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What is better for mitigating carbon emissions – Renewable energy or nuclear energy? A panel data analysis

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ABSTRACT

This paper investigates the determinants of carbon emissions based on energy consumption, analyzing the data of 30 countries using nuclear energy for the period 1990–2014. Renewable energy and nuclear energy consumption are adopted as determinants, and real coal price and real GDP are used as additive variables. The panel cointegration analysis and Granger causality tests are conducted to investigating the relationship among the variables. First, the panel cointegration test results suggest that long-run equilibrium relationship exists among carbon emissions, renewable energy consumption, and nuclear energy consumption. The results of the long-run cointegrating vector and Granger causality tests indicate that nuclear energy does not contribute to carbon reduction unlike renewable energy. Thus, the development and expansion of renewable, not nuclear, energy are essential to prevent global warming. Though there is a concern that rising energy prices caused by the expansion of renewable energy may impact the economy negatively, our empirical results also imply that renewable energy consumption will promote economic growth. In other words, our evidence shows that using and expanding renewable energy is both economically and ecologically beneficial.

1. Introduction

Greenhouse Gas (GHG) emissions have received considerable attention because of global warming. For example, the Intergovernmental Panel on Climate Change (IPCC) publishes a yearly report on these aspects. The United Nations Framework Convention on Climate Change (UNFCCC) also holds an annual meeting called the Conference of the Parties (COP) to discuss these topics. However, attempts to control carbon emissions have not been entirely successful. The first period of the Kyoto Protocol concluded in 2012, and thereafter, the Copenhagen Climate Change Conference (COP15) was unsuccessful because the decisions made therein had no binding force among the parties. The most recent and successful conference, COP21, was held in 2015 and drew up the Paris Agreement which has binding force. The Intended Nationally Determined Contributions (INDCs) were set by the participating nations, and the Paris Agreement was ratified on November 4, 2016.

GHGs include not only carbon dioxide (CO_2) but also gases such as methane, Nitrous oxide, CFC-12, and HCFC-22. In addition, GHGs also include numerous variation of gases above this. According to [1], CO_2 is not the main contributor to global warming in per unit terms. For example, CO_2 and methane (CH_4) are assigned the Global Warming Potential (GWP)[1] of 1 and 21, respectively. Despite this fact, CO_2 is acknowledged to be the biggest contributor to global warming because of its overwhelming quantity. CO_2 accounted for 76% of total GHG emissions as of 2010, as per [2]. In addition, according to [3], energy will play an important role in achieving INDCs, because two-thirds of all GHG emissions result from energy production and consumption. Therefore, we attempt to analyze the determinants of carbon emissions using two kinds of energy consumption variables.

Although renewable and nuclear energy are recognized as contributors of carbon emissions reduction, there has been a lot of controversy as to which is better. According to [4], renewable energy may adversely affect carbon emissions, an effect that is beneficial to the

Abbreviation: ADF, Augmented Dickey–Fuller; AMG, Augmented Mean Group; AIC, Akaike Information Criterion; ARDL, Autoregressive-Distributed Lag; COP, Conference of the parties; DOLS, Dynamic Ordinary Least Squares; FLM, ECM, Error Correction Model; ECT, Error Correction Term; EKC, Environmental Kuznets Curve, Fourier Lagrange Multiplier; FMOLS, Fully Modified Ordinary Least Squares; GDP, Gross Domestic Product; GHG, Greenhouse Gas; GMM, Generalized Method of Moment; GNI, Gross National Income; GWP, Global warming potential; IEA, International Energy Agency; IPCC, Intergovernmental Panel on Climate Change; IPS, Im-Pesaran-Shin; INDC, Intended nationally determined contribution; LLC, Levin-Lin-Chu; LLL, Larsson–Lyhagen–Löthgren; LM, Lagrange Multiplier; KPSS, Kwiatkowski–Phillips–Schmidt–Shin; SVAR, Structural Vector Auto Regression; VECM, Vector Error Correction Model; ZA, Zivot–Andrews; REG, Renewable Electricity Generation

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[1] GWP indicates the GHG emissions impact in the CO_2 equivalent form. For example, methane has 21 times higher impact on global warming than carbon dioxide in the same quantity.

