Sustainable Connection Amid Renewable Energy, Non-Renewable Energy Usage, and Economic Growth in South Africa

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ABSTRACT

Purpose
This paper assesses the relationship between renewable and non-renewable energy sources and economic growth in South Africa.
Methodology
The study employs the Vector Error Correction Model (VECM) and the Wald-Granger Causality Approach, utilizing data spanning the period from 1990 to 2020.
Findings
The findings reveal an absence of bidirectional Granger causality among the variables. The VECM results further indicate that, in the short run, imports (IMP) and non-renewable energy (NREN) have a slightly more pronounced impact on GDP growth than exports (EXP) and renewable energy (REN). In the long run, both imports and non-renewable energy significantly influence GDP growth more than renewable energy and exports.
Conclusion
In essence, strategic policies in the energy sector are imperative for ensuring a positive impact of energy consumption on the economy. Given the critical role of the energy sector, the South African government must implement policies conducive to enhancing the overall performance of the economy.

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1. Introduction

A sustainable environment is an essential element of any nation's plan related to renewable energy (REN) and non-renewable energy (NREN), and economic growth (EcGr) is now a major topic of academic inquiry (Bekun et al., 2023). Additionally, as global warming and climate change pose two of the most dangerous threats to the continued existence of humans and ecosystems, researchers must emphasize their empirical discussion on these issues in the coming decade. Naturally, one of the main reasons for the issue as mentioned earlier is greenhouse gas emissions (GHG). The threat of GHG emission and global warming has drawn attention to the relationship between EcGr, REN, and NREN, which stimulates the environmental quality of any nation.

The Environmental Kuznets Curve (EKC) paradigm, which denotes a non-linear connection between EcGr and climate challenges, has been extensively used to analyze the influence of economic growth goals on the environment (Ozturk, et al., 2010; Sadorsky, 2009). According to the EKC framework, environmental degradation rises along with economic expansion in the initial stages before falling after economic growth reaches a certain degree (the turning point). This phenomenon represents an inverted U-shaped connection between variables. Numerous empirical studies support this claim such as (Sarkodie et al., 2018; Erdogan, 2020; Bekun et al., 2023). Other non-linear relations, such as U-shaped and N-shaped connections, have been hypothesized to exist according to several empirical research studies (Elliott, 2016; Saidi, 2020).

Sustainability advancement, which focuses on economic growth that addresses societal requests while simultaneously protecting the national endowment and societal endowed resources for upcoming generations, is known as sustainability advancement (Adekunle et al., 2023; Adekunle et al., 2022; Bekun et al., 2023; Manta et al., 2020; Tong et al., 2020). High economic expansion has boosted energy demand, GHG emissions, and global warming. Warnings regarding REN and NREN have a significant impact on the state of the world economy (Adekunle, 2023; Guo et al., 2022; Sha, 2022). Particularly for emerging nations that have a pressing need for energy (Bekun et al., 2023). When there are energy supply bottlenecks or shortages, the economy may be pressured, and sustainable development opportunities may be jeopardized.

Although REN and NREN are necessary for EcGr, they can also be the main factor in environmental deterioration (Khan et al., 2021). Energy-environmental issues are a major focus of researchers and policymakers around the globe due to their severe consequences on the economy. Several experts contend that NREN, not REN, is the cause of the inverse implications on the aggregate society. Therefore, increasing the use of REN rather than NREN possesses several probable benefits, such as reducing global warming emissions, increasing the variety of energy sources, and reducing reliance on nonrenewable energy (Can et al., 2019).

Therefore, governments in both developed and developing countries must give top emphasis to maintaining sustainable economic growth. Additionally, boosting economic growth while pursuing goals aimed at enhancing environmental quality and minimizing environmental harms is one of the most important things that countries can do to achieve sustainable development (Adekunle, 2023; Apergis et al., 2009; Shakib et al., 2021).

Essentially, this current study examines the connection between nonrenewable energy, renewable energy, import, export, and economic growth in the emerging economy of South Africa. By examining the substantial differences between the effects of REN and NREN (energy sources) on climate change, particularly in the African context distinguished by its energy sector wealth (abundance of natural resources), this paper adds to the body of prior literature. The VECM technique is used in this investigation, covering the period 1990-2020.

