



# ASSOCIATION BETWEEN RENEWABLE ENERGY CONSUMPTION AND SOME MACROECONOMIC VARIABLES: PANEL EVIDENCE FROM ASIAN PACIFIC COUNTRIES

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## Abstract

This study aims to investigate the association between Renewable Energy Consumption and macroeconomic variables, including Carbon Dioxide Emissions, Financial Development Index, Energy Poverty Index, Gross Domestic Product, Trade Openness, and Urbanized Population, across 36 Asian and Pacific countries from 1998 to 2023. Using the fixed-effects model and quantile regression, the study finds that Gross Domestic Product, Financial Development Index, and Urbanization have a positive impact on energy use. In contrast, the Energy Poverty Index and CO<sub>2</sub> emissions have a negative impact. Granger causality test results indicate bidirectional causality between renewable energy consumption & gross domestic product and renewable energy consumption & CO<sub>2</sub> emissions. Further, unidirectional Granger causality is observed between renewable energy consumption and financial development index, renewable energy consumption and trade openness, renewable energy consumption and urbanization, and carbon dioxide emissions and energy poverty index. This study suggests that access to clean, affordable energy can eliminate energy poverty and facilitate greater consumption of renewable energy. This study also recommends that strengthening financial development instruments in 36 Asian and Pacific countries can lead to greater renewable energy consumption and a more robust economic growth trajectory.

**Keywords:** Renewable Energy Consumption, Macroeconomic Variables, Hausman Test, Fixed Effect Model, Granger Causality and Quantile Regression.

## 1. INTRODUCTION

Renewable Energy is widely recognized as a crucial determinant of a nation's economic progress, serving as a vital catalyst for comprehensive development (Ito, 2017; Shahbaz et al., 2013; Jamel & Derbali, 2016). Economists believe that renewable energy consumption is associated with economic activities and plays a significant role in the economic development of a nation (Lee and Chang, 2008), Narayan and Smith, 2008) & Tsani, 2010). Therefore, the connection among renewable energy consumption and macroeconomic variables has received increased attention globally. Asian and Specific countries appeared as the main drivers of the world economy, helping meaningfully to production, export, import, commerce, innovation, research, and development. During the last forty years, the region has converted from an agrarian economy to an industrial economy with a fair amount of technological upliftment.

Asian and Specific economies contribute over 60% of the world's GDP in terms of purchasing power parity (PPP) and 45 % of the world's GDP in nominal terms. Major countries included in this list are China, India, Japan, Singapore, South Korea, and Australia. Of the above list, China contributed around 20% of global GDP, whereas India contributed 7%. Japan is performing well in innovation and technological development. This region is also a major contributor to Global trade, accounting for nearly 55% of global exports and imports. Vietnam, China, Singapore, and South Korea are highly connected to the global value chain. Another key contribution of this region is the performance of its manufacturing sector, which accounts for around 60% of global manufacturing output in textiles, machinery, electronics, and automobiles. The correlation between renewable energy consumption (REC) and major

macroeconomic variables such as carbon dioxide (CO<sub>2</sub>) emissions, financial development, gross domestic product (GDP), trade openness, energy poverty, and urbanization has garnered considerable awareness in recent studies.

For the following reasons, the study concentrates on the Asian and Pacific countries. First, they are among the world's fastest-growing economies. Second, Asian and Pacific countries contributed 45% of the world's Gross National Product, valued at 2005 US Dollar purchasing power parity, from 2008–2017 (Mahalik et al., 2021). Our study contributes to the present body of knowledge in three ways. First, the inclusion of urbanization and trade openness in the relationship between renewable energy and growth has not been exhaustively studied, especially in Asian and Pacific countries. Second, to our knowledge, this is the first study to investigate the factors affecting renewable energy consumption by using key macroeconomic variables for Asian and Pacific countries. Thirdly, this study suggests to policymakers in Asian and Pacific countries how to become energy-efficient nations based on its findings.

## 2. METHODOLOGY

The data for the study were collected from the World Development Indicators database of the World Bank. The research period considered for the empirical observation is 1998 to 2023.

