing the externalities from pollution. Studies such as Stern (2004), Luzzati and Orsini (2009), Halicioglu (2009), Acaravci and Ozturk (2010), Al-Mulali et al. (2015) and Apergis and Ozturk (2015), among others, provide reviews of the literature on the EKC hypothesis. Bilgili et al. (2016) confirmed that the EKC analysis is not robust for individual countries considering renewables as a source of energy, although the hypothesis was established for the full panel.

3. Model, data and estimations

In the following sub-sections we describe our models, data and estimation techniques.

3.1. Model and data

Here we propose a supply-demand framework. On the supply side, the output (GDP) is produced by conventional inputs such as labour and capital, energy inputs (such as non-renewable and renewable sources) and institutional quality. Our simple model effectively analyses the substitution effects of energy and non-energy related inputs and the role of the institution into the growth process. The conventional, neo-classical, one-sector aggregate production technology is employed, where labour, capital and types of energy are treated as separate inputs. We also include the role of institutional quality into the growth process. The variables are defined below, and the subscripts i and t denote country and time period, respectively.

$$GDP_{it} = f\ (LF_{it}, GFCF_{it}, NREC_{it}, REC_{it}, IQ_{it}) \quad (1)$$

On the demand side, we postulate implicitly that energy consumption causes increased CO_2 emissions. Other related sources of increased environmental degradation are a weak institution and higher per capita GDP. A combination of energy policies in combination with appropriate institutional conditions may reduce CO_2 emissions in an economic environment experiencing increasing growth.

$$CO_{2,it} = f(NREC_{it}, REC_{it}, IQ_{it}, GDPPC_{it}) \quad (2)$$

Economic output is measured by gross domestic product (GDP) in constant 2005 US$; CO_2 emissions (CO_2) are measured in per capita metric tons; labour (LF) is the total labour force; capital (GFCF) represents the gross fixed capital formation in constant 2005 US$; non-renewable energy consumption (NREC) is the sum of coal, gas and oil in Quadrillion Btu. Renewable energy consumption (REC) is the sum of hydro, wind, solar, geothermal, marine, waste, and solid, liquid and gaseous biofuel-derived energy, measured in Terajoules The institutional quality (IQ) is measured using the economic freedom index. The economic freedom index is a combination of five different categories or sub-indices, namely, the size of government, property rights and legal structure, access to sound money, international trade and trade policies, and the regulation of business, labour and credit markets (Gwartney et al., 2012). For further information on the economic freedom index, the reader is referred to the

Freedom House Report (2012). Finally, the GDP per capita (GDPPC) is measured in constant 2005 US$. The GDP, CO_2, LF, GFCF and GDPPC data were obtained from the World Development Indicators (WDI) online database published by the World Bank.[4] IQ data was sourced from the Fraser Institute Index and NREC and REC from the US Energy Information Administration (EIA) and World Bank. [5]We consider annual data from 1991 to 2012, the longest available period for our panels.

We considered 85 developed and developing economies across the globe. The selection of these countries was based on the availability of data. However, countries included also meet the criteria of having set at least one type of national renewable energy target as of mid-2015 (IRENA, 2015; REN21, 2014; and REN21, 2015). For empirical purposes, the considered countries have been classified into a series of groups based on their region and income level as defined by the World Bank. The purpose of dividing the sample countries into sub-groups is to identify the heterogeneity across these groups. Furthermore, among these regions, we have a mixture of leaders and laggards in renewable deployment. The considered groups are as follows: Full Sample, High Income Countries (HIC), Middle & Low Income Countries (M&LIC), Middle East and North Africa (MENA), Sub-Saharan Africa (SSA), Europe & Central Asia (ECA), South Asia and East Asia Pacific (SA&EAP), Annex 1 countries and Non-Annex 1 countries. Annex 1 and Non-Annex 1 countries are classified by the United Nations Framework Convention on Climate Change (UNFCC). The detailed list of countries for each of these groups is provided in Appendix- I and summary statistics and unconditional correlations are presented in Appendices II and III, respectively.

[4] World Bank Group (Ed.). (2012). *World Development Indicators 2012*. World Bank Publications.

[5] Gwartney, James, Lawson, Robert, & Hall, Joshua. (2012). 2012 Economic Freedom Dataset. *Economic Freedom of the World: 2012 Annual Report* and U.S. Department of Energy. Energy Information Administration: Washington, DC (on-line data)

3.2. Estimations and Endogeneity Issues

3.2.1. Estimation procedures

Our main empirical strategy is based on the system general method of moments (GMM).[6] The system GMM estimator is particularly useful in this context. In addition to controlling for country-specific effects, it preserves the cross-country dimension of the data that is lost when only the first differenced equation is estimated (Castello`-Climent, 2008). Also, endogeneity and reverse causality issues have been addressed widely using the system GMM estimator.