2. Literature Review

Destek and Sinha (2020) conducted a study on the impact of various factors, including REN and NREN, on environmental degradation in 24 OECD countries from 1980 to 2014. The study utilized the Panel Mean Group estimator (PMG) and the Ecological Footprint (EF) as a measure of climate change. According to the findings, non-renewable energy raises the ecological footprint (EF), whereas renewable energy lowers it. Belaid and Zrelli (2019) examined the link between CO2 and REN in nine Mediterranean nations from 1980 to 2014. According to the empirical findings, renewable electricity has an advantage over nonrenewable electricity in terms of its effect on environmental quality. According to the findings, increasing the usage of REN sources is a workable plan for preserving the environment and achieving energy security. The use of REN from 1990 to 2016 was examined by Alola et al. (2019) for the main economies in the European Union, including France, Germany, and the United Kingdom. The FMOLS and DOLS analyses provided evidence of a bidirectional Granger Causality between the use of renewable energy and carbon emissions, which helps to slow down environmental degradation. Chen et al. (2019) used FMOLS and DOLS to analyze the impact of REN and NREN on CO2 in China from 1995-2012. The results showed that while REN indirectly influenced environmental degradation in the Eastern and Western regions, NREN indicated a favorable influence on climate change that varied across the nation. The center region showed a negligible influence.

GMM estimation was used by Hanif et al. (2019) to analyze 25 developing Asian countries from 1990 to 2015. The findings demonstrated that NREN is a major contributor to climate change and that REN aids in reducing carbon emissions. As another illustration, Cheng et al., (2019) examined the effect of REN on CO2 per person for BRICS countries from 2000 to 2013. The study conducted by Zafar et al. (2019) used both OLS and quantile regression methods to analyze the impact of renewable energy (REN) supply on CO2 emissions per person in G-7 and N11 countries from 1990 to 2016. The results from both approaches were in agreement, confirming that the reduction in carbon emissions caused by renewable energy improved environmental quality for both sets of countries. The study also employed the CUP-FM and CUP-BC algorithms to evaluate the data. Zhang and Liu (2019) conducted a study between 1995 and 2014 to analyze the relationship between carbon dioxide (CO2) emissions, non-renewable energy sources (NREN), and renewable energy sources (REN) for ten countries in Northeast and Southeast Asia. According to their findings using Fully Modified Ordinary Least Squares (FMOLS) and Autoregressive Moving Average (ARMA) models, NREN is the primary contributor to carbon emissions. However, the use of REN can help to reduce carbon emissions. However, many scholars also established the merits of REN over NREN to regulate climate change, such as Salari et al. (2021), who examined 74 different countries between 1990 and 2015 to analyze renewable and non-renewable energy with environmental degradation. The results of FMOLS demonstrated that while renewable energy decreased environmental degradation, non-renewable energy had a beneficial impact and contributed to it. Chen et al., (2019) investigated the relationship between REN and climate change in China from 1980 to 2014 using the ARDL methods. The outcomes demonstrate rising NREN increased environmental deterioration while increasing REN decreased it.

Dasanayaka et al. (2022) conducted a study on the impact of renewable energy on the economic growth of Sri Lanka, a South Asian Island nation. They employ a method known as structural equation modeling. The study's findings indicate that the GDP of Sri Lanka is not significantly impacted directly by the use of REN. Sri Lanka wants to be completely dependent on renewable energy sources by 2050, in line with international trends and economic trends. Luqman et al. (2019) examined the asymmetric effects of nuclear and renewable energy on Pakistan's economic growth using the NARDL model for the years 1990 to 2016. The study's findings indicate that the variables' cointegration is asymmetric. Both positive and negative shocks to nuclear and renewable energy variables have a beneficial effect on Pakistan's economic expansion. Next, utilizing the Granger causality test and the ARDL model technique, Bouyghrissi et al. (2020) examined the connections among CO2 emissions, renewable and NREN consumption, and economic growth in Morocco from 1990 to 2014. The economic aspect of sustainable development in Morocco is positively impacted by renewable energy, according to empirical findings, which also establish a direct association between the use of REN and EcGr. Slusarczyk et al. (2022) also looked into the connection between EcGr and REN sources for the two economies of the European Union. For the low-income Polish and high-income Swedish economies, a comparative study was done. To respond to inquiries about the connection between economic expansion and renewable energy sources, they employ the regression model. In this study, data from 1991 to 2022 are analyzed. The variables GDP and GNI for Sweden (84.6% and 83.7%, respectively) and Poland (79.9% and 79.2%, respectively) that influence the adoption of renewable energy sources have a positive association (statistically significant).

