NEXUS BETWEEN RENEWABLE ENERGY, NON-RENEWABLE ENERGY CONSUMPTION, CO2 EMISSION AND ECONOMIC GROWTH IN SOUTH AFRICA

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Abstract

This paper examines the nexus amid renewable energy, non-renewable energy consumption, CO_2 emissions and economic growth in South Africa. VECM and Granger causality approach were employed in the paper. Empirical result suggested that carbon emissions granger cause GDPC uni-directionally. Essentially, From the various empirical estimation, it is discovered that CO_2 has a positive impact on GDPC in the study. This shows that disregarding the ecological contamination cause by CO_2 that animate the GDPC, which make it challenging for severe measure by government to control fossil fuel byproduct cause by non-environmentally friendly power in the framework. REN shows causality with GDPC in one direction, and that implies REN accessibility move with growth in GDPC. Since the review assessment results likewise exhibit that CO_2 has a causality with economic growth in SA. The public authority needs to intiate severe guideline with respect to weighty fossil fuel byproduct innovation this would empower the turn of events and execution of more powerful and low-carbon innovation across all enterprises, eventually advancing economic growth in SA.

Keywords: renewable energy; CO_2 emissions; economic growth; South Africa.

Introduction

Sustainability of the environment, the green economy, and climate change become key topics in academic discuss. It is undeniably one of the most dangerous dangers to human and ecological survival that climate change poses (Adekunle et al., 2022). For this reason, it is crucial for researchers to focus on the primary causes and effects of both global warming and climate change in the coming decade. It goes without saying that one of the main causes of the aforementioned issue is CO_2 emissions. The current threat of climate change and global warming has drawn attention to the pertinent connections between energy consumption, ecological damage, and economic indicators (such GDP growth, production, oil prices). The reduction of CO_2 emissions into the atmosphere is the primary goal. SA is the largest energy consumer in the Middle East when compared to other nations. By the end of 2019, the country's average oil consumption was approximately 4.3 million barrels per day (bpd), up from an average of 4.1 million bpd in 2018 (Ministry of Energy, 2020). South Africa (SA) consumes a significant amount of energy on a national level. It is important to remember that SA is predicted to use 10 quadrillion British thermal units of primary energy globally in 2020. This nation is the second-largest energy consumer in the Middle East due to its strong domestic consumption. It's interesting to note that in 2020, oil accounted for 62% of SA energy consumption and natural gas for 38% (US. Energy information Administration, 2021). Oil manufacturing has decreased since 2015, despite increases in natural gas resources and processing capacity. Moreover, SA energy consumption over the same period was largely derived from coal and solar energy, in particular. SA produced 586.4 million metric tons of carbon emissions in 2021 from fossil fuel and industrial usage, placing it among the top countries in the world in terms of CO_2 emissions per person at about 19 metric tons. Many nations, including SA, are focusing more on energy alternatives to fossil fuels as a result of environmental concerns and issues with energy security. More specifically, these nations held the view that, in addition to being readily available, nuclear and renewable energy sources are free energy sources that can be useful substitutes for fossil fuels in the fight against climate change and global warming. This is according to Elliot (2016).

By creating pertinent policies and initiatives to promote investment in the renewable energy industry, governments began looking at energy security and the consumption of renewable energy sources in an effort to improve the usage of secure energy. On the other hand, researchers in the fields of economics and finance have focused more on the relationship between the use of renewable energy, the reduction of CO_2 emissions, and macroeconomic variables. This topic is beginning to receive a lot of attention from researchers in both developed and developing nations.

The relationship between energy consumption and economic growth has been the subject of a great deal of research (Adekunle et al., 2023; Bekun et al., 2023; Al-Mulali et al., 2014; Sinha et al., 2017, 2018; Sinha et al., 2018).