In our models, there are a few key variables that may be endogenous as results of reverse causation. For instance, literature exists to suggest that feedback effects may exist between institutions and growth (e.g., Aisen & Veiga, 2013; Glaeser et. al., 2004), renewable energy consumption and growth (e.g., Apergis and Payn, 2012; Bhattacharya et al., 2016) and CO_2 emissions and economic development (e.g., Stern, 2004; Apergis and Ozturk, 2015). The theoretical and empirical literature has demonstrated that differences in institutions explain a substantial proportion of cross-country differences in economic growth. The evidence further suggests that good institutions promote economic growth. Conversely, a case has also been made for the way in which institutional improvement is facilitated by human capital accumulation and associated growth (e.g., Acemoglu et al., 2005; Glaeser et al., 2004). Similar arguments have been advanced in the case of economic growth and CO_2 emissions. Furthermore, omitted variable bias, which is another cause of endogeneity, may be an issue. Therefore, we have adopted the dynamic system GMM model (GMM-SYS) to address

[6] We also compare the system-GMM with pooled ordinary least squares (POLS) and fixed/random effects estimation techniques. As shown in Table 1, results do not significantly differ suggesting the robustness of our results. The preference for system-GMM as our main estimation technique is because of its effectiveness in dealing with endogeneity. This is discussed in further details in the next section.

potential endogeneity, and to ensure the reliability of our estimates (Arellano & Bond, 1991; Arellano & Bover, 1995; Blundell & Bond, 1998).

3.2.2. Endogeneity issues

We adopted a variant of models (1) and (2) to deal with issues of endogeneity. The GMM model may be stated as follows:

$$Y_{it} = \beta_1 Y_{i,t-1} + \beta_2' \boldsymbol{Z}_{it} + \vartheta_i + \mu_t + \varepsilon_{it} \tag{3}$$

$$CO_{2_{it}} = \beta_1 CO_{2_{i,t-1}} + \beta_2' \boldsymbol{P}_{it} + \vartheta_i + \mu_t + \varepsilon_{it} \tag{4}$$

where Y_{it} and $CO_{2_{it}}$ are the log of GDP and CO_2 emissions, respectively. $Y_{i,t-1}$ is the lagged dependent variable in the output model and $CO_{2_{i,t-1}}$ is the lagged dependent variable in the CO_2 model. $\boldsymbol{Z}_{it}$ and $\boldsymbol{P}_{it}$ represent a vector of control variables (as discussed earlier) in the output and CO_2 regressions, respectively. ϑ_i is the unobserved fixed-effect term, μ_t includes time effects, and ε_{it} is the residual term in each model. β_s are respective elasticities with respect to output and CO_2 emissions. Variables are measured in logarithm for estimation purposes. Notations for fixed effects and the error terms are maintained across models for ease in explaining notations.

Rewriting equations (3) and (4) as difference equations yields;

$$Y_{it} - Y_{it-1} = \beta_1 (Y_{i,t-1} - Y_{i,t-2}) + \beta_2' (\boldsymbol{Z}_{it} - \boldsymbol{Z}_{it-1}) + (\varepsilon_{it} - \varepsilon_{it-1}) \tag{5}$$

$$CO_{2_{it}} - CO_{2_{it-1}} = \beta_1(CO_{2_{i,t-1}} - CO_{2_{i,t-2}}) + \beta_2'(\boldsymbol{P}_{it-1} - \boldsymbol{P}_{it-1}) + (\varepsilon_{it} - \varepsilon_{it-1}) \qquad (6)$$

Differencing yields unbiased estimates. Specifically, differencing eliminates unobserved country (ϑ_i) and time (μ_t) fixed effects, which are possible sources of omitted variable bias. Following Arellano and Bond (1991), the regressors' lagged levels are used as instruments to rectify the potential endogeneity bias, and the correlation between dependent variables and error terms. This is conventionally referred to as the first difference GMM (GMM-DIF) estimation, which assumes weak exogeneity of regressors and the non-correlation of error terms. Building on this, Blundell and Bond (1998) show that the first difference GMM estimator may lead to biased estimates given the presence of weak instruments derived from lagged variables when explanatory variables are persistent. Thus, Blundell and Bond (1998) demonstrates the efficiency of the GMM-SYS estimator over the GMM-DIF estimator. Typically, GMM-SYS estimators generate instruments that remain good predictors for endogenous variables, and thus perform better than the GMM-DIF estimator when series are persistent (Blundell & Bond, 1998).

We ran regressions in STATA using the two-step estimator consistent with Roodman (2006). For the GMM estimator to be consistent, it must pass the Hansen J-test of over-identifying restriction and should have no second-order serial correlation in the error term of the difference. In GMM-SYS estimations, the over-identifying restriction tests examine the joint validity of all instruments and thus work with the null hypothesis that the over-identifying restrictions are valid. The second-order autocorrelation test examines the null hypothesis that there is no autocorrelation or that the error term is not serially correlated. To check the validity of the models, we conducted these required tests. The results are reported at the bottom of Table 1. Specifically, given the p-values which are greater than 0.05, we cannot reject the null hypothesis that the full set of orthogonality conditions are valid. Similarly, given the p-values for the autocorrelation test, we cannot reject the null hypothesis of no second-order serial correlation in the first-differenced error terms.

