6th AIEE ENERGY SYMPOSIUM

Renewable Energy Proliferation for Energy Security: Role of Cross Border Electricity Trade

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TRANSITION

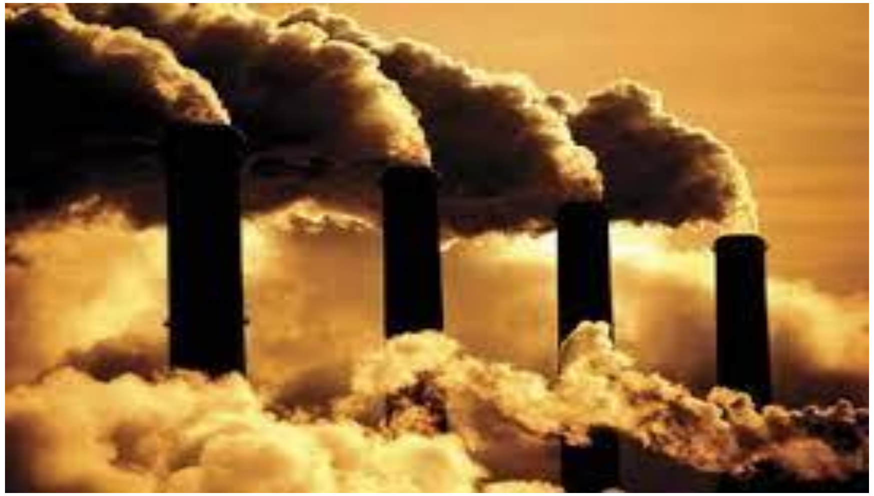
- There can be witnessed a transition from conventional energy sources, particularly coal, to greener energy i.e., renewable energy sources
- Therefore, to achieve energy security, conventional energy sources and renewable energy sources must supplement each other
- There is a need to promote renewable energy production as it not only aids in energy security but also facilitates sustainable development

SUSTAINABLE DEVELOPMENT GOALS

7 AFFORDABLE AND CLEAN ENERGY

- Affordable and clean energy is one of the United Nation’s Sustainable Development Goals (UNSDGs). It aims to "Ensure access to affordable, reliable, sustainable and modern energy for all.”
- Energy productivity is crucial for sustainable development (Enflo et al., 2009)

- The environmental and economic fallout of anthropogenic climate change, triggered mostly by energy production, are increasingly obvious and relevant (Buso & Stenger, 2018)
- Greenhouse gases that result from energy use are doing more and more damage to the healthy development of society (Sheng & Yang, 2014)
- Thus, there is a need to reduce emissions of greenhouse gases



- A prominent mitigation strategy is to replace the polluting fossil fuel based resources for renewable energy resources (Silva et al., 2018)
- Renewable energy offers a better alternative, but there are multiple barriers to its proliferation

BARRIERS

1 Intermittency

2 Reliability

3 Market Size

- Cross border electricity trade, by offering potential solutions to these problems, provides a new direction for energy security and sustainable development through its positive effects on the renewable energy (Pu et al., 2021)
- Moreover, it appears that trade costs are not very high in utilities such as electricity (Gomtsyan, 2016)

LITERATURE BACKGROUND AND RESEARCH GAP

- Ahmed et al. (2017) found that an integrated ASEAN power grid can enhance power generation from countries with abundant renewable resources to meet the growing demand at load centres in the ASEAN region
- Haque et al. (2020) demonstrated that cross border electricity trade is attractive to Bangladesh
- The macroeconomic theory provides convincing arguments in support for the significant and positive effects of international trade on output and growth (Singh, 2010)
- There are further empirical evidences on the dynamic relationship between output, energy production, and international trade (Halicioglu & Ketenci, 2018)
- Yet, there are hardly any empirical study to explore the relationship between cross border electricity trade and renewable energy production

RESEARCH QUESTIONS

RQ1

- What is the causal direction between renewable energy generation and cross border electricity trade?

RQ2

- How are these variables related?

DATA

- 35 Countries
- OECD & BRICS
- 29 Years (1990-2018)
- International Energy Agency & World Bank

METHODS

RQ1

- Panel Granger Causality Test
- Procedure proposed by Dumitrescu & Hurlin (2012)

RQ2

- Nonparametric Kernel Regression
- On lines of Racine & Li (2004) and Li & Racine (2004)

The goal of the analysis is to explore the role of economic output and cross border electricity trade in promoting renewable energy. The model is:

$$R = f(XM, Y, country, time) \qquad (1)$$

$where, R$ is $renewable$ $energy$ $generation; XM$ is the $total$ $cross$ $border$ $electricity$ $trade;$ and, Y is the $gross$ $domestic$ $product$ or the $output.$

In Kernel regression, a nonparametric regression, the unknown function *f*(.) is estimated through a kernel function *k*(.)