Furthermore, Apergis and Payne (2010b) contended that a notable surge in renewable energy may serve as a substitute energy source. According to Al-Mulali et al. (2013), there is a way to provide energy security while reducing a significant reliance on traditional energy sources by raising the share of renewable energy. The IEA (2020) reports that the fastest-growing energy source in the world is renewable energy, with yearly growth rates of about 3%. Governmentbacked initiatives including tax breaks, subsidies, and incentives have been the main forces behind the growth of renewable energy in recent years. At present, nations are prioritizing technology and renewable energy production, and these aspects have taken center stage in the development of energy policies.

New growth theories that have emerged recently place a great emphasis on the role that technological advancement plays in economic growth, while also endorsing the idea that innovation is the primary force behind modern productivity.

Comparably, Inekwe (2015) contended that the primary factor influencing long-term economic growth is research and development (R&D). Romer (1986) asserts that R&D spending is essential for the advancement of technology through the application of human resources and preexisting knowledge. These endogenous growth models also offer a framework for examining the relationship between productivity and R&D spending. The importance of investing in R&D expenditures for better output is supported by recent study. Economic growth is regarded as a competitive advantage for businesses and the economy, and R&D investments are crucial for this (Grossman and Helpman, 1994). R&D spending and GDP have been found to be positively correlated by a number of research (Bhattacharya et al., 2016; Bayarçelik et al., 2012; Freimane et al., 2016).

To the best of the researcher knowledge, little studies have carefully examined carbon emission effect in South Africa in conjunction with renewable and non-renewable element. Additionally, the majority of empirical research employed conventional techniques like dynamic ordinary least square (DOLS), bivariate and multiple wavelet method and autoregressive distributed lag model (ARDL) to examine the relationship between renewable and non-renewable energy, carbon emissions, and macroeconomic indicators. In the current study, the relationships in the time-frequency space between renewable energy, non-renewable energy, carbon emissions, and economic growth using vector error correction model (VECM). With our many contributions, we significantly enhance the body of literature on the connection between South Africa's economic growth, CO_2 emissions, and use of renewable energy. Initially, every prior empirical study that has examined the relationship between renewable energy, CO_2 emissions, and economic growth indicators has concentrated on dependency. However, no research has looked at the connection between measures of economic growth and CO_2 emissions and renewable energy categorized by source and aggregate level. Second, not much study has used advanced techniques to examine the connection between economic growth and the consumption of renewable energy. More specifically, to the best of the researcher knowledge, no research has examined this relationship in the context of South Africa by excluding and regulating the impacts of pertinent variables on CO_2 emission in the time-aggregate domain. Because of this, the study will use VECM analysis to examine the connection between CO_2 emissions instantaneously across time and across scales (short-run and long-run scales), aggregate economic indicators (GDP per capita), and renewable and non-renewable energy consumption by source. Energy scientists, energy investors, and policy officials are expected to find value in the study's results, implications, and conclusions. SA has also implemented ambitious renewable energy policy objectives using various approaches. SA has an abundance of solar resources, which makes it one of the major exporters of renewable energy in the future. Given that the renewable energy sector is regarded as a major growth opportunity, one of the most intriguing 2030 Vision directives is the execution and enhancement of investment in the energy sector. Renewable energy sources are essential for South Africa sustainable development because they are unrestricted globally and environmentally benign. Providing a healthy life for present and future generations is one of the 2030 Vision's strategic goals. There is a perceived ultimate relationship between renewable energy sources and opportunities for economic growth. There are several reasons why SA can benefit economically, both directly and indirectly, from switching to renewable energy sources rather than fossil fuels on a macro and local basis. For example, it will result in more jobs being created at lower costs, including jobs in manufacturing, engineering, marketing, and other fields, with the hope that these jobs will continue to rise in the coming years. Additionally, energy consumers in residential and commercial settings can lower their energy costs by installing solar panels, which lowers power costs. This is made possible by investments in the renewable energy sector. Additionally, by moving to the renewable energy industry, SA may be able to lessen its reliance on oil supplies and its GDP's susceptibility to changes in oil prices. Our research goals can be divided into four main categories that are mutually included in both theoretical and practical frameworks. Our goal is to engage in substantive scholarly discourse regarding climate change, environmental sustainability, and the impact of renewable energy utilization on economic expansion and investment opportunities. Using a bivariate and multivariate wavelet framework and a spectral causality test in the frequency domain, we offer fresh insights into the relationship between renewable energy consumption by source and CO_2 emissions as well as on the aggregate economic indicator. Furthermore, we offer practical implications for the policy problems (2030 Vision) related to the development of investments in the energy industry, which necessitate collaboration between the public and private sectors. From a methodological perspective, we want to make use of several methods, such as the spectral Granger causality test in the frequency domain, to evaluate the relationship between GDP growth per capita and CO_2 emissions as well as the use of renewable and non-renewable energy. Additionally, we employ a variety of wavelet techniques, such as multiple and bivariate wavelet approaches. In particular, we use the multi-wavelet approach to evaluate the causal links, both short- and long-term, between GDP per capita in SA, carbon emissions, and the consumption of renewable and non-renewable energy. The following are the research questions we have developed for our study: i) Does the use of renewable energy, CO2 emissions, and economic growth have any causal relationships? ii) Do non-renewable energy usage and CO2 emissions have any causal relationships, either in the short run, with economic growth throughout time?