3.2.3. Long-run output and CO_2 emission elasticities

We estimated a single cointegrating vector, based on Equations (1) and (2), to investigate the long-run economic output and CO_2 emissions elasticities, respectively. With regards to the panel data set, the application of ordinary least squares (OLS) to Equations (1) and (2) is asymptotically biased, and its distribution relies upon a nuisance parameter. Pedroni (2000, 2001) argued that, in the course of regression estimation, nuisance parameters can result from the presence of serial correlation and endogeneity among the regressors. Therefore, to address these issues, we employed Fully Modified OLS (FMOLS) models based on the approach suggested by Pedroni (2000, 2001). More specifically, in this study, we utilised the grouped-mean FMOLS estimator, which averages over the individual cross-section estimates. Pedroni (2001) showed that, in the presence of heterogeneity in the cointegration relationship, the grouped-mean estimator provides consistent estimates of the sample mean of the cointegrating vector, in contrast to the pooled and weighted estimators. This model utilises a non-parametric approach to address the issues of endogeneity and serial correlation present in the model. Therefore, we employed the FMOLS model to estimate the long-run output and CO_2 emissions elasticities.

4. Empirical findings and discussion

For empirical purposes, we ran regressions for the full sample and estimations across regions. The results of these models are presented and discussed below:

4.1. Estimates for full sample

The results for the full sample of 85 countries are presented in Table 1. The economic growth and CO_2 emissions models are presented for the POLS, FE-effects and RE-effects estimations (Column 1-6) while the last two columns (Column 7-8) provide system GMM estimates. For the output model, the coefficients of non-renewables, renewables, and institutions are positive and strongly significant across various estimation techniques. Following the discussion in the preceding section, we considered system GMM estimates as consistent for both the output and CO_2 models and checked the validity of the instruments using the tests for over-identification and autocorrelation.

Table 1: Analysis of full sample data

	Pooled OLS Column 1,2		Fixed Effect Column 3,4		Random Effect Column 5,6		Sys-GMM Column 7,8	
Variables	GDP	CO_2	GDP	CO_2	GDP	CO_2	GDP	CO_2
GDP_{t-1}							0.763***	
							(0.005)	
$CO_{2\ t-1}$								0.706***
								(0.007)
LF	-0.017**		0.330***		0.177***		0.002	
	(0.009)		(0.027)		(0.019)		(0.005)	
GFCF	0.787***		0.290***		0.355***		0.098***	
	(0.024)		(0.008)		(0.009)		(0.001)	
NREC	0.166***	0.019***	0.190***	0.027***	0.274***	0.024***	0.077***	0.006***
	(0.019)	(0.001)	(0.012)	(0.001)	(0.013)	(0.001)	(0.004)	(0.000)
REC	0.051***	-0.010***	0.064***	-0.011***	0.078***	-0.012***	0.032***	-0.004***
	(0.007)	(0.001)	(0.008)	(0.001)	(0.008)	(0.001)	(0.001)	(0.000)
IQ	0.148***	-0.020***	0.090***	-0.001	0.085***	-0.003*	0.056***	-0.003***
	(0.050)	(0.003)	(0.013)	(0.001)	(0.015)	(0.001)	(0.004)	(0.000)
GDPPC		-0.010***		-0.042***		-0.032***		-0.007***
		(0.001)		(0.002)		(0.002)		(0.000)
Constant	5.855***	0.134***	12.317***	0.409***	12.477***	0.284***	3.224***	0.105***
	(0.482)	(0.011)	(0.400)	(0.017)	(0.327)	(0.018)	(0.090)	(0.007)
Hausman test					527.57	84.99		
(p-value)					0.000	0.000		
Hansen j-test							81.262	79.839
(p-value)							1.000	1.000
AR(2) test							-2.296	0.686
(p-value)							0.217	0.492

Notes: Variable Notations: GDP: GDP; CO_2: CO_2 emissions per capita; LF: labour force; GFCF: gross fixed capital formation; NREC: non-renewable energy consumption; REC: renewable energy consumption; GDPPC: GDP per capita; IQ: Institutional Quality. All variables are in logarithmic form; Robust standard errors in parentheses; *** $p<0.01$, ** $p<0.05$, * $p<0.1$. POLS: Pooled-OLS technique; Panel-FE and Panel-RE are fixed and random effect technique; SYS-GMM: System GMM technique. Hansen J-test denotes to the over-identification test for the restrictions in GMM estimation; The AR (2) test is the Arellano-Bond test for the existence of the second-order autocorrelation in first differences of residuals; The Hausman test is used to differentiate between Panel-FE and Panel-RE models, and to determine which is preferred.

Based on the system GMM results in the output model, the GFCF is positively associated with GDP. Specifically, at the 1% significance level, a 1% increase in GFCF is associated with a 0.098% increase in GDP. We further note that although both NREC and REC are positively associated with GDP, the effect of NREC appears to be relatively stronger than that of REC. In this regard, a 1% increase in NREC and REC is associated with a 0.077% and 0.032% increase in GDP respectively. The coefficient is more than two times higher for non-renewables compared to renewables. Similarly, a 1% increase in IQ is associated with a 0.056% increase in GDP. The lagged GDP is positive and strongly significant at the 1% level with a coefficient of 0.763. Overall, the findings from the full sample data set suggest that both non-renewable and renewable energy generation have significant positive impact on economic output. However, the impact is much stronger from non-renewables. Most importantly, the institutions play a pivotal role in the growth process.