In our nonparametric estimation, for the continuous variable, we have used two different kernel functions - Epanechnikov kernel and Gaussian kernel given in the following equations (2) and (3)

$$Epanechnikov: K(\alpha) = \begin{cases} \frac{3}{4}(1-\alpha^2) & \alpha \in [-1,1] \\ 0 & \alpha \notin [-1,1] \end{cases} \qquad (2) \qquad Gaussian: K(\alpha) = \frac{1}{\sqrt{2\pi}} e^{-\frac{1}{2}\alpha^2} \qquad (3)$$

The bandwidth and the kernel function, which are defined in terms of α are associated through the relation given by equation (4)

$$\alpha = \frac{x_i - x}{h} \qquad (4)$$

We have used kernel functions proposed by Racine & Li (2004) for the non-metric variables and are shown in equations (5) and (6)

$$Unordered\ Factor\ Variable\ (country): l = \begin{cases} 1 & if \ \ x_i = x \\ \lambda & if \ \ x_i \neq x \end{cases} \qquad (5)$$

$$Ordered\ Factor\ Variable\ (year): l = \begin{cases} 1 & if \ \ |x_i - x| = 0 \\ \lambda^{|x_i - x|} & if \ \ |x_i - x| > 1 \end{cases} \qquad (6)$$

We have also estimated a couple of parametric models for comparison. We have used Mean Group and Common Correlated Effects Mean Group estimations as proposed by Pesaran (2006)

RQ1

Table 1: Causal Inferences

Unbalanced Panel			
Causal Inference	Lags	Ztilde	p-value
Renewable Energy Generation Granger Causes Cross Border Electricity Trade	1L	8.860	0.000
Cross Border Electricity Trade Granger Causes Renewable Energy Generation	1L	4.655	0.000
Renewable Energy Generation Granger Causes Cross Border Electricity Trade	2L	5.760	0.000
Cross Border Electricity Trade Granger Causes Renewable Energy Generation	2L	2.460	0.014
Balanced Panel			
Causal Inference	Lags	Ztilde	p-value
Renewable Energy Generation Granger Causes Cross Border Electricity Trade	1L	8.031	0.000
Cross Border Electricity Trade Granger Causes Renewable Energy Generation	1L	2.809	0.005
Renewable Energy Generation Granger Causes Cross Border Electricity Trade	2L	4.562	0.000
Cross Border Electricity Trade Granger Causes Renewable Energy Generation	2L	1.960	0.050
Balanced Panel			
Causal Inference	Lags	Zbar	p-value
Renewable Energy Generation Granger Causes Cross Border Electricity Trade	1L	10.479	0.000
Cross Border Electricity Trade Granger Causes Renewable Energy Generation	1L	4.005	0.000
Renewable Energy Generation Granger Causes Cross Border Electricity Trade	2L	7.057	0.000
Cross Border Electricity Trade Granger Causes Renewable Energy Generation	2L	3.552	0.000

Unbalanced panel is the comprehensive dataset comprising of 35 countries and a time period of 2018-1990, whereas, the balanced panel comprises of a shorter dataset where missing data rows are dropped.

RQ2

Table 2 [Panel A]: Non-Parametric Regression (Local Linear with Epanechnikov kernel)

	Gradient Partial Elasticity (Mean)	Gradient Partial Elasticity (Median)	Individual Significance	Selected Bandwidth#
Cross Border Trade	0.165	0.109	0.000	1.86E+07
Output	1.045	0.894	0.000	1.16E+00
Country (Unordered Factor)	-0.540	-0.309	0.000	2.62E-04
Year (Ordered Factor)	-0.013	-0.008	0.000	5.79E-01

		Kernel Type	
Number of Observations	987	Continuous	Epanechnikov
Residual Standard Error	0.0961	Unordered Categorical	Li and Racine
R-Squared:	0.998	Ordered Categorical	Li and Racine

Significance level is based on bootstrapping with 299 replications

Bandwidth Selection Method: Expected Kullback-Leibler Cross-Validation

Bandwidth Type: Fixed

Table 2 [Panel B]: Non-Parametric Regression (Local Linear with Gaussian kernel)

	Gradient Partial Elasticity (Mean)	Gradient Partial Elasticity (Median)	Individual Significance	Selected Bandwidth#
Cross Border Trade	0.165	0.111	0.000	2.76E+07
Output	1.056	0.902	0.000	1.20E+00
Country	-0.538	-0.322	0.000	3.04E-04
Year (Ordered Factor)	-0.013	0.007	0.000	5.79E-01

		Kernel Type	
Number of Observations	987	***Continuous***	***Gaussian***
Residual Standard Error	0.0958	Unordered Categorical	Li and Racine
R-Squared:	0.998	Ordered Categorical	Li and Racine

Significance level is based on bootstrapping with 299 replications

Bandwidth Selection Method: Expected Kullback-Leibler Cross-Validation

Bandwidth Type: Fixed

SUMMARY OF RESULTS

Panel Granger Causality

- Bi-directional causality

Nonparametric Estimation (Kernel Regression

- Cross border trade in electricity positively and significantly effects the renewable energy expansion
- Output also positively and significantly effects renewable energy generation
- Both the country and the time dimensions have significant effects

Comparative Models

- Parametric models give results similar to the nonparametric ones

IMPLICATIONS

- It is recommended to promote cross border electricity trade to support renewable energy generation
- Growth in renewable energy production would promote sustainable development and would help in achieving energy security
- The study advocates for concerted policy intervention to promote cross border electricity trade

LIMITATIONS AND FUTURE SCOPE

- Energy prices are important determinants in cross border electricity trade and concerns regarding stability of prices and revenues may be the reasons why some countries block electricity inflows at the borders (Ziesemer, 2019)
- The present study is slightly limited in the sense that pricing information is kept beyond the scope of the present work
- Nevertheless, the study may be extended by incorporating variables capturing price differentials across countries

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THANK YOU