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Analysis of the Impact of Green Trade on Sustainable Growth in Saudi Arabia

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ABSTRACT

Green economic growth is about getting more economy from our natural asset endowment. And here the environment' economy – for the growth of economy it is beneficial, because does, as it were, stimulate protection/s conservation of the environment and welfare of society from the use these resources, namely the consumption of all resources renewable and nori renewabhi, though sparingly with measure. It also calls for maintenance of the natural wealth needed for the continuing green revolution. green growth concentrates on finding ways to achieving environmental sustainability. If, however, the economy can be developed funding 'freely' without restrictions systematically, it leads to devastation/wealth sustainable economy. The Saudi Vision 2030 highlights the importance of green economic growth by actively fostering natural resources through their protective sustainable usage, disaster and climatic change resilience and mitigation actions. Here, we fill the gaps of natural resources toward green economic growth with emphasis on green trade with Saudi Arabia from 1995 to 2023. This study employs Autoregressive Distributed Lag (ARDL) cointegration approach augmented with Dynamic Autoregressive Distributed Lag (DYNARDL) model. Per the findings from both models, it is evident that green trade, in the long run, has a positive impact on green economic growth. In the short-run, there are signs of a positive impact only from the DYNARDL approach. These outcomes suggest that the appropriate direction should be set toward the increase of green trade to strengthen economic growth and favorable resource utilization in Saudi Arabia.

Keywords: Green Trade, Green Growth, Dynamic ARDL, Saudi Arabai Economy, Simulation
JEL Classifications: C13, C22, E27, O20, O44

1. INTRODUCTION

Green economic growth means establishing an economy that protects natural resources, enhances their long-term capacity, and promotes responsible use. In Saudi Arabia, this approach is essential for the country's economic development without destroying the environment. It focuses on sustainable and efficient using of renewable and non renewable resources in order to provide a clean and healthy environment which benefits the society. In giving importance to preserving resources, green economic growth seeks to ensure sustainable wealth. Absent from any discussion of economic growth is the idea that the economy will stagnate if resources are used in a wasteful manner, and therefore green economic growth is necessary to improve environmental quality and promote development.

In due course, an EMF requires various conservation aids, including a durable green economy (D'Amato, 2015; Hassan, 2024; Brandi et al., 2020) in which Saudi Arabia is heavily investing through Vision 2030 where sustainability, carbon reduction, expansion of renewable energy and environmental monitoring place at the forefront. At the core of this approach are the "Green Saudi Arabia" and "Green Middle East" plans, which will see carbon neutrality achieved by 2060. Latest issues Saudi Arabia widens green trade horizons As part of its strategic objectives, Saudi Arabia has moved towards promoting green trade as a vital contributor to environmental sustainability. Green trade refers to those trade acts that cause no harm to the environment and involve environmentally friendly activities, including clean energy, green products, and sustainable services. Harnessing the potential of green trade will rely on strong involvement of communities, businesses, and government bodies.

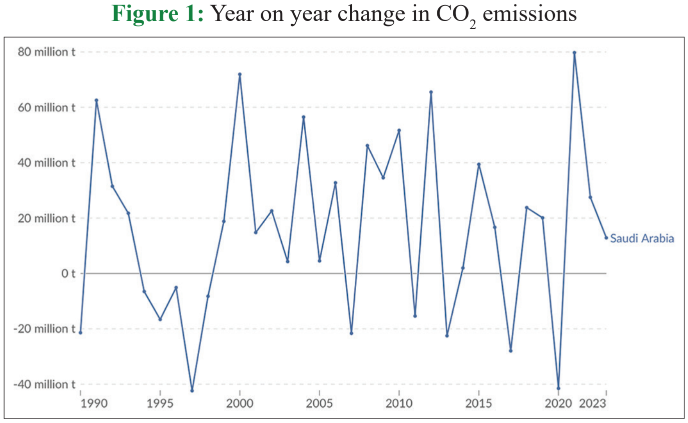
Abroad, institutions such as the World Trade Organization (2023) view green trade as a critical element in promoting economic development without destroying the environment, particularly in the least developed countries. Such projects allows countries to reap the benefits of global trade and support sustainable development.

