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Effects of International Climate Policy on Renewable Energy Consumption: The Context of the Kyoto Protocol

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Abstract

Purpose: The key objective of this study is to explore the effect of the Kyoto Protocol on Renewable Energy Consumption at the national level.

Methodology: The study employed the matching and difference-in-differences (DiD) estimation approaches. The study analysis is based on secondary resources assessed through openly access documents, journals, and libraries. Data used in the analysis were collected from publicly available data sources.

Findings: The study finds that the Kyoto Protocol has a significant and positive impact on renewable energy consumption at the national level in the Annex I countries compared to non-Annex I countries. It indicates that there has been a specific effect of the Kyoto Protocol on renewable energy in Annex I countries since these countries were legally bound with emissions reduction commitments of the Protocol. Findings indicate that Annex I countries overlooked environmental pollution at the early stages of their economic and industrial development, but with their higher economic development, they are taking measures to prevent environmental pollution, such as increasing REC. Findings here reckon with the argument of the effectiveness of global climate governance in mitigating climate change effects.

Unique Contribution to Theory, Practice and Policy: Findings support the Environmental Kuznets Curve (EKC) proposition. Results stresses on the effectiveness of global climate governance for mitigating climate change effects. In this context, rich countries should deliver more financial and technological supports to poor countries.

Keywords: *Climate change, Climate policy, Kyoto Protocol, Renewable Energy Consumption.*

1. Introduction

Climate change has become an existential issue for humankind. Perceiving a clear indication of global environmental threats (Przychodzen and Przychodzen, 2020:1), states have been adopting different policies — globally and nationally – to slow down and mediate climate change effects. With the establishment of the United Nations Framework on the Convention of Climate Change (UNFCCC) in 1992, countries have become successful in formulating major international climate policies (i.e., Kyoto Protocol, Paris Agreement) to curb the greenhouse gases (GHG) emissions.[1] The importance of effective universal climate policy becomes unavoidable, as "the public goods nature of CO_2 emissions" (Aichele and Felbermayer, 2013: 731) and the externalities caused by the emissions are affecting everyone. However, debate remains on the effectiveness of universal climate policy in addressing climate change effects.

Aligning with policy-making, states have been implementing various measures in mitigating emissions at the national level. Renewable energy generation is one of the key solutions in this regard. Over the years, there has been increasing growth in renewable energy consumption across countries. Although renewable energy covers 26.2% of global final energy consumption (Raturi, 2019; 41), in 2019, for the first time, the increase in renewable electricity generation surpassed the increase in fossil-fuel electricity demand that led to a decline in fossil-fuel electricity generation (IRENA, 2020: 22; Kåberger, 2020). The International Renewable Energy Agency (IRENA) predicts that by 2050 renewable energy use will reach 70-80% shares in total energy mixes across regions (IRENA, 2020:17). Recent interactive collaboration between the government and non-government organizations (NGOs) has led the rise in renewable energy consumption (Hein and Holstenkamp, 2018). Yet, there remain inadequate institutional coordination and investor - state disputes regarding global energy governance (Tienhaara and Downie, 2018). In this regard, a question emerges; To what extent could the global climate governance play a significant impact on renewable energy as a means to curb emissions level.

For addressing this question, the study focused on the Kyoto Protocol, and explored the effect of the Kyoto Protocol on renewable energy consumption (REC). As the first major international climate agreement, the Kyoto Protocol was adopted in 1997, ratified by 191 countries and entered into force in 2005 (Kyoto Protocol, UNFCCC, 2005). The key argument of the Protocol was the legally binding emissions targets for developed country parties for the six major GHG and three market-based mechanisms: Emissions Trading (ET), Clean Development Mechanism (CDM), and Joint Implementation (JI) (Kyoto Protocol, UNFCCC, 2005). Wohlgemuth and Missfeldt (2000: 306) argue that these three Kyoto Mechanisms - ET, JI, and CDM - would allow the investors to receive 'GHG emission reduction credits' and would lead to towards zero GHG emissions gradually.

[1] The GHG include Carbon-dioxide, Methane, Nitrous-oxide, Hydrofluorocarbons, Perfluoro-carbons, and Sulfur-hexafluoride.