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Table 1
Selected studies on the link between Renewable Energy Consumption (REC) and carbon emissions (CE).

References	Countries (Period)	Methodology	Variables	Additive variables	Results
[23]	G7 countries (1980–2005)	Pedroni cointegration	REC	Real oil price	Unidirectional
		FMOLS	CE		CE to REC (positive)
		DOLS			
[24]	19 developed, developing countries	LLL cointegration	REC	Real GDP	Bidirectional
	(1984–2007)	LLL long-run estimator			REC to CE (positive)
		Granger causality	CE	Nuclear energy consumption	CE to REC (negative)
[5]	U.S (1960–2007)	Toda–Yamamoto Granger causality	REC	Nuclear energy consumption	Unidirectional
			CE	Real GDP	CE to REC (positive)
				Energy Price index	
[25]	India (1960–2009)	SVAR model	REC	Real GDP	Unidirectional
			CE		REC to CE (negative)
[9]	U.S. (1949–2009)	Toda–Yamamoto Granger causality	REC	Real GDP	No relationship
			CE	Real oil price	
[26]	7 Central American countries	Bai–Perron cointegration	REC	Real GDP	Bidirectional
	(1980–2010)	FMOLS		Real oil price	REC to CE
		Regime-wise Granger causality	CE	Real coal price	CE to REC
					(the sign is unreported)
[27]	16 EU countries (1990–2008)	Panel fixed effect model	REC	Real GDP	Positive relationship
				EKC	
			CE	Fossil fuel consumption	
[28]	10 MENA countries (1980–2009)	Pedroni, Kao cointegration	REG	Real GDP	Unidirectional
		FMOLS		EKC	REC to CE
		DOLS	CE	Nonrenewable electricity generation	(the sign is unreported)
		VECM			
[29]	BRICS countries (1971–2010)	ZA unit root	REC	Real GDP	Unidirectional
		ARDL			India, South Africa
		FMOLS	CE	Trade openness	
		DOLS			CE to REC (positive)
		VECM			
[30]	29 OECD countries (1980–2011)	Johansen–Fisher, Westerlund	REC	Nonrenewable energy	Unidirectional
		cointegration		consumption	
				Population	
				Urbanization	
				Population density	
		AMG	CE	Real GDP	CE to REC (positive)
				EKC	
		Granger causality		Energy intensity	
				Share of industry (% of GDP)	
				Share of services (% of GDP)	
[31]	SAARC countries (1975–2010)	Johansen cointegration	REC	Real GDP	Unidirectional: Bangladesh,
				Resource depletion (% of GNI)	India
				Poverty	REC to CE
		Granger causality	CE		Bidirectional: Nepal
					REC to CE
					CE to REC
					(the sign is unreported)
[32]	11 South American countries	Pedroni cointegration	REC	Real GDP	Bidirectional
	(1980–2010)	FMOLS			REC to CE (negative)
		Granger causality	CE	Real oil price	CE to REC (positive)
[33]	Tunisia (1980–2009)	ZA unit root	REC	Real GDP	Unidirectional
		ARDL		Nonrenewable energy consumption	
		VECM	CE	Trade	CE to REC (positive)
				EKC	
[34]	Turkey (1961–2010)	ADF	REG	Real GDP	Unidirectional
		KPSS unit root			
		ARDL	CE	EKC	REC to CE (positive)
		Granger causality			
[10]	U.S. (1960-2007)	FLM unit root test	REC	Nuclear energy consumption	Unidirectional
		Johansen cointegration	CE	Real GDP	
		Granger causality		Energy price index	REC to CE (negative)
[8]	China (1952–2012)	Johansen cointegration	REG	Fossil fuel energy consumption	No relationship
			CE	Labor force	
		Granger causality		Real GDP	
[4]	27 advanced economies (1990–2012)	Kao and Fisher cointegration	REC	Nonrenewable energy consumption	Unidirectional
				Real GDP	
		FMOLS		EKC	REC to CE (negative)
		Granger causality	CE	Trade openness	
				Urbanization	
				Energy price	
[35]	17 OECD countries (1977–2010)	Pedroni cointegration	REC	Real GDP	Negative relationship
		FMOLS	CE	EKC	
		DOLS			

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