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Factors affecting Renewable Energy Consumption: A Panel Data Analysis In ASIAN Countries

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ABSTRACT

The present research article has been to conducted to explore the link between non-fossil energy usage and its determinants namely cross border trade (TO), foreign direct investment (FDI), urbanization, CO2 releases, and institutions effectiveness quality (QGOV) in a panel of Asian nations i.e China, India, Japan, Pakistan, and Sri Lanka. The data has been collected from different data provider sources and covering time spam 1996 to 2020. Two different econometric techniques are applied in the present research article i.e Modified Ordinary Least Squares (FMOLS) and Dynamic Ordinary Least Squares (DOLS). As indicated by both of the models urbanization, FDI, and the governance quality contribute positively to the REC. Conversely, trade openness and CO2 releases exhibit a negative impact,that will lead to a decline in REC. The findings underscore the significance of government policies aimed at augmenting the supply of RE from contemporary sources, thereby encouraging the conversion from outdated to up-to-date clean energy sources.

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INTRODUCTION

Government policies are shifting towards the development of low-carbon economies and improved energy efficiency, environmental changes, and global heating. The anticipated advantages of enhanced energy efficiency include reduced costs related to energy sector for consumers and decreased CO_2 discharges. Consequently, RE is gaining prominence as a crucial alternative energy source. Given its significance in discussions about the future of reliable and sustainable energy, understanding the main factors of renewable energy and drawing policy is essential.

As the consumption of from non-fossil fuel sources took an upsurge during the last few years that encourage economists and researchers to examined the scenario, but there still need to investigate it in order for further future predictions as developing nations like Pakistan and other countries included in the study, are not utilizing renewable energy sources as it would be. The fast increase in population and economical in South Asian countries, including India, have led to a surge in energy demand. To address this, these countries are actively transitioning to alternative energy sources, particularly RE, to shrink the reliance on fossil energy sources.

A very rich debate is available the factors contributing to fossil fuel energy usage, but there is limited knowledge about the determinants of REC. in the present study we will try to fill this gap by expanding the current literature on energy consumption by including renewable energy in case of 5- Asian Countries. By keeping in view the scarcity and global warming and other factors that damage the environment, the importance of clean energy production and consumption is crucial to understand. As it is clear from the literature that in future most of economies will be relying renewable energy consumption and this source of energy will be fast growing sector until 2030.

The study's objective is to empirically analyze determinants such as cross border trade, FDI, urbanization, CO_2 discharges, and governance quality on non-fossil energy utilization in five Asian countries. The inclusion of the governance variable has important in addressing issues related to government transparency and the potential misuse of funds for renewable energy for illegal purposes. The study employs FMOLS and DOLS techniques that address the problems like endogeneity and auto-correlation in co-integration regressions, ensuring unbiased parameter estimation.

The structure of the remaining paper includes a reviews of the existing literature in section-2, methodology in section-3, empirical results and conclusions in sections 4 and section 5 includes for the Policy implications.

LITERATURE REVIEW

Rich literature is available on the non-fossil fuel energy usage and its determinants both in time series and panel data analysis. For instance, a research study by Omri and Nguyen (2014), for 64 Countries on renewable energy usage. In their study they has utilized the data covering time span 1990 - 2011, by applying panel GMM model, And positive association among REC , cross border trade and CO_2 releases. Similarly, REC determinants has been explored by Sadorsky (2009) for G-7 nations and found the same results. Another study conducted by Apergis and Pyne (2014) for 7 American states covering period 1980 – 2010. Their results show invers relation between CO_2 emissions and REC. Chen (2018) examined urbanization, CO2 emissions, growth rate of GDP, and foreign trade on non-fossil energy usage in 30 Chinese provinces for the time span 1996- 2013, with outcomes indicating positive substantial effects.

On the other side of the story, there are some investigations that revealed inverse connection between REC and CO_2 productions. Mehrara, et.al.(2015), conducted a research study in case of ECO Countries for the time span of 192 to 2011, by applying BMA. modle of ec-integration. Their study indicate REC has negative impact on growth rate of CO_2 releases. Ackah and Kizys (2015) explored non-fossil fuel energy in case of African states that producing Oil, for the time span 1985 - 2010, concluding that CO2 emissions have a negative

and statistically insignificant influence on RE utilization. Similar study by Olarewaju, et. al. (2019), for African nations concluded that negative ling exists between the two variable.