About the CO_2 model, the coefficients on all variables (non-renewables and renewables), except institutions, have the expected signs and strongly significant across various estimation techniques. As expected, we find that the use of NREC promotes environmental degradation proxies by carbon emissions, while the use of REC reduces the levels of CO_2 emissions for all three estimation techniques. Here, a 1% increase in NREC and REC is associated with a 0.006% increase and a 0.004% decline in CO_2 emission, respectively. Similarly, a 1% increase in IQ and GDPPC is associated with a 0.003% and 0.007% reduction in CO_2 emissions, respectively. The lagged CO_2 is positive and strongly significant at the 1% level with a coefficient of 0.706. The observed results in the system GMM are broadly consistent with the literature (e.g., Bilgili et al., 2016). It should be noted here that the purpose of this paper is to analyse the shift from non-renewables to renewables and the role of institutions in this process. Therefore, we have not validated the EKC hypothesis as discussed elsewhere (Bilgili et al., 2016).

4.2. Estimates for various regions

Table 2 presents the estimates for output and CO_2 models across the following six regions: High-Income Countries, Middle & Low-Income Countries, Middle East and North Africa, Sub-Saharan Africa, Europe & Central Asia, South Asia and East Asia Pacific (Column 1-12). Estimates from Annex 1 and Non-Annex 1 countries are shown in column 13-16.

With regard to the output models, the coefficient for non-renewables is positive and significant for HIC (0.038); M&LIC (0.059); SSA (0.079); ECA (0.067); and for the Annex 1 group (0.082). For renewables, the coefficient is positive and significant for M&LIC (0.061); ECA (0.049) and for the Non-Annex 1 group (0.239), but negative and significant for the HIC (0.005). Besides ECA region, our findings corroborate the recent increase in renewables deployment and associated growth for M&LIC suggested in a recent report from Bloomberg New Energy Finance (BNEF, 2015). Better institutions are consistently associated with higher levels of economic output. Statistically, insignificant coefficients were found for the MENA, SA&EAP and Non-Annex 1 groups, and the positive and significant coefficient for HIC (0.091), M&LIC (0.034), SSA (0.110), ECA (0.028), and Annex 1 (0.113). The findings suggest that removing institutional barriers from some regions (those being, in the case of this study, MENA, SA&EAP and Non-Annex 1) will play a key role in decoupling energy and growth, particularly when implemented in combination with changes in the energy mix and other macroeconomic and related energy policies.

The results for the CO_2 emissions models are similar, where we find that non-renewables promote environmental degradation across all regions except MENA and Non-Annex 1. In particular, there are positive and statistically significant coefficients for HIC (0.003), M&LIC (0.006), SSA (0.004), ECA (0.005), SA&EAP (0.014) and Annex 1 (0.004). On the other hand, renewables remain consistent with our primary results on the full sample, leading to a decline in CO_2 emissions across the considered regions. Particularly, the coefficient of renewables is negative and statistically significant for M&LIC (0.002), Africa (0.002), ECA (0.001), and Annex 1 countries (0.004). The coefficient for institutions is also negative and significant for HIC (0.004), M&LIC (0.005), SSA (0.002), and ECA (0.008).