1. Methods

The study's theoretical framework will assist us in selecting the model variables. The countries of Southern Africa are emerging economy, which may be attributed to the consumption of energy in two main forms: renewable and nonrenewable energy. In essence, the combustion of fossil fuels is the primary source of nonrenewable energy consumption. This process leads to the breakdown of the fossil fuels' hydrocarbon structure, which pollutes the surrounding air. As a result, continued use of this kind of energy is bad for the nation's sustainable development as well as the quality of the environment since it degrades the environment's hygienic conditions. In summary, technology inflow has the scale, composition, and technical effects on the economy when energy consumption has a scale effect; capital investment, which includes both building capacity for renewable energy generation and nonrenewable energy generation, has the composition effect. Given this, it is reasonable to argue that both the use of renewable and nonrenewable energy sources will contribute to economic growth.

In order to evaluate the connection between amid CO_2 per capita and non-renewable energy, renewable energy and GDP per capita, we used annual data for SA from 1990 to 2020. The data employed sourced from EIA expect GDP per capital obtained from WDI. The underlying series included GDP per capita, the amount of energy used for renewables relative to total energy usage, the amount of energy used for non-renewables, or coal, natural gas, and oil use, and the amount of carbon emissions per person, measured in metric tons.

To account for the spillover dynamics across many variables, the study designs a Granger causality and VECM in the frequency domain. The causation can also be computed at all locations in the frequency distribution, according to (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. 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 covers the years 1990 to 2020, is used in this study.

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

GDPC = *f*(CO2, REN, NREN, EXP) (1)

Where

GDPC = gross domestic product per capital

CO2 = Carbon emission

REN = Renewable energy

NREN = Nonrenewable energy

EXP = Export

Essentially, the current study modified the functional relationship above thus

GDPC = *f*(CO2, REN, NREW, EXP) (2)

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

The econometric specification of the model is specified below:

$$GDPC = REN + NREW + CO_2 + EXP \quad (3)$$

$$GDPC = \beta_0 + \beta_1 REN + \beta_2 NREW + \beta_3 CO_2 + \beta_4 EXP \quad (4)$$

$$GDPC = \beta_0 + \beta_1 REN + \beta_2 NREW + \beta_3 CO_2 + \beta_4 EXP + \varkappa \quad (5)$$

$$GDPC = \beta_0 + \beta_1 REN + \beta_2 NREW + \beta_3 CO2 + \beta_4 EXP + \hat{e} \quad (6)$$

GDP is the endogenous variable while REN, NREN, EXP and CO_2 are the exogenous variables.

Equation (6) is modelled to show the connection amid GDPC and other specified variables in South Africa (SA). $\beta_0 - \beta_4$ are the parameters to be estimated in the model.