Sbia, et.al. (2014),and Polat, (2018) conducted research studies on the determinants of REC in UAE Countries, covering the period 1975Q1-2011Q4, and 85 advanced and developing nations covering time span 2002-2014. Both the studies shown invers connection between cross border trade, FDI and growth rate on REC. Hagert and Marton (2017) evaluated the effect of FDI on REC in middle-income states from 1990 - 2010, by a panel data Fixed effect modeling technique, reporting a negative relationship between FDI and cross border trade with the share of non-fossil fuel energy consumption. Paramati, et.al. (2016), also put efforts to examine FDI and REC relationship for 20 emerging countries by using panel co-integration for the time span 1991-2012 and found positive link between the two variables.

Some empirical investigation tried to show the exact scenario between government quality in energy sector policy and renewable energy deployment. For example, in an article by Fredriksson,et. al. (2004), in case of in 12 OECD countries from 1982- 1996. Concluded that weak policy regulations can reduce or collapse the energy sector. Cadoret, and Padovano, (2016), analyzed political drivers of RE deployment in European nations, finding that the quality of governance indicator (i.e., corruption) positively influences renewable energy deployment. Sekrafi, and Sghaier (2016), and Bellakhal,et. al. (2016), discovered vital factors of renewable energy consumption in the MENA region from 2000-2013, and 1984-2012. Their studies confirmed that corruption will increase clean energy usage.

METHODOLOGY AND DATA PERIOD

In our investigation, we have employed yearly statistics covering the years 1996-2020 for 5 Asian nations panel. The variables under scrutiny encompass the total RE utilization , Additionally, we examined CO_2, (mt per capita), along with Urbanization, is the total of resident living in cities. 2017). Furthermore, information on corruption, used as a proxy for governance quality, was acquired from the International Country Risk Guide (ICRG). Trade openness was evaluated by the sum of exports and imports as a percentage of GDP. The data set estimated in our study for the variables has been collected form the well-known data providers source, World Bank (WDI, This extensive dataset facilitated our exploration of the dynamic relationships among these key variables across the chosen Asian countries throughout the specified timeframe.

Experimental Model

In this study we have adapted the following model by keeping in view the studies conducted by Omri,et.al(2014), Sadorsky (2009a), and Salim,et.al (2012):

$$RE = f(TO, FDI, CO2, URB, QGOV) \quad \text{---------- (1)}$$

Where:

In our model RE which the controlled variable of our study signifies the renewable energy usage taken as a percentage of total energy consumption.Where in the list of independent variables like TO indicates cross border trade, FDI, the total foreign direct investment inflow, CO2 releases, URB is the total population living in the urban areas, and the final variable

QGOV is the quality of government which indicates the effectiveness of government policies in regulating the public sectors. The final econometrics model can be express as follow.

$$RE_{it} = \beta 0 + \beta 1TO_{it} + \beta 2FDI_{it} + \beta 3CO2_{it} + \beta 4URB_{it} + \beta 5QGOV_{it} + \mu_{it} \text{ ----------(2)}$$

Here, βj (j=1,2,3,…,5) denotes the coefficients of the long run estimations for all the control variables, "*i"* panel of countries, and "*t*" represents period.

The study proceeds with panel unit root tests to assess the stationarity of the series. Levin,et.al. (2002), and Im,et.al. (2003), unit root test for panel data is employed. Subsequently, in this research article we have Pedroni, (1999, 2004), to check for the co-integration among the variables. We tested the null and Alternate hypothesis of co-integration,

FMOLS And DOLS

Pedroni introduced the Fully Modified Ordinary Least Squares (FMOLS) procedure to address the problem of heterogeneity in analyzing vibrant co-integrated panels. This method incorporates individual intercepts and allows for variations in auto-correlation possessions among the error procedures across particular adherents of the panel. It is particularly designed to handle alterations in individuals mean values and variations in their responses to short-run turbulences from co-integrating equilibrium.

On the other hand, the Dynamic Ordinary Least Squares (DOLS) procedure, initially proposed by Kao and Chiang (2001), extends the DOLS method to panel investigations. This estimator is designed to address endogeneity in the model and provides finite sample properties for Ordinary Least Squares (OLS), DOLS, and Pedroni's FMOLS. In panel data analysis, the DOLS estimator can be derived by including lagged difference in the regression that can control for the endogeneity problem:

$$y_{i,t} = \beta_i' x_{i,} + \Sigma^{q}_{g=-p} \eta_{ij} \Delta x_{i,t} + j + \gamma_{li}' D_{li} + \varepsilon_{i,} \text{ ..... (4)}$$

The parameter q in the DOLS estimator represents the number of lags, and its selection is typically determined is based on AIC or BIC information critaria. These criteria help choose the appropriate number of lags that balance the trade-off between model fit and complexity.

Monte Carlo simulations, which involve creating computer models to mimic real-world scenarios through random sampling, have been employed to assess the performance of different econometric estimators in restricted samples. In the case of the DOLS estimator, Monte Carlo simulations have led to the conclusion that it outperforms both OLS and FMOLS in terms of unbiased estimation when dealing with limited sample sizes.

