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NON LINEAR CARBON EMISSION IN THE SUSTAINABILITY OF RENEWABLE ELECTRICITY

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Abstract

The effects of global warming have made it clearer in recent years that energy transformation is now a crucial component of reaching carbon neutrality. Therefore, this study focuses on the connection between carbon emissions and electrical energy transformation in particular. The time series approach is used in this work to investigate energy transition problems. This study investigates the nonlinear effects of carbon emission variations on the usage of coal, oil, and renewable electrical energy sources. There is a significant correlation between three variables, namely renewable electricity, oil and coal where the significant number is less than 0.05. The largest coefficient contributing to carbon emissions is oil followed by coal. While renewable energy reduces carbon emissions with a negative coefficient. This study was conducted in the period 1990-2022.

Keywords: sustainability, carbon emission, electricity

Introduction

The world is still reliant on fossil fuels, despite the pressing need to cut carbon emissions. As of 2019, fossil fuels still account for 84% of the world's energy system and 64.2% of its electricity generation. (Council, 2023). However, Indonesia's primary energy mix is still dominated by fossil fuels, which account for around 90% of energy production with abundant renewable energy resources of more than 3,000 GW, mostly consisting of solar power, but also wind, hydro, bioenergy, ocean and geothermal (IRENA, 2020). Indonesia is the 9th largest CO2 emitter in the world, while its per capita emissions are well below half the global average. Therefore, sustainable and low-carbon development in the country is very important for the country itself and the global community as a whole. This can go both ways (Council, 2023).

Energy transformation is now a crucial component of reaching carbon neutrality, since the effects of global climate change have been more apparent in recent years (Feng & Zhao, 2022).The main cause of global warming is carbon dioxide (CO2) gas. The economy will eventually be impacted by carbon emissions' effects on the environment. The causes of CO2 emissions are numerous. Energy use and income are the main determinants. (Zaekhan & Nachrowi, 2015). In the instance of 15 nations, the study's findings indicate a negative correlation between ecological footprint and renewable energy consumption and a positive correlation between ecological footprint and natural resource income in both low and high countries. It is strongly advised that these nations invest in renewable energy technology and research in order to transition their energy consumption policies to more sustainable development (Ullah et al., 2021).

Policy initiatives are required to steer the global electricity transition towards a sustainable energy and electricity system in order for it to remain technically and economically feasible and advantageous. Additionally, large-scale deployment of renewable energy must incorporate measures to increase the efficiency of non-renewable resources, which continue to play a significant role in stabilizing and reducing costs (Kabeyi & Olanrewaju, 2022).

Renewable Energy Solutions for heating, cooling, and electricity generation in buildings with thermal energy storage are crucial due to the Clean Energy Transition needed in various countries and regions, aiming for Net Zero Energy. It is vital to implement efficient Renewable Energy-Based heating and cooling systems for buildings. Policy measures are necessary to guide the global electricity shift towards a sustainable energy and power system to ensure it remains technically and economically viable and

beneficial. Moreover, extensive implementation of renewable energy should include strategies to enhance the efficiency of non-renewable resources, which still significantly contribute to stabilization and cost reduction (Zhang et al., 2022).

Methods

This research intends to examine the nonlinear or asymmetric connection between Renewable Energy Consumption and the Ecological Footprint. To examine this asymmetric relationship, a transformation of the model is conducted from a linear equation to a nonlinear equation (Ullah et al., 2021). The relationship between CO2 emissions and environmental quality in renewable energy is seen in the non-linear relationship, one of which is the Kuznets curve, in the development of electricity sources derived from renewable energy (Salem et al., 2021).

A study refines the traditional Cobb–Douglas production function (Cobb & Douglas, 1928), (Varian, 2010), (Mansfield, 1975), dividing energy into renewable and non-renewable energy so that the extended Cobb–Douglas production function can be expressed in terms of these influential variables by including output as carbon emissions (Feng & Zhao, 2022).

Equation related in the renewable electricity as follow:

$$E(R,F,C) = A \prod_{i=R,F,C} X_i^j$$

Where:
E = Carbon emission
R = Renewable electricity
F = Fuel consumption for the electricity prime over
C = Coal consumption for electricity prime over

Equation will be as follow:

$$E(R,F,C) = A\, R^{\alpha} F^{\beta} C^{\gamma}$$

Where:
A = constant
α, β, γ = parameter

Convert to the naturalist logarithmic

$$Ln\, E(R,F,C) = Ln\, A + \alpha\, Ln\, R + \beta\, Ln\, F + \gamma\, Ln\, C$$

Results

The data processed from 1990 - 2022, then transferred into natural logarithmic form as in Table 1 Indonesia Electricity on Renewable Energy, Fuel and Coal

Table 1: Indonesia Electricity on Renewable Energy, Fuel and Coal

Year	CO2 (Ktons) E	Renewables (%) R	Fuel (%) F	Coal (%) C	LnE	LnR	LnF	LnC
2022	598,169.44	0.1230	0.7955	0.6394	13.30163	-2.09557	-0.228738526	-0.44724
2021	584,004.63	0.1216	0.7867	0.6257	13.27766	-2.10702	-0.23992074	-0.46887
2020	563,197.00	0.1127	0.7778	0.6120	13.24138	-2.18303	-0.251229412	-0.49098
2019	605,290.60	0.1625	0.7690	0.5983	13.31346	-1.81708	-0.262667434	-0.5136
2018	568,007.60	0.1704	0.7602	0.5847	13.24989	-1.76961	-0.2742378	-0.53673
2017	515,395.70	0.1256	0.7513	0.5710	13.15269	-2.07465	-0.285943608	-0.56042
2016	483,978.70	0.1207	0.7425	0.5573	13.0898	-2.11445	-0.297788066	-0.58468