Ocal and Aslan (2013) analyzed the causal connection between environmentally friendly power utilization and financial development in Turkey. The review results support the protection speculation. The observational test consequences of the ARDL approach show that sustainable power utilization adversely influences monetary development, and the Toda-Yamamoto causality test shows unidirectional causality from financial development to sustainable power utilization. Moreover, Lee and Jung (2018) analyzed the causal connection between environmentally friendly power utilization and monetary development in South Korea, utilizing the ARDL cointegration procedure and the VECM causality test for the period 1990-2012. The outcomes support the preservation speculation for South Korea. As far as possible experimental outcomes show that sustainable power utilization adversely influences monetary development, and the VECM causality test results show a unidirectional connection between financial development and sustainable power utilization. They suggested that financial development is an immediate driver of environmentally friendly power in South Korea. Then, Namahoro et al. (2021) analyzed the deviated connection between environmentally friendly power utilization and financial development utilizing the NARDL model and causality tests from 1990 to 2015 in Rwanda. The aftereffects of the review show proof that environmentally friendly power utilization influences financial development in Rwanda.

Besides, Zhe et al. (2021) assessed the positive effect of involving environmentally friendly power on financial development in Turkey from 1990 to 2015 utilizing VAR examination. According to the research, utilizing renewable energy sources doesn't have any adverse effects on the economy's growth. Similarly, Benlaria and Hamid Hamad (2022) concentrated on the awry connection between environmentally friendly power utilization and financial development joining capital and work for the instance of Saudi Arabia during the 1990-2019 period. The NARDL cointegration model is utilized to test the cointegration between factors. The aftereffects of the review show that there is an uneven connection between the factors. Strategies to advance monetary development are fundamental for supporting the environmentally friendly power area in Saudi Arabia. Then the most recent concentrate by Minh and Van (2023) looks at the connection between genuine Gross domestic product and the utilization of sustainable power in Vietnam for the 1995-2019 period. They utilize the ARDL model to assess the connection between sustainable power utilization, capital, work, and financial development over the long haul and decide causality utilizing the Granger causality test. This study presents moderate evidence of a one-way relationship between the use of environmentally friendly power and economic development, and this relationship persists over time.

3. Methodology

This linear process, despite being one of the most popular traditional time-domain causality tests, is nevertheless insufficient because it only looks at the interaction between variables in a static way. This flaw prompts us to point out that Granger causality can dynamically analyze the causation between variables (Breitung et al., 2006). To account for the spillover dynamics across many frequencies, they designed a Granger causality test in the frequency domain. The causation can also be computed at all locations in the frequency distribution (Breitung et al., 2006). The fundamental idea behind this spectrum tool is to break down the causation between two variables, Y and X, into its short-, medium-, and long-term components. It states that Y and X are two-time series that are stationary. Essentially, the World Development Indicator (WDI), produced by the US Energy Information Administration (EIA) and covering the years 1990 to 2020, is used in this study.

The current empirical work is based on Aswadi et al. (2023), which specifies the functional specification as:

$$GDP = f(GFCF, LF, ENC) \quad (1)$$

Where GDP = gross domestic product
GFCF = gross fixed capital formation
ENC = energy consumption
Essentially, the current study modified the functional relationship above thus

$$GDP = f\ (REN, NREW, EXP, IMP) \quad (2)$$

Where REN represents renewable energy; NREN represents nonrenewable energy; EXP represents export and IMP represents import.

The econometric specification of the model is specified below:

$$GDP = REN + NREW + EXP + IMP \quad (3)$$
$$GDP = \beta_0 + \beta_{1REN} + \beta_{2NREW} + \beta_{3EXP} + \beta_{4IMP} \quad (4)$$
$$GDP = \beta_0 + \beta_{1REN} + \beta_{2NREW} + \beta_{3EXP} + \beta_{4IMP} + \varkappa \quad (5)$$
$$GDP = \beta_0 + \beta_{1REN} + \beta_{2NREW} + \beta_{3EXP} + \beta_{4IMP} + \hat{e} \quad (6)$$

GDP is the endogenous variable while REN, NREN, EXP and IMP are the exogenous variables.

Equation (6) is modeled to show the connection between GDP and other specified variables in South Africa (SA). $\beta 0 – \beta_4$ are the parameters to be estimated in the model.