In Saudi Arabia, the Saudi Green Initiative (SGI) reflects this commitment by inspiring collective action to cut emissions, support clean energy and safeguard precious natural resources. The SGI—by bringing together government, private sector and civil society in a common endeavour—helps to turn sustainability goals into practical measures in support of national and international environmental goals.

As Figure 1 indicates, the carbon dioxide levels of Saudi Arabia has climbed steadily over the last decades with an overall rise since the 1970s based on the fact that there was a fairly strong growth in different period. Emissions between 1990 and 2023 are up 258.2%. Greenhouse gas emissions (excluding land use, land-use change and forestry) increased by 262% from 1990 to 2019, amounting to 774 million tonnes of CO_2 equivalent (Mt CO_2-eq) per year. The increase is mainly driven by the sustained increases in the energy and industrial establishments' emissions since 1990, which must be taken into consideration in shaping environmental policies.

Many works had been published on climate change, impacts, and mitigative options. For instance, Martín-Ortega et al. (2024) underline the crucial function of transparency in efforts to reduce greenhouse gases, and Tsepi et al. (2024) analyse the impact of environmental policies which reduce CO_2 emissions. Furthermore, the works made by Losada-Puente et al. (2023); Chendrawan, (2017) and Yassine et al. (2024) highlight the role that policies and community actions can play in abating emissions supporting the claims made in this paper. In the era of still-evolving problems indicated above, relevant conclusions of this study are of special significance to policy makers, researchers and the industry. For policy makers, the study provides policy guidance on how policies can better address sustainable management of resources, ensure reserves for future generations and reduce environmental degradation.

Figure 1: Year on year change in CO_2 emissions



Source: Our World in Data

This study provides a contribution to academic discussions on the nature of green economic growth and further informing the drivers of green economic growth and future avenues for research, including other ideas to realise the sustainability goals. For the private sector, the research emphasizes the importance of investment in government-led policies as well as galvanizing public involvement in green economy development. Moreover, the study investigates (2) the extent of renewable resources for controlling the CO_2 emissions to the atmosphere in relationship with specificgreen economy growth pattern in the case of the Kingdom of Saudi Arabia.

It is important to have an –a more – sophisticated understanding of green economic growth dynamics." Studying the potential reinforcement relationship among green trade, natural resources and green economic growth is yet very limited both in theory and practice, which motivates us to establish for the 1st time our perspective based on the dynamic ARDL simulation approach in the context of Saudi Arabia. With the Dynamic ARDL, it is possible to simulate how increases in green trade affect the future economic growth, this gives a more accurate assessment of the effects in the short and long runs. Through the inclusion of green trade along with conventional determinants such as oil reserves and gas reserves, the research attempts to provide an extensive understanding of how the duo impact sustainable economic growth.

The results are also relevant for emerging economies which grapple with the difficult task of reconciling economic development and environmental preservation. The methodological process and results provide a useful policy framework and theoretical framework for policy makers and researchers interested in promoting green economic growth in resource-based economies. By examining how economic growth, environmental sustainability and resource management are intertwined, this work may also enrich the international debate on sustainable development and provide guidance for Saudi Arabia in its journey towards climate-related restructuring.

2. LITERATURE REVIEW

Green trade and green growth have gained increasing attention as countries move towards environmentally sustainable development while pursuing economic development (Mahajan et al., 2023; Wei et al., 2023). "Trade" in green trade Trade and Investment Green trade refers to envi- ronmentalfriendly practices that can mitigate ecological harm, which in- clude clean energy and environmentally sound goods, services and technologies. Whereas a green economy is oriented to growing that economy's size in an environmentally sustainable way that also sustains the world's resources. In this paper, we analyze existing literatures on the relationships between green trade and green growth and their impacts on economic development and environmental sustainability.

Green trade is the trade of goods and services that pro-motes environmental sustainability such as renewable power, energy-saving goods, and green technology (Tietenberg & Lewis, 2023 and Wei et al., 2023). In theory green trade is perceived as a means of promoting economic growth while mitigating environmental degradation with a view to encouraging sustainable consumption and production (Porter and Linde, 1995). The EKC hypothesis postulates that although the initial phases of economic development accelerate environmental degradation, a rise in income levels enforces escalating investments for environmental preservation and also enhances the environmental quality facilitating the switch to a green trade and sustainable development (Grossman and Krueger, 1995; Sarkodie and Strezov, 2019).