Studies (Aichele and Felbermayer, 2013; Liu et al., 2019; Przychodzen and Przychodzen, 2020; Aichele and Felbermayr, 2013; Grunewald and Martinez-Zarzoso, 2016; and Cifci and Oliver, 2018) suggest that policies play a vital role in reducing GHG emissions, especially in wealthy and industrialized countries. Authors argue that these countries undertook various measures to curb CO_2 emissions, including renewable energy generation. However, their present day effort of reducing emissions is linked with historical context of industrial and economic development. Building on these studies and adopting a global sample of 173 countries, the current study explores the effect of the Kyoto Protocol on REC. Adding a policy variable – Kyoto commitments – this study follows the Environmental Kuznets Curve (EKC) framework[2] to analyze the effects of the Kyoto Protocol on REC.

Following the matching and difference-in-differences (DiD) estimation approaches, this study finds that the Kyoto Protocol has a significant and positive impact on REC at the national level. Findings here reckon with the argument of the effectiveness of global climate governance in mitigating climate change effects. At the same time, results support the EKC proposition as well. The rest of the paper is outlined as follows. Section 2 focuses on the issues related to global climate governance and renewable energy. Section 3 describes data and methods. Section 4 presents the results, and section 5 concludes the study.

2. International Climate Policy and Renewable Energy

Climate change has been a global problem, and "its very nature crosses over and between the domestic and international arenas of politics and policymaking" (Harris, 2007: 5). Initiatives for combating climate change effects require collective action at both the international and national levels to minimize the effects of climate change (Esty, 2008 and 2009). Realists express their pessimism about having effective global climate governance (Vogler 2015), while liberal institutionalists express optimism on the institutional establishment (Bäckstrand and Lövbrand, 2015). The latter group emphasizes on the importance of international climate governance. In this regard, the Kyoto Protocol has played a significant role in addressing climate change.

Entered in 2005, the Kyoto Protocol instituted the legal regulations of GHG emissions reduction for the developed countries. It encourages the promotion of REC (Kyoto Protocol, UNFCCC, 2005). Article 2 of the Kyoto Protocol stresses the importance of research, promotion, and development of new and renewable forms of energy; Article 6 focuses on Joint Implementation (JI); Article 12 brings up the Clean Development Mechanism (CDM); Article 17 emphasizes the Emissions Trading (ET) (Kyoto Protocol, UNFCCC 2005). As of the first

[2] According to the Environmental Kuznets Curve (EKC) theoretical approach, countries disregard the environmental quality of their economic development (at the primary stages) during the industrialization process based on high consumption of fossil fuels. Once they reach a certain income threshold, they become more concerned about environmental pollution (Grossman and Kruger, 1991; Shafik, 1994; Jebli et al., 2016). Thus, they focus more on environmental pollution reduction measures, including using more clean energy and green technologies (Nguyen and Kakinaka, 2019).

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commitment (five-year period 2008-2012), it sets targets for 41 industrialized countries and the EU to reduce their CO2 emission by an average of 5% compared to the 1990 level (UNFCCC, 2005). At the same time, the Kyoto Protocol offers "economic incentives for significant emissions abatement in developing countries" (Wohlgemuth and Missfeldt, 2000: 307), which would lay the better ground for REC.

Liu et al. (2019) find that policies, and policy support have a positive impact on renewable energy capacity. Przychodzen and Przychodzen (2020) show that implementation of Kyoto commitments at the national level are positively related to an increasing amount of renewable energy. Nguyen and Kakinaka (2019) argue that economic growth and REC are positively associated with high-income countries. In contrast, they are negatively associated with low-income countries. Studies by Sadorsky (2009a, 2009b), Salim and Rafiq (2012), and Apergis and Payne (2014) argue that increasing CO_2 emissions per capita leads to higher REC per capita, and an increase in the latter leads to lower CO_2 emissions per capita. In the same way, they argue higher oil prices lead to a rise in REC, and the rise in REC slopes the oil prices down. The nexus between GDP growth and renewable energy indicates a bidirectional and significant causal relationship (Apergis and Payne, 2014: 4524). Per the EKC proposition, Jebli et al. (2016) suggest that growth in real GDP has a positive effect on renewable energy. At the same time, by reducing CO_2 emissions, renewable energy plays a vital role in boosting economic growth (Sadorsky, 2009a and 2009b; Payne, 2012; Salim and Rafiq, 2012; and Apergis and Payne, 2014). Shafiei and Salim (2014) find that REC significantly and negatively impacts CO_2 emissions, while non-renewable energy and CO_2 emissions are significantly and positively associated. Their analysis also supports the EKC based on the inverse relationship between urbanization and CO_2 emissions.