The following equation expresses the regression model.

$$REC_{it} = \alpha_i + \beta_1 \ln CO2_{it} + \beta_2 FDI + \beta_3 EPI_{it} + \beta_4 GDP_{it} + \beta_5 TO_{it} + \beta_6 UR_{it} + u_{it}$$

Where,  $REC_{it}$  = Renewable Energy Consumption,  $\alpha_i$  = Individual effects,  $CO2_{it}$  = Carbon Dioxide Emissions,  $FDI_{it}$  = Financial Development Index,  $EPI_{it}$  = Energy Poverty Index,  $GDP_{it}$  = Gross Domestic Product,  $TO_{it}$  = Trade Openness,  $UR_{it}$  = Urbanized Population and  $u_{it}$  = Term of random disturbance.

## 3. EMPIRICAL RESULT AND DISCUSSION

Table 1 depicts descriptive statistics for dependent and independent variables for all the countries from 1998 to 2023.

**Table 1: Descriptive Statistics**

	REC	CO <sub>2</sub>	FDI	EPI	TO	UR	GDP
<b>Mean</b>	7.271	150.581	25.446	26.813	16.457	52.415	18.500
<b>Median</b>	7.190	8.43007	25.342	26.710	4.674	55.919	21.491
<b>Maximum</b>	9.437	2700.442	29.456	30.294	2841.578	86.824	26.396
<b>Minimum</b>	5.574	2.614	22.383	23.636	-571.667	17.184	0.000
<b>Std. Dev.</b>	0.993	406.298	1.430	1.298	187.155	21.275	8.436
<b>Skewness</b>	0.190	3.357	0.470	0.2445	13.744	-0.193	-1.550
<b>Kurtosis</b>	2.180	15.096	3.207	3.0258	209.830	1.661	3.840

Source: Author's compilation from WDI

**Table 2: Cross-sectional Dependence Test Result**

Test	Statistic	Prob.
Pesaran CD	1.411160	0.1582

Source: Author's own calculation from WDI

This study used the Pesaran CD test to assess cross-sectional dependence in the residuals. From the table above, we can see that the test is not significant at the 5% level.

**Table 3: Unit Root Test Results**

Variables	Levin, Lin, and Chu	ADF-Fisher and Chi-Square	PP-Fisher Chi-Square
	Level I(0)	Level I(0)	Level I(0)
REC	5.31***	2.93**	3.71***
CO2	3.27***	6.48***	6.65***
FDI	2.86**	15.08***	12.92***
EPI	2.98**	25.62***	38.98***
UR	2.40**	65.93***	75.04***
TO	6.78***	86.30***	120.10***
GDP	3.17***	6.37***	7.06***

Note: (\*\*\*) show significance at 1% level and (\*\*) show significance at 5% level.

Source: Author's own calculation from WDI

Table 3 reveals that the dependent and independent variables are stationary at level I(0) at 1% and 5% level of significance, which satisfies the assumptions of the cointegration test.

**Table 4: Pedroni Cointegration Test**

Cointegration Test	Statistic	P Value
Panel v	-0.202282	0.5802
Panel rho	2.221935	0.9869
Panel PP	2.274208	0.9885
Panel ADF	1.684561	0.9540
Group rho	3.137528	0.9991
Group PP	3.074468	0.9989
Group ADF	2.166645	0.9849

Source: Author's own calculation from WDI

Out of all seven-panel test statistics, none are significant at a 1% or 5% level of significance. So, there is no cointegration among the variables. After checking the cointegration of the model, this paper calculated Hausman test to understand whether there is fixed effects or random effects.

**Table 5: Hausman Test Results**

Test Summary	Chi-Sq. Statistic	Chi-Sq. d.f.	P Value
Hausman Test	27.284***	8	0.0006

Source: Author's calculation

In Table 5 Chi-square statistics is 27.284, which is significant at 1%. Hence, the null hypothesis must not be accepted i.e. fixed effect is a better fit for this model.