2.Findings and discussion

Table 1 below represents the unit root testing which signifies I(0) and I(1) and serve as yardstick for appropriateness of VECM for the study and the optimum lags selection is based at 1 following the Schwarz information criterion.

Table 1: Unit root

		DF Null (H_0): Non-stationary				PHIL-PER Null (H_0): Non-stationary			
		DF_α				ERS_α			
	$z_{\cdot t}$	$\tau_{\cdot\mu}$	1%	5%	Prob.	τ_τ	1%	5%	Prob.
Intercept without Time Trend	$GDPC$	1.62	2.64	-1.95	0.11	0.75	3.67	2.96	0.81
	$NREN$	0.38	2.64	1.95	0.70	1.70	3.67	2.96	0.41
	REN	1.35	2.64	1.95	0.18	0.97	3.67	2.96	0.77
	EXP	2.84	2.64	1.95	0.00	2.98	3.67	2.96	0.04
	$CO2$	0.58	2.64	1.95	0.61	1.93	3.67	2.96	0.31
	$\Delta GDPC$	1.36	2.64	1.95	0.18	1.42	3.67	2.96	0.55
	$\Delta NREN$	6.03	2.64	1.95	0.00	6.64	3.67	2.96	0.00
	ΔREN	2.21	2.64	1.95	0.03	2.67	3.67	2.96	0.08
	ΔEXP	8.95	2.64	1.95	0.00	25.5	3.67	2.96	0.01
	$\Delta CO2$	5.53	2.64	1.95	0.00	6.09	3.67	2.96	0.00
Intercept with Time Trend	$GDPC$	0.56	4.29	3.56	0.97	1.23	4.29	3.56	0.88
	$NREN$	0.84	3.77	3.19	0.41	0.91	4.29	3.56	0.94
	REN	1.53	3.77	3.19	0.13	1.36	4.29	3.56	0.84
	EXP	5.42	3.77	3.19	0.00	1.39	4.29	3.56	0.84
	$CO2$	0.94	3.77	3.19	0.35	0.62	4.29	3.56	0.05
	$\Delta GDPC$	1.79	3.77	3.19	0.08	0.29	4.30	3.57	0.91
	$\Delta NREN$	7.28	3.77	3.19	0.00	7.28	4.30	3.57	0.00
	ΔREN	2.64	3.77	3.19	0.01	2.52	4.30	3.57	0.31
	ΔEXP	6.41	3.77	3.19	0.00	26.85	4.30	3.57	0.00
	$\Delta CO2$	7.02	3.77	3.19	0.00	7.17	4.30	3.57	0.00

Source: Author's Compilation, 2024

Table 2: Lags Determinati

Lag	LogL	LR	FPE	AIC	SC	HQ
1	-590.2737	NA	8.56e+12*	43.94812	45.13759*	44.31175*
2	-565.2860	32.12704	9.91e+12	43.94900	46.32794	44.67626
3	-536.2943	26.92085	1.18e+13	43.66388*	47.23228	44.75478

Source: Author's Compilation, 2024

Johansen Cointegration Test (JCT)

JCT was used in the study to determine the long-term relationships between the variables. It will be employed in this study since Johansen's (1999) method provides the greatest likelihood for finite-order VECM and is simple to compute for such systems. The outcome is displayed in Table 3 below.

Table 3: Test of Unrestricted Cointegration (Trace)

Hypothesized No. of CE(s)	Eigenvalue	Trace Statistic	0.05 Critical Value	Prob.**
None *	0.575405	80.07149	69.81889	0.0061
At most 1 *	0.539190	55.22952	47.85613	0.0087
At most 2 *	0.471633	32.76119	29.79707	0.0221
At most 3	0.232745	14.26024	15.49471	0.0761
At most 4 *	0.202917	6.577087	3.841466	0.0103

Trace test indicates 3 cointegrating eqn(s) at the 0.05 level
* denotes rejection of the hypothesis at the 0.05 level

Source: Author's Compilation, 2024

Table 4: Unrestricted Cointegration Rank Test (Maximum Eigenvalue)