The prime benefit of DOLS estimator is its capability to control endogeneity effectively. By incorporating lead and lagged differences of the regressors, the DOLS method mitigates endogenous feedback issues, providing a robust correction for endogeneity in the explanatory variables. This feature enhances the reliability of the estimation process and contributes to the method's appeal in empirical research. Researchers, such as Lean and Smyth (2010) and Afonso and Jalles (2012), have highlighted the robustness and efficacy of the DOLS method in handling endogeneity concerns in econometric models.

EXPERIENTIAL RESULTS

The summary statistics for the data are reported in the bellow table. The mean value for RE

consumption is 47.24, the cross border trade has a mean 41.1. The average Foreign Direct Investment 1.47, CO_2 discharges is 3.20. while, urbanization is possess a mean of 40.6, the final variable corruption has a mean of 2.77. in the bellow table we has observed that standard deviation is high in case of Urbanization which is 23.0304 while the lowest is recorded for the government regulations which is 0.984.

Table 1: *Summary Statistics*

	RE	TO	FDI	CO2	URB	QGON
Mean	47.24095	41.05665	1.476804	3.201006	40.57545	2.773333
Median	50.84280	35.55468	1.070660	0.991030	32.09200	2.500000
Maximum	78.08724	88.63644	6.186882	9.909203	91.30400	5.000000
Minimum	11.69580	15.67452	-0.052908	0.223240	18.19600	1.000000
Std. Dev.	14.92583	18.67798	1.433159	3.494991	23.03333	0.983972
Skewness	-0.655930	0.784946	1.225687	1.012740	1.137275	0.731715
Kurtosis	3.136193	2.659942	3.730870	2.283729	2.863926	2.764724
Jarque-Bera	9.060023	13.43855	34.08023	24.03967	27.04214	11.44261
Probability	0.010781	0.001207	0.000000	0.000006	0.000001	0.003275
Sum	5905.119	5132.081	184.6005	400.1258	5071.931	346.6667
Sum Sq. Dev.	27654.76	43459.48	257.6892	1514.655	65786.24	120.0569
Observations	125	125	125	125	125	125

Author's own calculation

To check for the multicollinearity amongst the variables we have utilized the Correlation matrix and reported n table-2. As it is clear for the bellow results there is no multi-collinearity problem is our data set. Generally, we observed no correlation among the variables . All the values are lower than 8.5 so no problem in the data set.

Table 2: *Correlation Matrix*

	RE	TO	FDI	CO2	URB	QGON
RE	1.000000					
TO	0.159256	1.000000				
FDI	-0.632315	0.304215	1.000000			
CO2	-0.345457	-0.414125	-0.165464	1.000000		
URB	-0.266222	-0.522910	-0.289695	0.839306	1.000000	
QGON	0.238905	-0.095934	-0.307781	0.465004	0.428986	1.000000

Author's own calculation

Tests for the order of integration

As it is important to note for the order of integration amongst the variable in advance of the co-integration so we have used the two well-known test namely, Levin *et.al*, (2002) and Im *et.al*,(2003) the outcomes of the tests are reported in the table -3 bellow. All the variables exhibit unit root at level but no unit root at first difference.

Table 3: *Unite root tests*

	At Level		At First Difference	
Variables	**LLC**	**IPS**	**LLC**	**IPS**
RE	-1.36255	-0.42188	-5.84823***	-5.90020***
CO_2	0.75589	2.26584	-4.26755***	-5.09484***
FDI	4.15700	-1.15169	-8.60160***	-9.56044***
TO	-0.35095	0.85539	-5.26001***	-4.73663***
QGOV	-1.05243	-1.80315	-5.89181***	-4.79897***

URB	0.09198	2.39129	-3.88599**	-2.90446*

Note: *,**,*** are shows significance level at 1,5, and 10 percent separately. Author's own calculation

Table-4 presents the outcomes of Pedroni cointegration tests (Pedroni, 2001, 2004), The null hypothesis of no co-ntegration has been refused by two out of four group statistics, with in the dimension. Simultaneously, two out of three panel statistics also reject the null hypothesis. The outcome indicates a co-integration among these variables in the four SAARC countries.

To further validate and accuracy of these results, the Kao cointegration test established by Kao (1999) is employed.