4. Results and Discussions

4.1. Unit Root Test

Table 1 below depicts the unit root test to launch the order of integration of the variables. As established by both the ADF and DF-GLS test. The Table confirmed that the variables are I(0) and I(1) order.

Table.1.Unit Root Test

		ADF Null (H_0): Non-stationary				DF-GLS Null (H_0): Non-stationary			
		ADF_α				ERS_α			
$z_{\cdot t}$		$\tau_{\cdot\mu}$	1%	5%	Prob.	τ_τ	1%	5%	Prob.
Intercept without Time Trend	REN	-1.62	-3.67	-2.97	0.45	-1.35	-2.65	-1.95	0.18
	GDP	-1.59	-3.57	-2.97	0.47	-1.37	-2.65	-1.95	0.18
	IMP	-1.51	-3.67	-2.96	0.51	1.09	-2.65	-1.95	0.28
	EXP	-3.06	-3.67	-2.96	0.04	2.83	-2.64	-1.95	0.00
	NREN	-2.00	-3.68	-2.97	0.28	-0.38	-2.64	-1.95	0.38
	ΔREN	-2.67	-3.67	-2.96	0.04	-2.21	-2.65	-1.95	0.03
	ΔGDP	-3.44	-3.67	-2.97	0.01	-3.52	-2.65	-1.95	0.00
	ΔIMP	-3.36	-3.67	-2.97	0.02	-4.57	-2.60	-1.95	0.00
	ΔEXP	-6.31	-3.69	-2.97	0.00	-8.97	-2.65	-1.95	0.00
	$\Delta NREN$	-6.74	-3.68	-2.97	0.00	-6.03	-2.65	-1.95	0.00
Intercept with Time Trend	REN	-0.89	-4.30	-3.57	0.94	-1.53	-3.77	-3.19	0.13
	GDP	-3.44	-3.68	-2.97	0.01	-3.52	-2.65	-1.95	0.00
	IMP	-0.34	-4.29	-3.57	0.98	-1.45	-3.77	-3.19	0.16
	EXP	-5.24	-4.29	-3.57	0.00	-5.43	-3.77	-3.19	0.00
	NREN	-0.33	-4.31	-3.57	0.98	-0.84	-3.77	-3.19	0.40
	ΔREN	-2.75	-4.30	-3.57	0.04	-2.64	-3.77	-3.19	0.01
	ΔGDP	-3.43	-4.31	-3.57	0.05	-3.59	-3.77	-3.19	0.00
	ΔIMP	-3.61	-3.77	-3.57	0.05	-3.77	-3.77	-3.19	0.00
	ΔEXP	-6.19	-4.32	-3.58	0.00	-6.42	-3.77	-3.19	0.00
	$\Delta NREN$	-7.31	-4.31	-3.57	0.00	-7.28	-3.77	-3.19	0.00

Source: Author's own elaboration

Table 1 above represents the unit root test which shows that all the variables were not stationary at level. Essentially, the study ensures stationarity of the variables used at I(0) and I(1) which necessitate the use of the Vector Error Correction Model (VECM).

4.2. Selection of Lags

The optimum lag selection is established in Table 2 below, to avoid spurious regression analysis as this can lead to misguided validations. Since the OpLS is established at 2 following the Schwarz information criterion. The estimation of the Johansson cointegration test and after that, the VECM procedure are established.

Table.2.Optimal Lags Selection (OpLS)

Lag	LogL	LR	FPE	AIC	SC	HQ
0	-761.7019	NA	4.09E+21	52.60013	52.64728	52.6149
1	-698.033	118.5558	5.43E+19	48.2781	48.3724	48.30767
2	-693.6053	7.939280*	4.29e+19*	48.04175*	48.18319*	48.08605*

Source: Author's own elaboration

4.3. Johansen Cointegration Test (JCT)

The study employed the Johansen Cointegration Test to establish long-run relationship amid the variables. Johansen's (1999) procedure is the maximum likelihood for the finite-order vector auto-regressions (VARS) and is easily calculated for such systems, so it will be used in this study. The result is shown below.