Hypothesized No. of CE(s)	Eigenvalue	Max-Eigen Statistic	0.05 Critical Value	Prob.**
None	0.575405	24.84196	33.87687	0.3958
At most 1	0.539190	22.46833	27.58434	0.1973
At most 2	0.471633	18.50095	21.13162	0.1122
At most 3	0.232745	7.683151	14.26460	0.4118
At most 4 *	0.202917	6.577087	3.841466	0.0103

Max-eigenvalue test indicates no cointegration at the 0.05 level

Source: Author's Compilation, 2024

Vector Error Correction Model (VECM)

It should be emphasised that the Vector error correction mechanism (VECM) aims to link the cointegrating equations' to their long-run static dispositions. The Vector Error Correction Method (VECM) was used to capture the short run variation, and the outcome is shown in Table 5 below. This model is estimated in the study so that causality and diagnostic tests can be performed.

Table 5: VECM Output

Cointegrating Eq:	CointEq1
GDPC(-1)	1.000000
CO2(-1)	-4.12E+11

	(5.3E+11)				
	[-0.78218]				
REN(-1)	1.06E+10				
	(3.3E+09)				
	[3.22094]				
NRENW(-1)	-5.07E+10				
	(1.1E+11)				
	[-0.45969]				
LOGEXP(-1)	1.02E+11				
	(1.7E+10)				
	[5.84457]				
C	-1.84E+11				
Error Correction:	D(GDPC)	D(CO2)	D(REN)	D(NRENW)	D(LOGEXP)
CointEq1	-0.037317	4.54E-13	-3.30E-12	2.54E-12	-1.09E-11
	(0.04234)	(1.6E-13)	(4.8E-12)	(7.5E-13)	(3.6E-12)
	[-0.88137]	[2.89175]	[-0.68817]	[3.38915]	[-2.99329]
D(GDPC(-1))	0.585586	-5.95E-13	-4.04E-11	5.33E-12	7.86E-12
	(0.33904)	(1.3E-12)	(3.8E-11)	(6.0E-12)	(2.9E-11)
	[1.72717]	[-0.47300]	[-1.05342]	[0.88740]	[0.27079]
D(GDPC(-2))	-0.420091	6.56E-13	4.68E-11	7.11E-12	-4.58E-11
	(0.34363)	(1.3E-12)	(3.9E-11)	(6.1E-12)	(2.9E-11)
	[-1.22251]	[0.51424]	[1.20492]	[1.16892]	[-1.55739]
D(CO2(-1))	2.06E+10	0.011026	-9.424349	2.258386	-0.839087
	(1.0E+11)	(0.38783)	(11.8215)	(1.85104)	(8.95114)
	[0.19746]	[0.02843]	[-0.79722]	[1.22006]	[-0.09374]
D(CO2(-2))	1.14E+11	0.223108	3.614109	3.989452	9.220090
	(1.0E+11)	(0.38006)	(11.5847)	(1.81396)	(8.77184)
	[1.11318]	[0.58703]	[0.31197]	[2.19930]	[1.05110]
D(REN(-1))	-4.90E+09	-0.022892	0.532308	-0.063397	0.102635
	(2.1E+09)	(0.00783)	(0.23870)	(0.03738)	(0.18074)
	[-2.32148]	[-2.92315]	[2.23002]	[-1.69617]	[0.56785]
D(REN(-2))	2.73E+09	-0.007384	0.242690	-0.059406	0.293014
	(2.8E+09)	(0.01040)	(0.31688)	(0.04962)	(0.23994)
	[0.97487]	[-0.71032]	[0.76588]	[-1.19729]	[1.22122]
D(NRENW(-1))	-1.72E+10	-0.057876	3.007320	-0.902504	0.403996
	(2.1E+10)	(0.07824)	(2.38485)	(0.37343)	(1.80579)
	[-0.81584]	[-0.73972]	[1.26101]	[-2.41682]	[0.22372]
D(NRENW(-2))	5.09E+08	0.021275	-1.269999	-0.566394	0.234579
	(2.3E+10)	(0.08598)	(2.62087)	(0.41038)	(1.98450)
	[0.02199]	[0.24743]	[-0.48457]	[-1.38017]	[0.11821]
D(LOGEXP(-1))	3.56E+09	-0.023241	0.193640	-0.147422	0.069710
	(3.5E+09)	(0.01303)	(0.39724)	(0.06220)	(0.30079)
	[1.01269]	[-1.78335]	[0.48746]	[-2.37009]	[0.23176]
D(LOGEXP(-2))	1.66E+09	-0.009318	0.180177	-0.052713	0.016244
	(2.4E+09)	(0.00884)	(0.26933)	(0.04217)	(0.20393)
	[0.69651]	[-1.05461]	[0.66900]	[-1.24997]	[0.07965]