Table 2: Analysis of System-GMM

	HIC (Column1-2)		M&LIC (Column3-4)		MENA (Column4-5)		AFRICA (Column7-8)		ECA (Column9-10)		SE-ASIA&PACIFIC (Column11-12)		ANNEX 1 (Column13-14)		NON-ANNEX1 (Column15-16)	
Variables	GDP	CO_2	GDP	CO_2	GDP	CO_2	GDP	CO_2	GDP	CO_2	GDP	CO_2	GDP	CO_2	GDP	CO_2
GDP_{t-1}	0.820***		0.806***		0.236		0.857***		0.811***		0.789***		0.836***		0.392	
	(0.013)		(0.009)		(1.581)		(0.006)		(0.006)		(0.129)		(0.034)		(0.276)	
$CO_{2\ t-1}$		0.825***		0.724***		0.529		0.728***		0.762***		0.100		0.685***		1.048***
		(0.023)		(0.014)		(1.436)		(0.013)		(0.013)		(0.348)		(0.019)		(0.146)
LF	0.034*		-0.022		1.666		-0.064***		-0.018		0.093		0.009		0.568	
	(0.020)		(0.018)		(4.633)		(0.009)		(0.011)		(0.215)		(0.116)		(0.459)	
GFCF	0.107***		0.081***		-0.037		0.098***		0.077***		0.030		0.097***		0.165**	
	(0.003)		(0.002)		(0.901)		(0.003)		(0.002)		(0.033)		(0.004)		(0.074)	
NREC	0.038***	0.003**	0.059***	0.006***	0.501	0.006	0.079***	0.004***	0.067***	0.005***	0.033	0.014***	0.082***	0.004***	0.099	0.002
	(0.004)	(0.001)	(0.004)	(0.000)	(0.742)	(0.006)	(0.005)	(0.001)	(0.005)	(0.000)	(0.071)	(0.004)	(0.006)	(0.001)	(0.078)	(0.004)
REC	-0.005*	-0.001	0.061***	-0.002***	-0.521	0.002	0.000	-0.002***	0.049***	-0.001***	0.197	-0.008	-0.000	-0.004***	0.239**	-0.002
	(0.003)	(0.000)	(0.005)	(0.001)	(0.848)	(0.006)	(0.002)	(0.000)	(0.007)	(0.000)	(0.129)	(0.010)	(0.002)	(0.000)	(0.103)	(0.003)
IQ	0.091***	-0.004***	0.034***	-0.005***	-0.075	0.012	0.110***	-0.002***	0.028**	-0.008***	0.100	-0.001	0.113***	-0.001	0.135	-0.028
	(0.009)	(0.001)	(0.007)	(0.001)	(0.906)	(0.024)	(0.005)	(0.000)	(0.014)	(0.002)	(0.113)	(0.012)	(0.009)	(0.001)	(0.165)	(0.054)
GDPPC		-0.005**		-0.006***		-0.047**		-0.006***		-0.005***		-0.019		-0.008***		0.008
		(0.002)		(0.001)		(0.022)		(0.001)		(0.000)		(0.021)		(0.002)		(0.009)
Constant	1.419***	0.054***	2.551***	0.059***	-0.588	0.308	2.103***	0.061***	2.637***	0.054***	0.532	0.149	1.534	0.098***	-1.396	0.008
	(0.209)	(0.020)	(0.163)	(0.006)	(18.408)	(0.196)	(0.148)	(0.009)	(0.164)	(0.008)	(1.289)	(0.217)	(0.974)	(0.017)	(4.056)	(0.098)
Hansen J-test	36.188	36.412	41.729	40.649	3.390	0.511	36.286	35.285	43.551	37.876	7.968	6.458	30.924	29.098	4.672	8.885
(p-value)	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
AR(2) test	-3.274	-0.733	-1.156	1.426	0.469	0.594	-2.271	1.255	-1.537	0.468	-0.557	0.298	-2.219	0.991	-0.567	-0.807
(p-value)	0.001	0.463	0.247	0.153	0.638	0.552	0.023	0.209	0.124	0.639	0.577	0.765	0.026	0.321	0.570	0.419

Notes: Variable notations are from Table 1; all variables are in logarithmic form; Robust standard errors in parentheses; *** p<0.01, ** p<0.05, * p<0.1. Hansen J-test denotes to the over-identification test for the restrictions in GMM estimation; The AR (2) test is the Arellano-Bond test for the existence of the second-order autocorrelation in first differences of residuals. Classification of regions is: High-Income Countries (HIC), Middle & Low-Income Countries (M&LIC), Middle East and North African countries (MENA), Sub-Saharan African countries (SSA), Europe & Central Asia (ECA), South Asia and East Asia Pacific (SA&EAP).

For both the models, heterogeneity across regions is noticeable. Combining the major findings across the regions, renewables appear to work in favour of reducing CO_2 emissions. Furthermore, a strong institutional set up has a positive effect on the renewables deployment process and overall growth.

4.3. Long-run aspects

We have the long-run output and CO_2 emission elasticities for the full sample and sub-regions using a single cointegrating vector. For this purpose, we have applied the grouped-mean FMOLS model based on the approach developed by Pedroni (2000, 2001). This is a robust model to handle the endogeneity and serial correlation that are present in the model. The results of the long-run elasticities calculations are presented in Table 3. The findings show that both non-renewable and renewable energy consumption has a significant positive impact on economic output from the panels. More importantly, the effect of renewable energy consumption on economic output is stronger than that of non-renewable energy consumption in the full sample, M&LC, MENA, SSA, ECA, SA&EAP and Non-Annex 1. Conversely, non-renewable energy consumption has a stronger impact on economic output than renewable energy consumption in the HIC and Annex 1 sub-samples, although the observed differences in impact are minimal. Thus, overall, our results suggest that the consumption of renewable energy favours economic output more than the use of non-renewable energy sources, for low-income countries. Furthermore, our results show that institutions play a positive role in increasing economic output across all panels, except SSA. This indicates that higher economic freedom is positively associated with the economic output. Better institutions enable legislative implementation, policy integration, leadership, economic efficiency and stakeholder participation to expedite the deployment process.