Table 4: *Co-integration results*

(within-dimension)				
			Weighted	
	S.t	**P**	**S.t**	**P**
Panel v-stat	-0.490785	0.6882	-0.757527	0.7756
Panel rho-stat	1.519828	0.9357	1.172710	0.8795
Panel PP-stat	0.492011	0.0000**	-0.292106	0.0000**
Panel ADF-stat	-0.757340	0.0000**	-0.952437	0.0000**
(between-dimension)				
	Stat	Prob		
Group rho-stat	2.050707	0.9799		
Group PP-stat	0.556754	0.0001**		
Group ADF-stat	0.107041	0.0010**		

*Author's own calculation. Note: ** shows significant at 5%.*

Long Run Results

Table no 5 presents the long-run outcomes obtained from OLS, FMOLS, and DOLS methods. The differences between the three methods are not substantial in relations of magnitude, symbol, and implication. Examining the assessed coefficients:

1. **Trade Openness:** the invers relation testified by FMOLS and DOLS approaches, suggesting that an upsurge in trade openness cuts RE utilization. A 1% upsurge in openness of trade leads to a 0.55% and 0.66% decrease in RE consumption, respectively. This outcomes bring into line with the findings of previous studies (Hagert and Marton, 2017; Lau et al., 2018).

2. **FDI (Foreign Direct Investment inflows):** adverse link has been noted by our study between FDI and RE ingestion. As a 1% rise in FDI reduces RE consumption by 7.05% and 2.34% , as given by the two estimation methods FMOLS and DOLS, respectively. This suggests that FDI discourages the use of RE, possibly because foreign firms, despite being more energy-efficient, may still prioritize non-renewable sources.

3. **Urbanization:** the effect of Urbanization on RE consumption is positive, suggesting that a 1% increase in urbanization will give an upsurge to RE consumption by 9.24%. This suggests that urban areas prioritize energy-efficient technologies, such as solar power, in housing and office projects.

4. **Quality of Governance (Corruption Proxy):** The coefficient for corruption, used as a proxy for quality of governance will bring efficiency in the use of RE consumption. If there is 1% improvement in governance quality it will results in a 4.37%, 0.59%, and 1.69% increase in RE consumption according to OLS, FMOLS, and DOLS models, respectively. This indicates that nations with better governance tend to promote transparent and corruption-free developmental projects.

5. **CO_2 Discharges:** the final and most important and contributor to damage environment is the CO_2 gas releases, that can be control by shifting from nonrenewable sources to that of renewable energy sources. As according to our study findings there is inverse link between the CO_2 emissions and RE consumption. As indicated by our models 2.45%, 9.78%, and 3.31% increase in RE usage will occur if there is a one percent reduction in CO_2 releases. The finding of this study is coinciding with (Olarewaju et al., 2019; Mehrara et al., 2015; Ackah and Kizys, 2015).

Table 5: *Present OLS, FMOLS and DOLS.*

D .Variable: Renewable Energy Consumption						
	OLS		**FMOLS**		**DOLS**	
Variable	**C.f**	**t.s**	**C.f**	**t.s**	**C.f**	**t.s**
TO	0.150396	2.99666**	-0.53075	-0.966382	-0.663192	3.27212***
FDI	-7.05678	-11.1897***	-2.343325	-3.673298**	4.853121	2.092239**
CO_2	-2.451528	-2.703913**	-9.785568	-6.07176***	-3.314245	-9.6135***
URB	0.040743	0.282572	9.242121	4.350141***	-0.774351	-4.01697**
QGOV	4.374319	4.813145***	0.594814	-2.862666**	1.699705	3.60383**
R-sq	0.708881		0.950427		0.992490	
Adj R-sq	0.656649		0.946371		0.967258	

*Author's own calculation. Note: **, *** show significant at 5% and 1%.*

CONCLUSION AND POLICY RECOMMENDATION

This aims to explore the effect of diverse control variable i.e. openness, CO_2 discharges, foreign direct investment inflow, regularity quality, and Urbanization, on the controlled variable Renewable energy usage, across a panel of 5 ASEAN nations for the time span of 1980- 2018. This panel data set is particularly noteworthy due to the rapid energy consumption growth in these ASEAN countries.

Based on the outcomes of all the three estimation techniques, trade liberalization and CO_2 releases impacts the non-fossil energy consumption in negative in the long run. Conversely, urbanization, FDI, and quality of governance exhibit optimistic and noteworthy effect on RE consumption.

Despite ongoing efforts to formulate policies related to renewable energy consumption, implementation remains in the early stages. Challenges, particularly in financing renewable energy projects, persist due to the substantial financial investments required. Recommendations include integrating RE policies into overall development plans, such as encouraging smart cities, developing solar energy infrastructure, and implementing water conservation measures.

The study concludes that enhanced governance positively correlates with increased renewable energy consumption. Therefore, it emphasizes the importance of leaders being informed about renewable energy to implement effective policies. Informed and conscientious leaders can contribute to quality governance in resource management. This study serves as a valuable

guide for policymaking in RE consumption and highlights the positive impact of trade openness on promoting renewable energy consumption.

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