C	3.16E+09	0.004551	-0.172538	-0.020594	0.254711
	(2.6E+09)	(0.00951)	(0.28978)	(0.04537)	(0.21942)
	[1.23432]	[0.47869]	[-0.59541]	[-0.45388]	[1.16085]

Source: Author's Compilation, 2024

Granger Causality Test

Table 6 below, show that there is at least uni-directional causality among the variables. There is Unidirectional Causality between CO_2 and GDPC. From the various empirical estimation, it is discovered that CO_2 has a positive impact on GDPC in the study. This shows that disregarding the ecological contamination cause by CO_2 that animate the GDPC, which make it challenging for severe measure by government to control fossil fuel byproduct cause by non-environmentally friendly power in the framework, this verifies the past review (Adekunle et al., 2023; **Saba**, 2023). The outcomes of this study have in like manner shown that the coefficient of CO_2 is positive and tremendous in the VECM assessment.

Taking into account that the vast majority of African nations produce non-practical power sources like oil based commodities, the incredible impact of monetary development on ecological contamination prompts the review to check out at the fundamental components of development. Moreover, REN shows causality with GDPC in one heading, and that implies REN accessibility move with development in GDPC. A few earliest investigations likewise show that REN advances monetary development, for example, the examination on African countries led by Mujtaba et al., 2021 which is comparative with the review result. Notwithstanding, thought rising natural disintegration is generally brought about by energy and financial extension (Bekun et al., 2023).

As to PHH or PHV speculation, the review reasons that send out which is finished result of FDI essentially influences development with uni-directional development, proposing that FDI section into African countries injuriously affects the climate particularly with trade excitements. Indeed, even while trade assumes a fundamental part in driving financial extension, natural quality can be unfavorably and seriously affected by it. Various examinations have offered genuine evidence of the issues. The half and half capability of product, which contributes mechanical advancement to both ecological quality and monetary advancement. Other exploration uncovered that the low measure of commodity surge to the getting countries could represent the negative impacts of product on ecological quality. Nonetheless, if trade outpouring arrives at a huge level, it can extraordinarily support upgrading the environmental elements. As indicated by Lee et al. 2008, mechanical advancement abilities deteriorate how much ecological contamination when trade surge is little. Notwithstanding, in the event that send out surge surpasses an edge, mechanical development capacities work on the nature of the climate.

Considering that REN efficiency brings down contamination by consuming less energy, policymakers ought to urge it to address both monetary and ecological inadequacies. The utilization of sustainable power sources rather than non-inexhaustible ones further develops natural quality by expanding energy productivity since their exist causality among REN and GDPC.

In similar setting, legislators ought to fund energy-saving drives and present public-private organization speculations (PPPI) to help maintainable energy and different drives of a comparable sort (Lin et al., 2018). In this manner, the most ideal sort of open confidential organization would decrease an unnatural weather change by offering privately owned business' monetary motivations to subsidize relief drives (Bildirici et al., 2020). The energy business is one region where the public-private organization can uphold interests in environment transformation, as verified by Doytch, 2020; Gui-Diby et al., 2015 and Hanni et al., 2011. Thus, executing speculations through open confidential organizations can both diminish ecological effect and advance monetary development.