2015	489,052.80	0.1065	0.7336	0.5578	13.10023	-2.23961	-0.309774499	-0.58375
2014	484,640.10	0.1148	0.6609	0.5245	13.09116	-2.16456	-0.414152737	-0.64531

Table 1. (continue)

Year	CO2 (Ktons) E	Renewables (%) R	Fuel (%) F	Coal (%) C	LnE	LnR	LnF	LnC
2013	448,400.20	0.1227	0.6527	0.5150	13.01344	-2.09801	-0.426637673	-0.66359
2012	481,791.30	0.1124	0.6534	0.5108	13.08527	-2.18569	-0.42556578	-0.67178
2011	475,800.90	0.1199	0.6530	0.4421	13.07275	-2.1211	-0.42617815	-0.81622
2010	415,536.60	0.1585	0.6715	0.4032	12.93733	-1.842	-0.398241263	-0.90832
2009	391,082.70	0.1323	0.6552	0.4203	12.87667	-2.02268	-0.422814746	-0.86679
2008	376,137.80	0.1332	0.6381	0.4111	12.83771	-2.0159	-0.449260268	-0.88892
2007	379,956.60	0.1290	0.6458	0.4489	12.84781	-2.04794	-0.437265421	-0.80096
2006	364,467.00	0.1226	0.6518	0.4406	12.80619	-2.09883	-0.428017513	-0.81962
2005	342,148.10	0.1361	0.6500	0.4061	12.743	-1.99437	-0.430782916	-0.90116
2004	341,235.40	0.1361	0.6432	0.4012	12.74033	-1.99437	-0.441299561	-0.9133
2003	333,878.10	0.1364	0.6244	0.4112	12.71853	-1.99216	-0.47096409	-0.88868
2002	305,633.00	0.1495	0.6255	0.3967	12.63014	-1.90046	-0.469203949	-0.92457
2001	302,055.00	0.1747	0.6146	0.3725	12.61836	-1.74469	-0.486783629	-0.98752
2000	280,635.70	0.1596	0.6195	0.3643	12.54481	-1.83508	-0.478842578	-1.00978
1999	279,482.90	0.1412	0.6221	0.3418	12.5407	-1.95758	-0.474654427	-1.07353
1998	262,705.10	0.1577	0.6066	0.3097	12.47879	-1.84706	-0.499885684	-1.17215
1997	261,157.00	0.1034	0.6205	0.2789	12.47288	-2.26915	-0.477229674	-1.2769
1996	236,717.10	0.1553	0.6151	0.2516	12.37462	-1.8624	-0.485970423	-1.37991
1995	223,678.80	0.1646	0.6059	0.2427	12.31797	-1.80424	-0.501040323	-1.41593
1994	199,175.80	0.1566	0.5747	0.2493	12.20194	-1.85406	-0.553907113	-1.3891
1993	185,087.30	0.1978	0.5908	0.2353	12.12858	-1.6205	-0.526277728	-1.44689
1992	171,415.60	0.2384	0.5570	0.2737	12.05185	-1.43381	-0.585190039	-1.29572
1991	162,314.50	0.2056	0.5481	0.2958	11.99729	-1.58182	-0.601297527	-1.21807
1990	148,342.90	0.2092	0.5343	0.2990	11.90728	-1.56446	-0.6267978	-1.20731

Source: Processed from (Macrotrends, 2024), (Agency, 2024), (Indonesia, 2024), (Syahrial et al., 2011)

Data from Table 1: Indonesia Electricity on Renewable Energy, Fuel and Coal were then processed using SPSS software

Table 2: Coefficients

Coefficients[a]

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Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.
		B	Std. Error	Beta		
1	(Constant)	13.279	.274		48.388	.000
	LnR	-.360	.110	-.182	-3.284	.003

Table 2. (continue)

Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.
		B	Std. Error	Beta		
	LnF	1.546	.358	.401	4.322	.000
	LnC	.632	.124	.475	5.101	.000

a. Dependent Variable: LnE

$$\alpha = -0.360$$

$$\beta = 1.546$$

$$\gamma = 0.632$$

$$Ln\,A = 13,279$$

$$A = 584.780$$

$$E\,(R, F, C) = 584.780\,R^{-0.360}\;F^{1.546}\;C^{0.632}$$

From the Table 2: Coefficients, result from SPSS, it appears that the Renewable electricity, Fuel and Coal variables have significant numbers below 0.05, which indicates that nonlinearly the three variables have a significant effect on carbon emissions. However, the different results are in renewable energy where the constant parameter is negative, which means that increasing renewable energy will reduce carbon emissions.

Table 3: Model Summary

Model Summary

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate
1	.972[a]	.944	.939	.10092

a. Predictors: (Constant), LnC, LnR, LnF

Table 3: Model Summary is resulted from the SPSS. While the correlation figure is 94.4%, which shows that the renewable energy, fuel and coal variables can explain the relationship with carbon emissions with a high correlation. Only 5.6% is influenced by factors outside the three variables.

Conclusion

As the effects of climate change have been more apparent in recent years, energy transformation has emerged as a crucial component of reaching carbon neutrality. Thus, the relationship between electrical energy transformation in particular and carbon emissions is the focus of attention in this study. This study examines the issue of energy transition using the time series method. This study explores the nonlinear impact of changes in carbon emissions on the use of renewable electricity sources, oil and coal. There is a significant correlation between three variables, namely renewable electricity, oil and coal where the significance figure is less than 0.05. The coefficient of the largest carbon emission contributor is oil followed by coal. While renewable energy reduces carbon emissions with a negative coefficient. This study was conducted in the period 1990-2022.

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