Table.3.Unrestricted Cointegration Rank Test (Trace)

Hypothesized		**Trace**	**0.05**	
No. of CE(s)	Eigenvalue	Statistic	Critical Value	Prob.**
None *	0.96336	159.9202	69.81889	0
At most 1 *	0.665082	70.64187	47.85613	0.0001
At most 2 *	0.499787	41.10743	29.79707	0.0017
At most 3 *	0.450559	22.40393	15.49471	0.0039
At most 4 *	0.206197	6.234854	3.841466	0.0125

Source: Author's own elaboration

Table.4.Unrestricted Cointegration Rank Test (Maximum Eigenvalue)

Hypothesized		**Max-Eigen**	**0.05**	
No. of CE(s)	**Eigenvalue**	**Statistic**	**Critical Value**	**Prob.****
None *	0.96336	89.27833	33.87687	0
At most 1 *	0.665082	29.53444	27.58434	0.0277
At most 2	0.499787	18.7035	21.13162	0.1058
At most 3 *	0.450559	16.16908	14.2646	0.0247
At most 4 *	0.206197	6.234854	3.841466	0.0125

Source: Author's own elaboration

Table 4 above, shows that both trace and maximum eigenvalue test show that there are stable and long-term equilibrium relationships among the variables. On the premise of the existence of cointegration relationships, VEC modeling can be further conducted

4.4. Vector Error Correction Model (VECM)

It must be noted, that the error correction mechanism (ECM) is meant to tie the short-run dynamics of the cointegrating equations to their long-run static dispositions. To capture the short-run fluctuation, the Vector Error Correction Method (VECM) was employed and the result is presented in Table 5 below. The study estimates this model to be able to test for Causality and diagnostic tests.

Table.5. VECM Output

Cointegrating Eq:	**CointEq1**
GDPC(-1)	1.000000
REN(-1)	1.26E+10 (4.9E+09) [2.55697]
NRENW(-1)	2.18E+11 (4.7E+10) [-4.64899]
LOGIMP(-1)	8.01E+10 (4.2E+10) [1.89793]
LOGEXP(-1)	1.08E+11 (2.5E+10) [4.40488]
C	-4.00E+12

Error Correction:	**D(GDPC)**	**D(REN)**	**D(NRENW)**	**D(LOGIMP)**	**D(LOGEXP)**
CointEq1	-0.007429 (0.03553) [-0.20909]	-4.52E-12 (3.8E-12) [-1.19545]	2.04E-12 (6.4E-13) [3.20309]	-1.12E-13 (9.0E-13) [-0.12407]	-7.57E-12 (3.1E-12) [-2.43343]
D(GDPC(-1))	0.433817 (0.43945) [0.98718]	-1.28E-11 (4.7E-11) [-0.27345]	9.08E-13 (7.9E-12) [0.11508]	-3.79E-12 (1.1E-11) [-0.34086]	1.81E-11 (3.8E-11) [0.47060]
D(GDPC(-2))	-0.279441 (0.44927) [-0.62199]	1.17E-11 (4.8E-11) [0.24567]	5.66E-12 (8.1E-12) [0.70166]	-1.05E-11 (1.1E-11) [-0.92429]	-5.14E-11 (3.9E-11) [-1.30481]
D(REN(-1))	-6.32E+09 (2.1E+09) [-3.01750]	0.559087 (0.22302) [2.50689]	-0.090393 (0.03762) [-2.40261]	-0.135340 (0.05305) [-2.55134]	-0.047281 (0.18353) [-0.25762]
D(REN(-2))	2.25E+09 (2.8E+09) [0.79507]	0.334072 (0.30108) [1.10959]	-0.072628 (0.05079) [-1.42995]	0.014688 (0.07161) [0.20511]	0.334858 (0.24776) [1.35153]
D(NRENW(-1))	-1.53E+10 (1.2E+10) [-1.27647]	1.713128 (1.27922) [1.33920]	-0.448234 (0.21580) [-2.07709]	-0.042964 (0.30427) [-0.14120]	0.408836 (1.05269) [0.38837]
D(NRENW(-2))	2.13E+10 (1.5E+10) [1.45351]	-0.621777 (1.56054) [-0.39844]	0.116367 (0.26326) [0.44202]	0.268563 (0.37119) [0.72353]	2.674134 (1.28420) [2.08233]
D(LOGIMP(-1))	8.98E+09 (1.4E+10)	-0.775831 (1.54148)	0.000207 (0.26004)	0.289493 (0.36665)	0.217977 (1.26851)