Alternative green exchange techniques that limit the import of coal, petroleum derivatives, and other filthy energy sources ought to be thought about by the lawmakers in these countries. This approach can assist with diminishing CO_2 and work with the reception of elective energy arrangements across public lines. Both exchange balance and ecological quality will benefit. Thusly, it very well might be feasible to accomplish specific Economical Advancement Objectives (SDG) all the while, explicitly SDG 7 (modest and clean energy) and SDG 13 (environment activity).

Table 6: Granger Causality Output

Null Hypotheses (H0)	$F-Stat$	**Probability**	**Remarks**
CO2 does not Granger Cause GDPC	5.23	0.01	Uni − directional Causality
GDPC does not Granger Cause CO2	1.46	0.25	
REN does not Granger Cause GDPC	5.42	0.01	Uni − directional Causality
GDPC does not Granger Cause REN	0.98	0.38	
NRENW does not Granger Cause CO2	0.88	0.42	No Causality
CO2 does not Granger Cause NRENW	2.85	0.07	
EXP does not Granger Cause CO2	0.12	0.88	Uni − Causality

CO2 does not Granger Cause EXP	5.52	0.01	
NRENW does not Granger Cause REN REN does not Granger Cause NRENW	2.17 5.72	0.13 0.00	*Uni − Causality*
EXP does not Granger Cause REN REN does not Granger Cause EXP	0.05 6.52	0.94 0.00	*Uni − Causality*
EXP does not Granger Cause NRENW NRENW does not Granger Cause EXP	0.31 5.43	0.73 0.01	*Uni − Causality*

Source: Author's Compilation, 2024

Conclusion

The findings of this study show causal connections among REN, economic growth, NRENW, CO_2 emanations and EXP in South Africa (SA). For South Africa, the legitimacy of a modified U-molded EKC is upheld. We utilized the VECM and Granger causality test to inspect the connections among RE, CO_2 discharges, send out and NRENW. Results additionally underline that RE, CO_2, NRENW and EXP are crucial in advancing monetary development. Experimental outcomes have made specific commitments to the hypothesis of the effect of sustainable power utilization on other large-scale factors. This review gives proof of the unidirectional causality between CO_2 outflows and Gross domestic product in granger causality test. In South Africa, the long-and economic elements of CO_2 emanations are altogether emphatically affected by GDPC. Accordingly, the South African government ought to zero in on approaches that advance the utilization of clean energy, which is less destructive to the climate, and feasible development, since there are immense expected wellsprings of clean energy in South Africa.

In addition, the significant expense of sustainable power in contrast with non-renewable energy source power is one of the principal impediments as of now present. Accordingly, environmentally friendly power costs in South Africa ought to precisely address their financial benefits. Policymakers in SA ought to painstakingly deal with the product surges which make fabricating tasks to precisely break down the harmony between financial benefit and ecological harm, since the review assessment results likewise exhibit that CO_2 has a causality with economic growth in SA. The public authority needs to order severe guideline with respect to weighty fossil fuel byproduct innovation this would empower the turn of events and execution of more powerful and low-carbon innovation across all enterprises, eventually advancing economic growth in SA. Since the weighty assembling innovation assumes a significant part in CO_2 discharges, policymakers ought to improve the country's RE organization and ecological quality. Notwithstanding other least circumstances, for example, clean water supply, food and security. This study has a few impediments such time span of study was short and the information were yearly. This can be impacted to explore result. Next to the concentrate just looks at GDPC, which is a critical supporter of CO_2. In any case, future examinations ought to extend exploration to different gases, like nitrogen dioxide and methane, and other natural elements, for example, wellbeing effects and waste, with respect to their consequences for economic growth. Besides, information on metropolitan populace and export outflow are by and large total information, so the review doesn't determine which territory or city is the wellspring of expanded ecological contamination, this is likewise an idea for future exploration headings.

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