Table 3: Long-run Output and CO_2 emission elasticities using FMOLS models

	Full Sample		HIC		M&LIC		MENA		SSA		ECA		SA&EAP		ANNEX 1		NON-ANNEX 1	
	(Column 1-2)		(Column 3-4)		(Column 5-6)		(Column 7-8)		(Column 9-10)		(Column 11-12)		(Column 13-14)		(Column 15-16)		(Column 17-18)	
Variables	GDP	CO_2	GDP	CO_2	GDP	CO_2	GDP	CO_2	GDP	CO_2	GDP	CO_2	GDP	CO_2	GDP	CO_2	GDP	CO_2
LF	0.734***		0.750***		0.720***		0.814***		0.555***		0.823***		0.447***		0.815***		0.691***	
	(0.052)		(0.050)		(0.085)		(0.061)		(0.194)		(0.090)		(0.103)		(0.080)		(0.036)	
GFCF	0.265***		0.310***		0.227***		0.262***		0.198***		0.348***		0.275***		0.325***		0.215***	
	(0.006)		(0.010)		(0.008)		(0.024)		(0.012)		(0.011)		(0.019)		(0.010)		(0.004)	
NREC	0.150***	0.030***	0.165***	0.040***	0.136***	0.021***	0.125***	0.014***	0.076***	0.020***	0.115***	0.041***	0.292***	0.029***	0.148***	0.041***	0.145***	0.022***
	(0.012)	(0.000)	(0.020)	(0.002)	(0.014)	(0.001)	(0.032)	(0.003)	(0.024)	(0.000)	(0.026)	(0.002)	(0.023)	(0.001)	(0.023)	(0.000)	(0.007)	(0.001)
REC	0.219***	-0.005***	0.152***	-0.005***	0.277***	-0.006***	0.132***	-0.007**	0.367**	-0.014***	0.141***	-0.004**	0.437***	-0.004**	0.128***	-0.003***	0.299***	-0.008***
	(0.031)	(0.000)	(0.011)	(0.002)	(0.056)	(0.001)	(0.034)	(0.003)	(0.165)	(0.000)	(0.013)	(0.002)	(0.054)	(0.002)	(0.012)	(0.000)	(0.029)	(0.001)
IQ	0.075***	-0.003***	0.157***	-0.001	0.006	-0.004**	0.294***	0.010*	-0.043	0.001*	0.217***	0.004	0.027	0.012*	0.131***	0.008***	0.035*	-0.011***
	(0.024)	(0.000)	(0.041)	(0.008)	(0.029)	(0.002)	(0.071)	(0.005)	(0.046)	(0.001)	(0.041)	(0.004)	(0.085)	(0.007)	(0.039)	(0.000)	(0.019)	(0.001)
GDPPC		-0.049***		-0.067***		-0.033***		-0.037***		-0.036***		-0.063***		-0.045***		-0.066***		-0.035***
		(0.000)		(0.003)		(0.001)		(0.004)		(0.000)		(0.002)		(0.002)		(0.000)		(0.002)

Notes: Standard errors in parentheses; ***, ** & * indicate the significance level at 1%, 5% and 10%, respectively. Classification of regions are: High- Income Countries (HIC), Middle & Low- Income Countries (M&LIC), Middle East and North African countries (MENA), Sub-Saharan African countries (SSA), Europe & Central Asia (ECA), South Asia and East Asia Pacific (SA&EAP).

Similarly, the findings of the long-run CO_2 emission elasticities indicate that the consumption of renewable energy reduces CO_2 emissions across all sample classifications, while non-renewable energy consumption has an increasing effect on emissions. The results further suggest that better institutions are associated with the decreasing CO_2 emissions in the case of MENA, SSA, ECA, SA&EAP and Annex 1 and have a negative effect in the case of the full sample, HIC, M&LIC and Non-Annex 1. Finally, we observe that an increase in per capita income (or GDPPC) leads to a significant reduction of CO_2 emissions. This means that higher income promotes the individual use of more environmentally friendly products and technologies, which in turn substantially reduces CO_2 emissions across these countries. This finding also suggests that as income grows, the country may invest more in renewable energy sources.

4. Conclusion and policy implications

Increasing CO_2 emissions and the associated environmental degradation has ignited a growing concern among individuals, policy makers and government officials from developed and developing economies around the world. As a way of dealing with the issues surrounding environmental degradation, international organisations such as the United Nations Framework Convention on Climate Change, among others, have been actively engaged in advocating for a reduction in CO_2 emissions across countries and regions. However, the majority of the economic activities across the globe are still predominantly dependent on fossil fuel consumption. Hence, CO_2 emissions can only be minimised by a significant reduction in fossil fuel energy consumption. Reluctance, and in some cases inability, due to various reasons, to adopt alternative cleaner energy sources to replace fossil fuels leads to the current state of perpetually increasing CO_2 emissions.

Nonetheless, some policymakers and governments have started to focus on renewable energy generation and consumption. As evidenced by our study, renewable energy consumption not only promotes economic development but also significantly reduces CO_2 emissions. Given these advantages, it is not surprising that many countries across the globe, both developed and developing, have started to give high priority to renewable energy sources.

Beyond, the benefits of renewable energy for sustainable economic growth, we have shown that additional factors, such as institutions, play a significant role. In this study, we have examined the impact of renewable energy consumption and institutions on economic output and CO_2 emissions across a panel of countries. In particular, we have considered 85 developed and developing economies around the world, used annual data from 1991 to 2012, and employed alternative panel econometric techniques to check the robustness of our major findings. We further split the sample across income groups, geographical locations, and classifications advanced by the UNFCCC. Specifically, we included sub-samples capturing the HIC, M&LIC, MENA, SSA, ECA, SA&EAP and Annex 1 and Non-Annex 1 regions.