From discussion in literature suggests that renewable energy plays a vital role in reducing emissions level under certain policy circumstances. Since the Kyoto Protocol has set legally binding emission reduction targets for the Annex I countries, I expect the following hypothesis;

H_I: Countries with emissions reduction commitment are more likely to have increased REC at their national levels compared to countries without emissions reduction commitment.

3. Data and Empirical Strategy

Variables and their sources

For this study, panel data are collected for a global sample of 173 countries for period of 1991-2012. Year 2005 is the treatment effect year since the Kyoto Protocol entered into force in 2005. For Kyoto commitment, it takes a value of one for the countries that ratified the Protocol with emissions reduction commitments and a value of zero for otherwise. Based on the UNFCCC country categorization, the Kyoto Protocol institutes legal regulations of CO_2 emissions reduction for 41 industrialized countries, also known as Annex I parties. On the other hand, 151 developing countries did not fall into this category, known as non-Annex I countries (UNFCCC, 2005). In this study, 37 Annex I countries comprise the treatment group, and 136 non-Annex I countries represent the control group.

The outcome variable, REC, is measured as % of renewable energy in total energy consumption and collected from the World Bank (World Bank, 2020). The key independent or treatment variable, Kyoto Commitment, is gathered from the UNFCCC. Variables, total population (millions), and GDP per capita (2010 constant US$) are resourced from the World Bank. Oil price is collected from British Petroleum (BP), and deflated with Consumer Price Index (CPI) to obtain the real oil prices. The CPI is from the International Monetary Fund (IMF). Capital stock (constant 2011 national prices in millions) from Penn World Table (PWT9.1) is divided by the total population to obtain its per capita value. Energy intensity is from the United States Energy Information Administration (USEIA). The democracy score is from Freedom House (FH). Data measurements and sources of variables, summary statistics, and correlation matrix are shown in Tables A.1, A.2 and A.3, respectively, in Appendix.

Models Specification

Given the context of the Kyoto commitments for Annex I but not for the non-Annex I countries, the study evaluates the differential effect of the Kyoto Protocol on REC between these two groups of countries using the DiD estimation approach. The DiD equation is as follows:

$$REC_{it} = \gamma_i + \lambda_t + \delta T_{it} + \beta X_{it} + \varepsilon_{it} \text{ .... (1),}$$

where REC_{it} is REC by country *i* in year *t*. γ_i denotes country-level fixed effects and considers unobserved, time-invariant heterogeneity across countries. λ_t denotes year-fixed effects and includes unobserved variation among countries. T_{it} indicates the *DiD* treatment, an interaction term between T_i which takes 1 for the Annex I countries starting from 2005, and 0 for otherwise. δ, the estimated coefficient, denotes the *DiD* treatment effect of the Kyoto Protocol on REC. X_{it} represents the control variables for country *i* in year *t*, and β are characterized as inter-related elasticities. ε_{it} represents the error term.

Since the study compares the effect of the Kyoto Protocol between Annex I and non-Annex I countries, the conditional average treatment effect on being treated indicates the effect of having the Kyoto commitments.[3] The conditional average treatment effect on the treated model is as follows:

$$ATT = E\left[Y_{i(1)} - Y_{i(0)} \middle| Z_i = 1\right] \text{............ (2),}$$

where *ATT* denotes the average treatment effect on being treated. *E* represents the expectation of operation. Y_i signifies the Kyoto commitments, which take a value of one for Annex I countries and zero for non-Annex I countries. Z_i has represented Kyoto over the years.

[3] In this regard, to overcome the self-selection problem, following Grunewald and Martinez-Zarzoso (2016), the study perceives the non-Annex I countries as a counterfactual group.

In the DiD estimation design, countries in both control and treatment groups must adhere to the parallel trend assumption of REC (both in non-Annex I and Annex I countries). Figure A.1[Appendix A] shows the violation of the parallel trend assumption. Thus, the study uses the propensity score matching (PSM) method and applies a logit estimator to estimate the propensity score (PS) to meet the parallel trend assumption. The logit model for the PSM is as follow:

$$Treat_i = \beta_1 lnPopn\_total_i + \beta_2 Popngrowth_i + \beta_3 Popngrowth_i^2 + \beta_4\, lnGDP\_pc_i + \beta_5\, GDP\_pcgrowth_i + + \beta_6 GDP\_pcgrowth_i^2 + \beta_7 lnRealoilprices_i + \beta_8 Realoilpricegrowth_i + \beta_9 Realilpricegrowth_i^2 + \beta_{10} lnCapitalstock_i + \beta_{11} Capitalstockgrowth_i + \beta_{12} Capitalstockgrowth_i^2 + \beta_{13} Energydensity_i + \beta_{14} Energydensitygrowth_i + \beta_{15} Energydensitygrowth_i^2 + \beta_{16} Democracy_i + \varepsilon_i \ldots (3),$$