**Table 6: Fixed Effect Model Results**

Variable	Coefficient	Std. Error	t-Statistic	P Value
CO <sub>2</sub>	-0.000144***	3.04E-05	-4.727410	0.0000
FDI	0.011478***	0.001576	7.280782	0.0000
EPI	-0.389984***	0.055516	-7.024660	0.0000
GDP	0.178354***	0.066631	2.676749	0.0079
TO	2.42E-05	5.18E-05	0.467453	0.6406
UR	0.009688***	0.002916	3.322633	0.0010
C	1.812073***	0.486878	3.721823	0.0002
R-squared	0.877925			
Adjusted R-squared	0.877002			
Standard Error	0.150639			
F-statistic	1058.780			
P Value	0.000000			

Source: Author's own calculation from WDI

Table 6 shows a positive association between Gross Domestic Product (GDP) and Renewable Energy Consumption (REC) in Asian and Pacific nations. This indicates that if these nations were to develop further, they would demand greater use of renewable energy for their citizens. The finding of this study is online with Lee and Chang (2005), Fotis et al. (2017), Pinzón (2018). Similarly, this study observed a positive relationship between urbanization and renewable energy use in Asian and Pacific nations. Rapid urbanization in these nations would result in a rise in the amount of physical infrastructure, which would need a higher level of renewable energy consumption. These results are similar to Jones (1991), Pachauri and Jiang, (2008), Liu (2009), Zhao and Zhang (2018). Financial Development Index (FDI) also has a positive relationship with renewable energy consumption. This implies that strengthening the financial inclusion instruments in these nations will enhance use of renewable energy consumption. This result is in line with Kutan et al. (2018), Alfaro et al. (2004).

On the contrary, CO<sub>2</sub> emission had a negative impact on renewable energy consumption in Asian and Pacific nations, which is statistically significant. This shows that more emissions will reduce the consumption of renewable energy. This result is similar to Martinsen et al. (2007), Fei and Rasiah (2014) and Zhang et al. (2014). Similarly, the Energy Poverty Index (EPI) has a negative association with renewable energy consumption. This indicates that if we can improve access to energy, which is above the minimum energy requirement that would warrant more renewable energy consumption in Asian and Pacific nations. Finally, trade openness has an insignificant relationship with renewable energy consumption.

**Table 7: Granger Causality Test**

Null Hypotheses:	W-Stat.	P Value
CO <sub>2</sub> does not cause REC	7.07950***	0.0000
REC does not cause CO <sub>2</sub>	7.25784***	0.0000
GDP does not cause REC	8.33697***	0.0000
REC does not cause GDP	5.89502*	0.0000
TO does not cause REC	2.61869	0.5968
REC does not cause TO	5.80364***	0.0002
UR does not cause REC	6.36588***	0.0000
REC does not cause UR	1.34165	0.2553
FDI does not cause REC	6.65316***	0.0000
REC does not cause FDI	2.33130	0.2104
EPI does not cause CO <sub>2</sub>	1.65307	0.3168
CO <sub>2</sub> does not cause EPI	4.65665***	0.0094

Source: Author's own calculation from WDI

Table 7 reports that a bidirectional causality exists between Renewable Energy Consumption and CO<sub>2</sub> emission in Asian and Pacific nations. This finding is analogous to Lee and Chang (2008), Narayan and Smith (2008), Tsani (2010). Similarly, there is also a bidirectional causality among Renewable Energy Consumption and Gross Domestic Product. Further, there is unidirectional causality observed between Renewable Energy Consumption & Trade Openness, Renewable Energy Consumption & Urbanisation and Renewable Energy Consumption & Financial Development Index, CO<sub>2</sub> Emissions and Energy Poverty Index. Results support the work of Wolde-Rufael (2006), Yoo (2006), Mozumder and Marathe (2007) and Pao and Fu (2013).

Table 8, below, shows that Gross Domestic Product (GDP) positively affects Renewable Energy Consumption across different quantiles. The magnitude of the variable has increased from the first to the fourth quantile, then declined. On the contrary, CO<sub>2</sub> emissions have a negative impact on Renewable Energy Consumption across different quantiles except the 5<sup>th</sup>

and 6<sup>th</sup> quantiles. Financial Development Index has a positive impact on all quintiles except the 8th quantile. The Energy Poverty Index and urbanization have positive impacts across the quantiles. Finally, trade openness has a positive impact up to the 7th quantile, and then it has a negative impact.