	[0.62035]	[-0.50330]	[0.00080]	[0.78956]	[0.17184]
D(LOGIMP(-2))	-8.51E+09	1.475221	-0.152038	-0.124864	-0.592267
	(1.4E+10)	(1.46844)	(0.24772)	(0.34928)	(1.20841)
	[-0.61677]	[1.00462]	[-0.61375]	[-0.35749]	[-0.49012]
D(LOGEXP(-1))	1.54E+09	0.315361	-0.123156	0.009181	-0.099620
	(3.2E+09)	(0.34593)	(0.05836)	(0.08228)	(0.28467)
	[0.47331]	[0.91163]	[-2.11038]	[0.11158]	[-0.34995]
D(LOGEXP(-2))	7.05E+08	0.133440	-0.043187	0.017071	-0.095211
	(2.3E+09)	(0.24912)	(0.04203)	(0.05926)	(0.20501)
	[0.30140]	[0.53564]	[-1.02762]	[0.28810]	[-0.46443]
C	3.01E+09	-0.173482	0.014496	0.071971	0.174008
	(2.6E+09)	(0.27799)	(0.04690)	(0.06612)	(0.22876)
	[1.15166]	[-0.62407]	[0.30911]	[1.08848]	[0.76066]
R-squared	0.578095	0.524681	0.621404	0.412898	0.607139
Adj. R-squared	0.288035	0.197899	0.361119	0.009265	0.337048
Sum sq. resids	5.64E+20	6.397112	0.182052	0.361923	4.332093
S.E. equation	5.94E+09	0.632313	0.106669	0.150400	0.520342
F-statistic	1.993017	1.605602	2.387398	1.022954	2.247902
Log likelihood	-662.0339	-19.06127	30.76904	21.14913	-13.60413
Akaike AIC	48.14528	2.218662	-1.340646	-0.653510	1.828866
Schwarz SC	48.71623	2.789607	-0.769701	-0.082565	2.399811
Mean dependent	5.62E+09	-0.307143	0.063250	0.044421	0.043126
S.D. dependent	7.04E+09	0.706021	0.133453	0.151102	0.639069
Determinant resid covariance (dof adj.)		1.67E+14			
Determinant resid covariance		1.02E+13			
Log likelihood		-617.9446			
Akaike information criterion		48.78176			
Schwarz criterion		51.87438			

Source: Author's own elaboration

Table.6.Stability Test for VECM

Lags	LM-Stat	Prob
1	19.54689	0.7702
2	21.66405	0.6551

Note: Probs from chi-square with 25 df.

Source: Author's own elaboration

4.5. Granger Causality Test

The cointegration test indicates a long-term equilibrium relationship between the two variables. However, in terms of a causal relationship, further testing is required. If variable X is useful in predicting Y, meaning the regression of Y is based on past values of Y, and past values of X are added, this can significantly enhance the explanatory power of the regression. In such a case, X can be referred to as the Granger cause of Y; otherwise, it can be termed a non-Granger cause. The p-value is less than the significance level of 5%, suggesting the need to accept the null hypothesis, indicating the existence of a Granger cause.

Table.7. Granger Causality Output

Null Hypotheses (H0)	Chi-Square	Probability	Remarks
GDPC does not Granger Cause REN	9.12	0.01	Uni-directional Causality (UDC)
REN does not Granger Cause GDPC	0.09	0.95	
GDPC does not Granger Cause NREN	7.01	0.03	Uni-directional Causality (UDC)
NREN does not Granger Cause GDPC	0.69	0.70	
GDPC does not Granger Cause IMP	0.65	0.72	No Causality
IMP does not Granger Cause GDPC	1.49	0.43	
GDPC does not Granger Cause EXP	0.22	0.89	No Causality
EXP does not Granger Cause GDPC	1.70	0.42	

Source: Author's own elaboration

In summary, as shown in Table 7 above, there is no bidirectional Granger causality among any of the variables. There is unidirectional causality from GDPC to REN, GDPC to NREN, while there is no Granger causality from GDPC to IMP, IMP to GDPC, GDPC to EXP, EXP to GDPC.

The connection between SA EcGr, NREn, REn, and FDI was explored using a dataset spanning from 1990 to 2020. The employed Wald Granger causality, as shown in Table 7, along with a variety of techniques, including the JCT and VECM. The results of the Wald causality test showed compelling evidence of long-term, transitory causality between GDPC and REN. It is also clear that GDPC Granger causes NREn. Our findings also showed that the use of REn and NREn impacts the rise of EcGr in SA. Specifically, there is no discernible causal association between GDPC and EXP, as well as GDPC and IMP over the long run. Furthermore, it is important to note that there is evidence of a persistent causal relationship across REn and EcGr, indicating that renewable energy significantly contributes to economic growth. We conclude that SA EcGr significantly benefits from renewable energy and NREn.