where $Treat_i$ equals a value of one for the Annex I group and zero for otherwise. The annual growth rates of variables - total Population, GDP per capita, real oil prices, capital stock per capita, and energy intensity - used in equation (3) are calculated as percentages. The logged values are used for the variables of the total population, GDP per capita, real oil prices, and capital stock per capita. Democracy is used as its base value. ε_i denotes the error term.

As of the PSM, the study applies the nearest neighbor approach to match the treatment group with the control group by using the variables that offer the closest PS for picking the observations that could be matched in both group comparison. Subsequently, the study employs the DiD estimation to the matched observations to estimate the effect of the Kyoto Protocol on REC. Thus, the study modifies equation (1), where it takes the following specification:

$$ATT_{PSM}^{DD} = E[(y_{ia} - y_{ib})|T = 1] - E[(y_{ia} - y_{ib})|T = 0] \ldots\ldots\ldots\ldots (4),$$

where *a* denotes post-treatment, *b* is for pre-treatment, and *T* takes a value of one for the treatment group and zero for otherwise. The DiD model estimates the impact of the Kyoto Protocol on REC by comparing the average changes in REC before and after 2005 for Annex I and non-Annex I countries.

4. Results

This study explores how compliance with the Kyoto Protocol could influence the states to increase their REC at the national level. Table 1 presents the results of propensity score estimation to ratify the Kyoto Protocol with emissions reduction commitments. Results from logistic regression (equation 3) [Table A.4 in Appendix A] show that variables — total population, population growth and its squared value, GDP per capita, real oil prices and their growth rate, and energy intensity — are statistically significant at the .01 level. Energy intensity growth and its squared value and democracy are statistically significant at 0.05. Variable capital stock per capita is statistically significant at the 0.1 level. The results suggest that the propensity scores from these variables determine the matching between the treated and control group. However, not all the variables used in equation (3) offer the scores for balancing between the treatment and control groups. Following Dehejia and Wahba (2002), this study carefully examines all variables used in equation (3) and finds four variables (total population, GDP per capita growth, real oil prices, and growth in capital stock per capita) to be the closest match to meet the balance between the covariates for treatment and control groups.

Following the nearest neighbor matching, the study creates the control group by matching Annex I countries to non-Annex I countries, which shows a likelihood of being in the treated group. After matching, the study conducts a balance test and the test of difference in mean of explanatory variables. As of the balance test result, the balancing property is met with a difference of -.603 in the mean difference between the treated and control group. Result on balance test is provided in Table A.4 [Appendix A]. Figure A.2 [Appendix A] shows the predicted propensity matching score (with the density of observations) between the treated and untreated groups.

Table 1 reports the results obtained from the *DiD* estimation. Models 1, 2, and 3 outline the results for the matched samples, whereas Models 4, 5, and 6 represent the results for the entire sample. Frequency weight is used in Models 1, 2, and 3 but not in Models 4, 5, and 6 while running the regression analysis. Limiting the sample to the matched samples compared to the total samples offers a means to control the endogeneity for the policy variable, the Kyoto commitments. All six models have calculated results using the year and country fixed effects, while standard error has been clustered.

Results of the Kyoto effect are shown in Model 1 of Table 1. It indicates a significant increase in REC in Annex I countries compared to non-Annex I countries. The difference in REC from pre-to post-Kyoto for non-Annex I countries is -.0612. The former coefficient is statistically significant at the .01 level, but the latter coefficient has no statistical significance. With two explanatory variables – total population and GDP per capita — Model 2 shows that Annex I countries, on average, have a 30.8% increase in REC compared to the non-Annex I countries, which have common characteristics regarding total population and GDP per capita but do not have the Kyoto commitments. The treatment effect is statistically significant at the .01 level.

The parameter estimates on GDP per capita and its squared value, statistically significant at the .05 level, indicate that GDP per capita has a negative impact, but a higher amount of GDP per capita has a positive impact on REC. This supports the EKC proposition that countries at the beginning of their economic and industrial development ignore environmental pollution. But when they reach a certain developmental threshold with higher GDP per capita, they become more concerned about reducing environmental pollution, such as consuming more renewable energy.