**Table 8: Quantile Regression Results**

VARIABLES	0.1	0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.9
<b>GDP</b>	1.09*** (4.47)	1.29*** (4.66)	1.81*** (6.23)	1.83*** (8.93)	1.37*** (5.58)	0.98*** (6.19)	0.69*** (3.27)	0.51*** (2.97)	0.48*** (3.22)
<b>CO<sub>2</sub></b>	-0.0001 (-1.61)	-0.0001 (-1.11)	-0.0001 (-0.80)	-0.0002 (0.48)	0.00002 (0.04)	0.0002 (0.81)	-0.0005** (2.37)	-0.0005** (-3.50)	-0.0006** (-5.15)
<b>FDI</b>	0.01* (1.86)	0.01* (1.69)	0.03** (2.39)	0.02*** (2.97)	0.01*** (3.15)	0.01** (2.04)	0.01* (1.83)	-0.01** (-2.04)	0.01** (-1.99)
<b>EPI</b>	1.07*** (4.92)	1.28*** (5.33)	1.81*** (7.44)	1.72*** (8.81)	1.27*** (5.65)	0.90*** (6.22)	0.62*** (3.22)	0.45*** (2.94)	0.41*** (3.13)
<b>UR</b>	0.02*** (12.37)	0.03*** (9.91)	0.03*** (12.39)	0.04*** (9.72)	0.05*** (16.95)	0.04*** (21.63)	0.04*** (13.86)	0.04*** (15.66)	0.04*** (17.90)
<b>TO</b>	0.0004*** (5.56)	0.0004*** (4.08)	0.002** (2.40)	0.0002* (1.78)	0.0001 (1.29)	0.00008 (1.12)	-0.0004 (-0.65)	-0.0002 (-0.34)	-0.0007 (-0.13)

Source: Author’s own calculation from WDI

#### 4. CONCLUDING REMARKS

The study findings indicate that increases in gross domestic product, financial development index, and urbanisation have a beneficial impact on renewable energy usage. Conversely, the study also shows that CO<sub>2</sub> emissions negatively affect renewable energy consumption. Trade openness has an insignificant impact on the renewable energy usage of Asian and Pacific nations. According to the Granger causality test findings, a bidirectional causality exists between renewable energy consumption & gross domestic product and and renewable energy consumption and CO<sub>2</sub> emissions. In addition, unidirectional Granger causation has been shown between renewable energy consumption & trade openness, between renewable energy consumption and urbanization, and renewable energy use and financial development index and energy poverty index and between renewable energy consumption. Last but not least, quantile regression results confirmed that gross domestic product, financial development index, trade openness, energy poverty index, and urbanization positively affect energy consumption.

#### 5. POLICY SUGGESTIONS

Based on the above findings, this study suggests that Asian and Pacific nations should focus on boosting their MSME sectors to boost economic growth. Again, policymakers across Asian and Pacific nations should strengthen the various instruments of financial development to support the use of more renewable energy and keep these economies on a fast-track growth path. This study suggests that the use of solar, wind, and biomass will enhance energy access, which ultimately improves energy poverty conditions. Improving access to affordable, reliable, and up-to-date energy services, including electricity and clean cooking fuels, can drive stronger economic growth. Policymakers within the Asian and Pacific nations region should develop a sustainable framework to maintain clean energy that can enhance economic progress and development within Asian and Pacific nations through reduced carbon emissions and certain economic activities that tend to negatively affect the economy. Further tight monetary policies in Asian and Pacific nations will curb CO<sub>2</sub> emissions and increase future energy demand.



Finally, this study recommends innovative and efficient urban designs to create a balanced energy demand for faster economic growth in Asian and Pacific nations.

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## Appendix -I

S.No.	Member Nations	Country's Code
1	Afghanistan	AFG
2	Australia	AUS
3	Bangladesh	BGD
4	Bhutan	BTN
5	Brunei	BRN
6	Cambodia	KHM
7	China	CHN
8	Fiji	FJI
9	India	IND
10	Indonesia	IDN
11	Japan	JPN
12	Kiribati	KIR
13	Laos	LAO
14	Malaysia	MYS
15	Maldives	MDV
16	Marshall Islands	MHL
17	Mongolia	MNG
18	Nepal	NPL
19	New Caledonia	NCL
20	New Zealand	NZL
21	North Korea	KOR
22	Pakistan	PAK
23	Palau	PLW
24	Papua New Guinea	PNG
25	Philippines	PHL
26	Singapore	SGP
27	Solomon Islands	SLB
28	South Korea	PRK
29	Sri Lanka	LKA
30	Taiwan	TW
31	Thailand	THA
32	Timor-Leste	TLS
33	Tonga	TON
34	Tuvalu	TUV
35	Vanuatu	VUT
36	Vietnam	VNM