Overall, the study demonstrates that NREn sources fueled economic expansion, particularly on short- and medium-term timescales. Furthermore, during the sample period and in the short term, non-renewable energy consumption has a significant impact on the increase of EcGr. Additionally, significant co-movements between renewable energy and GDPC are demonstrated, despite a low-level coefficient in the co-movement between renewable energy and EcGr. This suggests that the usage of renewable energy fuels economic growth. It is possible to comprehend the function of renewable energy in increasing growth in SA due to the positive coherency between EcGr and renewable energy in Table 5.

Using the VECM, we proceed by investigating the connection between REn, NREn, and EcGr. The study findings support those of (Aswadi et al., 2023; Adekunle et al., 2023). It's also noteworthy to state that the economic situation can be influenced by the combination of REn and NREn components. This suggests that SA economic growth is driven by NREn, as supported by VECM and Wald Granger causality. The research outcomes align with those of Adekunle et al. (2022) and Bekun et al. (2023), demonstrating the positive impact of renewable energy on economic growth while simultaneously mitigating carbon emissions. This underscores the importance of sustainable energy practices in addressing environmental and economic challenges. Furthermore, we concur with (Appiah-Otooh et al., 2023), who discovered that renewable energy had a detrimental effect on EcGr. According to the results, a one percentage point increase in renewable energy is directly correlated with a 0.3% decrease in EcGr. When examining how South Africa's (SA) use of renewable energy affects economic growth, we can see that, in the short run, renewable energy boosts economic growth by offsetting the effects of non-renewable energy sources like coal, oil, and natural gas. Our research showed how important renewable energy is to sustainability. More specifically, our findings indicate that green energy may support a cleaner, sustainable environment in addition to stimulating economic growth.

5. Conclusion

This research paper explores the connection between renewable energy, nonrenewable energy, and economic growth in South Africa over the period 1990 to 2020 using VECM and the Wald Granger causality method. Following the result of this study, there is a long-run relationship among the variables used for the study. The result obtained from the Vector Error Correction Model (VECM) shows that in a shorter period, IMP and NREN affect GDP growth slightly more than EXP and REN. In a similar vein, in the longer period, IMP and NREN also affect GDP growth significantly more than REN and EXP.

Renewable energy and non-renewable energy use have increased recently as a result of the global focus on environmental issues. The development and accessibility of markets for renewable energy will be accelerated by high and stable growth as well as the intergovernmental evaluation around the usage of NREN. Additionally, a shift to renewable energy is required to develop a better sustainable energy balance, which can support SA's long-term sustainable economic growth and sustainable energy supply. As a result, this study investigates how REN and NREN affect SA economic activities. Following the results of this study, there is a long-run connection between the variables used in the study.

The REN coefficient is significant and positive, indicating that increasing the REN will increase South Africa's (SA) economic growth. This suggests that the usage of renewable energy should be more encouraged in driving domestic and societal economic activities.

The consumption of non-renewable energy, meanwhile, is what drives South Africa's sustainable economic growth. The coefficient for renewable energy is positive and considerable. These findings demonstrate that fossil fuels, which account for 90% of the country's energy consumption, are not the primary determinant of growth in South Africa. This demonstrates that for South Africa to become one of the major contributors to economic growth and benefit from its favorable effects on economic growth and a sustainable environment, it must promote and accelerate the development of the renewable energy sector.

The government must implement strategic policies in the energy sector to ensure that energy consumption has a positive effect on the economy since the energy sector is crucial to enhancing the performance of the SA economy. Government policies are required to improve economic performance in the energy sector by assuring a switch from fossil fuels to renewable energy sources to lessen reliance on non-renewable fossil fuels and price stability, both of which are unfavorable during times of crisis such as low energy availability. Essentially, further research with a bigger sample size may enable us to identify a more suitable renewable energy policy for South Africa.

Author Contributions

Dr. Ahmed Adekunle carried out the conceptualization, formal analysis, and revised as well as. results estimation, tabulation of data, and response to reviewers' comments.

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Conflicts of Interest

The authors declare no conflicts of interest.

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