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Table 1: The effects of the Kyoto Protocol on REC

	(1)	(2)	(3)	(4)	(5)	(6)
Sample	Matched	Matched	Matched	Total	Total	Total
Variables						
Kyoto enter into force =1 if after 2004	-0.0612	0.0882	0.0766	-0.128**	0.00283	-0.0353
	(0.0428)	(0.0721)	(0.0682)	(0.0499)	(0.0701)	(0.0848)
Treatment effect	0.458***	0.308***	0.272***	0.545***	0.556***	0.527***
	(0.0840)	(0.0965)	(0.0983)	(0.0859)	(0.115)	(0.138)
Total population (log)		-0.528	-0.346		-0.231	-0.179
		(0.328)	(0.324)		(0.151)	(0.192)
GDP pc (log)		-1.418**	-2.097***		0.508	0.479
		(0.568)	(0.757)		(0.648)	(0.871)
GDP pc (log)_sq.		0.0766**	0.0967***		-0.0533	-0.0529
		(0.0307)	(0.0357)		(0.0452)	(0.0541)
Real oil prices (log)			-0.0271			-0.0183
			(0.0391)			(0.0161)
Capital Stock pc (log)			0.140			-0.140
			(0.249)			(0.129)
Energy Intensity			-0.0597***			-0.0622***
			(0.0220)			(0.0168)
Democracy			-0.0221			-0.0125
			(0.0188)			(0.00973)
Country Fixed Effect	Yes	Yes	Yes	Yes	Yes	Yes
Year Fixed Effect	Yes	Yes	Yes	Yes	Yes	Yes
Constant	2.362***	10.02***	13.13***	2.818***	2.743	4.916*
	(0.0152)	(2.733)	(3.078)	(0.0154)	(2.245)	(2.827)
Observations	1,510	1,496	1,472	3,778	3,644	2,901
R-squared	0.973	0.973	0.974	0.951	0.953	0.953

Notes: Robust standard errors in parentheses. *** p<0.01, ** p<0.05, * p<0.1

Results in Model 3 show that due to the Kyoto effect leads a significant increase in REC in Annex I countries compared to non-Annex I countries, which have common demographic, socio-economic, and political characteristics – total population, GDP per capita, real oil price, energy intensity, capital stock per capita, and democracy – but without the Kyoto commitments. The coefficient is statistically significant at the .01 level. Like results in Model 2, coefficients on GDP per capita and its squared value support the EKC proposition with more significance. The coefficient on energy intensity is statistically significant (at the .01 level).

Results from the total samples indicate that the treatment effect is statistically significant at the .01 level in all three cases. The coefficient on energy intensity in Model 6 (statistically significant at the .01 level) also signifies its negative impact on REC. Results from Models 5 and 6 do not support the EKC proposition. Robustness checks Table B.1(Compare mean difference (ATT) using other matching methods) and B.2 (The Pre-Kyoto differences) [Appendix B] suggest the significant impact of the Kyoto Protocol on REC in Annex I countries.

Results here reiterate findings from Przychodzen and Przychodzen's (2020) study of the post-socialist economies and the results of Liu et al. (2019) study of the E.U., OECD, India, and China context. At the same time, similar to studies by Sadorsky (2009), Payne (2012), Salim and

Rafiq (2012), Apergis and Payne (2014), and Jebli et al. (2016), the results of the current study support the EKC proposition, where GDP per capita has a negative impact. Still, a higher GDP per capita has a significant positive impact on REC.

5. Conclusion

Following the *Matching and DiD* methodological analyses, this study evaluates the differential effects of the Kyoto Protocol on REC. Results from this study suggest that the Kyoto Protocol has significant and positive impact on REC at the national level in Annex I countries compared to non-Annex I countries. It indicates that there has been a specific effect of the Kyoto Protocol on renewable energy in Annex I countries since these countries were legally bound with emissions reduction commitments of the Protocol. At the same time, the findings support the EKC proposition indicating that Annex I countries overlooked environmental pollution at the early stages of their economic and industrial development, but with their higher economic development, they are taking measures to prevent environmental pollution, such as increasing REC. Research findings here shed light to the debate on effectiveness of global climate governance for mitigating climate change effects supporting the liberal institutionalists' views on global cooperation. Thus, the increasing trend of REC started with the Kyoto Protocol should continue with Paris Agreement. However, all countries — Annex and non-Annex I — should focus on REC for militating climate change effects. In this regard, rich countries should deliver more financial and technological supports to poor countries. Further research can contribute more to this context.

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