Our results suggest that the role of institutions and renewable energy consumption have significant positive and negative impact on the economic output and CO_2 emissions across the panels, respectively. Therefore, a significant presence of institutions and the use of renewable energy increases will strengthen the growth process and enhance environmental quality. Consequently, both institutional quality and renewable energy consumption lead towards sustainable economic development across the globe.

The major implications of our long-run elasticities are as follows. 1) Renewable energy consumption has two advantages across all countries in the panel. First, it promotes economic output and second, it helps to reduce CO_2 emissions. Increasing the share of renewable energy sources can meet the increasing demand for energy, and also replace conventional energy sources. This can potentially assist economies to focus on economic development without undue concern for CO_2 emissions and the associated perils. Furthermore, the consumption of renewable energy allows countries to move towards sustainable economic development objectives. 2) Institutional quality plays a substantial role in promoting economic output. This promotion of economic output suggests that having higher economic freedom works in favour of economic development across the countries. This finding supports the prevailing literature insofar as that the institutional quality was shown to be a significant factor in economic development and prosperity across the globe (see, e.g., Aisen & Veiga 2013; Glaeser et. al. 2004). For instance, having more freedom allows individuals to think innovatively and participate more efficiently in productive activities. Accordingly, we argue that institutional quality should be promoted across countries with the aim of achieving associated benefits such as economic development and prosperity. For instance, countries with higher institutional quality give higher priority to sustainable economic development. These countries aim to reduce CO_2 emissions by increasing the share of renewable energy in their total energy mix and therefore adopt effective policies to discourage the use of conventional fossil fuel energy sources. 3) Higher levels of income are associated with a reduction in CO_2 emissions across the panels. Based on this result, we argue that, as economic prosperity increases, governments and individuals become increasingly capable of investing in and adopting environmentally friendly products, and will be more careful of the effect of their actions on the environment. This helps to reduce CO_2 emissions more organically and more efficiently. To choose alternative energy options such as renewables, governments, policy makers and regulators in each country should assess the range of goals and interests, from global to local level, in judging the impacts and risks of changes to the energy mix. In this aspect, as discussed previously, institutions play a significant role in implementing appropriate energy-mix and overall energy policies.

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Appendix-I: List of Countries

Full Sample
Algeria, Australia, Austria, Bangladesh, Belgium, Belize, Benin, Bolivia, Botswana, Brazil, Bulgaria, Chile, China, Costa Rica, Croatia, Cyprus, Czech Republic, Denmark, Dominican Republic, Ecuador, Egypt, El Salvador, Estonia, Finland, France, Gabon, Germany, Greece, Guatemala, Honduras, Hungary, Iceland, India, Indonesia, Iran, Israel, Ireland, Italy, Japan, Jordan, Kenya, Latvia, Luxembourg, Madagascar, Malaysia, Mali, Malta, Mauritius, Mexico, Morocco, Namibia, Netherlands, New Zealand, Nigeria, Norway, Pakistan, Panama, Peru, Philippines, Poland, Portugal, Romania, Russia, Rwanda, Senegal, Sierra Leone, Singapore, Slovak Republic, Slovenia, South Africa, Spain, Sri Lanka, Sweden, Switzerland, Thailand, Togo, Trinidad and Tobago, Tunisia, Turkey, Uganda, Ukraine, United Kingdom, United States, Uruguay, Venezuela
High Income Countries (HIC)
Australia, Austria, Belgium, Chile, Croatia, Cyprus, Czech Republic, Denmark, Estonia, Finland, France, Germany, Greece, Hungary, Iceland, Ireland, Israel, Italy, Japan, Latvia, Luxembourg, Malta, Netherlands, New Zealand, Norway, Poland, Portugal, Russia, Singapore Slovak Republic, Slovenia, Spain, Sweden, Switzerland, Trinidad and Tobago, United Kingdom, United States, Uruguay, Venezuela
Low and Middle Income Countries (L&MIC)
Algeria, Bangladesh, Belize, Benin, Bolivia, Botswana, Brazil, Bulgaria, China, Costa Rica, Dominican Republic, Ecuador, Egypt, El Salvador, Gabon, Guatemala, Honduras, India, Indonesia, Iran, Jordan, Kenya, Madagascar, Malaysia, Mali, Mauritius, Mexico, Morocco, Namibia, Nigeria, Pakistan, Panama, Peru, Philippines, Romania, Rwanda, Senegal, Sierra Leone, South Africa, Sri Lanka, Thailand, Togo, Tunisia, Turkey, Uganda, Ukraine
Middle East and North African countries (MENA)
Algeria, Egypt, Iran, Israel, Jordan, Malta, Morocco, Tunisia
AFRICA
Benin, Botswana, Gabon, Kenya, Madagascar, Mali, Mauritius, Namibia, Nigeria, Rwanda, Senegal, Sierra Leone, South Africa, Togo, Uganda
Europe & Central Asia (E&CA)
Austria, Belgium, Bulgaria, Croatia, Cyprus, Czech Republic, Denmark, Estonia, Finland, France, Germany, Greece, Hungary, Iceland, Ireland, Italy, Latvia, Luxembourg, Netherlands, Norway, Poland, Portugal, Romania, Russia, Slovak Republic, Slovenia, Spain, Sweden, Switzerland, Turkey, Ukraine, United Kingdom
SE-Asia & Pacific (SE-ASIA & Pacific)
Australia, Bangladesh, China, India, Indonesia, Japan, Malaysia, New Zealand, Pakistan, Philippines, Singapore, Sri Lanka, Thailand
Annex 1
Australia, Austria, Belgium, Bulgaria, Croatia, Cyprus, Czech Republic, Denmark, Estonia, Finland, France, Germany, Greece, Hungary, Iceland, Ireland, Italy, Japan, Latvia, Luxembourg, Malta, Netherlands, New Zealand, Norway, Poland, Portugal, Romania, Russia, Slovak Republic, Slovenia, Spain, Sweden, Switzerland, Turkey, Ukraine, United Kingdom, United States
Non-Annex 1
Algeria, Bangladesh, Belize, Benin, Bolivia, Botswana, Brazil, Chile, China, Costa Rica, Dominican Republic, Ecuador, Egypt, El Salvador, Gabon, Guatemala, Honduras, India, Indonesia, Iran, Israel, Jordan, Kenya, Madagascar, Malaysia, Mali, Mauritius, Mexico, Morocco, Namibia, Nigeria, Pakistan, Panama, Peru, Philippines, Rwanda, Senegal, Sierra Leone, Singapore, South Africa, Sri Lanka, Thailand, Togo, Trinidad and Tobago, Tunisia, Uganda, Uruguay, Venezuela

Appendix-II: Summary Statistics of the variables for full sample, across six-regions and ANNEX 1 AND NON-ANNEX 1 countries: 1991-2012

	GDP		CO_2		LF		GFCF		NREC		REC		GDPPC		IQ	
	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD
Full sample	24.942	1.993	-0.087	0.040	15.552	1.712	23.372	2.079	-0.622	2.100	11.272	2.036	8.555	1.541	1.871	0.230
HIC	25.862	1.806	-0.078	0.034	15.222	1.617	24.326	1.827	0.056	1.728	11.015	2.171	9.912	0.781	1.942	0.255
M&LIC	24.161	1.803	-0.094	0.043	15.833	1.741	22.562	1.931	-1.198	2.213	11.490	1.887	7.405	0.992	1.811	0.186
MENA	24.482	1.168	-0.073	0.018	15.196	1.552	22.994	1.202	-0.505	1.425	9.148	2.419	8.159	0.952	1.811	0.163
SSA	22.777	1.340	-0.125	0.044	14.998	1.307	21.042	1.422	-3.048	1.674	11.145	1.531	6.845	1.223	1.779	0.164
E&CA	25.840	1.554	-0.076	0.034	15.333	1.473	24.298	1.561	0.065	1.507	11.267	1.484	9.778	0.972	1.893	0.305
SE-ASIA & Pacific	26.071	1.446	-0.075	0.036	17.236	1.725	24.684	1.546	0.895	1.556	12.806	2.164	8.057	1.603	1.915	0.154
Annex1	25.970	1.794	-0.074	0.033	15.408	1.653	24.430	1.813	0.194	1.736	11.252	1.989	9.836	0.926	1.916	0.291
Non- Annex1	24.149	1.764	-0.096	0.042	15.664	1.749	22.556	1.895	-1.252	2.139	11.288	2.071	7.568	1.141	1.837	0.159

Note: Variable Notations: GDP: GDP; CO_2: CO_2 emissions per capita; LF: labor force; GFCF: gross fixed capital formation; NREC: non-renewable energy consumption; REC: renewable energy consumption; GDPPC: GDP per capita; IQ: Institutional Quality. Classifications of regions are: High Income Countries (HIC), Middle & Low Income Countries (M&LIC), Middle East and North African countries (MENA), Sub-Saharan African countries (SSA), Europe & Central Asia (ECA), South Asia and East Asia Pacific (SA&EAP)

Appendix-III: Unconditional Correlations between Variables: 1991-2012

	GDP	CO_2	LF	GFCF	NREC	REC	GDPPC	IQ
GDP	1.000							
CO_2	0.425	1.000						
LF	0.700	0.334	1.000					
GFCF	0.991	0.430	0.685	1.000				
NREC	0.937	0.643	0.756	0.929	1.000			
REC	0.582	0.080	0.797	0.559	0.527	1.000		
GDPPC	0.552	0.192	-0.204	0.558	0.397	-0.118	1.000	
IQ	0.219	-0.168	-0.127	0.240	0.076	-0.029	0.453	1.000

Note: Estimated using natural logarithms data.

- Renewable energy sources play a key role for economic growth and emissions
- The role of institutions is significant in renewable deployment
- Renewable deployment has been increasing in developing region
- Heterogeneity across countries can be significant in the deployment process