Empirical research on the impact of green trade on macroeconomic development has presented contradictory evidence. Several studies have found that green trade stimulates economic growth, creating new markets for eco-friendly products and technologies, improving energy efficiency and lower emissions (Pereira and Andraz, 2013). For example, Li et al. (2022) research in South Asian economics appears to confirm that green trade, with green innovation and clean energy, strongly enhances green economic growth by decreasing GHG emissions and stimulating industrial growth. Yet, some other works point to challenges such as high initial expenses and a market barriers, particularly in the developing world, that can constrain the positive implications of green trade (Chan & Sopian, 2022; Mahajan et al., 2021). The results emphasize that supportive policies and international cooperation are essential to resolving these barriers and achieving the full potential of green trade for sustainable economic growth.

Green growth policies aim to harmonise economic benefits with the need to protect the environment, through the use of regulatory mechanisms and financial incentives, and the generation of public awareness, to foster sustainable development (Hussain et al., 2022; Smulders et al., 2014). An example of such an approach is Saudi Arabias Vision 2030, which outlines mechanisms to enhance sustainability and resilience through green growth, with an emphasis on sustainable consumption and production, natural resource conservation, and climate change adaptation. Effective process of green growth policies should be supported by strong institutionalisation, widespread stakeholder involvement and monitoring and evaluation mechanism (Nhamo and Nhamo, 2014).

Green trade and green growth offer tremendous potential for supporting sustainable development, but significant challenges also persist. These include high transition costs, technological inclusiveness and the need for major investments in green infrastructure (Sachs et al., 2019). Another important issue is the lack of unified measurements and indicators to measure the effects of green trade and growth schemes with precision (Li et al., 2022). Government is encouraged by that and is committed to continuing to listen to Canadians and partners to support a safe and healthy environment, while accelerating the pace of transformation (Cheng et al., 2023). Case examples from various regions illustrate the implementation and the impacts of green trade and green growth strategies. One illustration here is the Green Deal of the European Union, which is designed to make Europe the world's first climate-neutral continent by 2050, and to set the pace for climate policies, according to a 'comprehensive policy approach for green trade and green growth' (Ossewaarde and Ossewaarde-Lowtoo, 2020). Under this grand challenges context, many Asian countries have adopted green growth strategies which focus on enhancing energy efficiency, scaling up renewable energy, and developing sustainable cities (Li et al., 2022). These cases demonstrate the different policy mechanisms and conditionality that determines greening trade and growth programmes at the regional level.

Green growth plays much on the efficient use of resources for economic development, yet not all countries consider appropriate to take this as a path to their development efforts. Research by Khan et al. (2023) suggest that there is a negative relationship between natural resource endowment and economic growth been that there is uncontrolled exploitation of the resources leading to environmental damages in G-7 nations. Gu et al. (2023) add that carbon dioxide and economic growth in these countries are positively associated, but this economic expansion is at the cost of the world environmental standard, suggesting an economic growth versus environmental sustainability trade-off.

Wang et al. (2023) observed that there is a negative association between natural resources and green economic growth, and they can be explained by inefficiency with respect to policy management which results in increasing the costs related to the utilization of the resource and the protection of the environment. These results highlight that natural capital dependence may act as a barrier to development and environmental goals in the absence of good governance and sustainable practices, especially where there are limited green growth policy frameworks and infrastructure.

The empirical data constantly tell us that trade in green contributes to boosting economic growth. For example, Ahmed et al. (2022) revealed that green trade can not only promote economic growth but also curb environmental deterioration. Huang and Zhao (2022) also found that the environmental policies of green trade and efficient resource use could greatly improve green growth in China's economy. Within this trajectory of green growth policies, researchers have observed a mix of successes and obstacles due to some economies trying to integrate green growth agenda into their development strategic (Alfantookh et al., 2023;Asha'ari et al., 2016; Kasayanond et al., 2019 and Osman, 2024) with special attention on how green trade has advanced environmental sustainability in Saudi Arabia. However, most of the above studies are unable to directly analyze the impact of green trade on green economic growth, an idea that encompasses not only economic development but also environmental conservation.

Against this background, this article intends to investigate the long-run cointegration relationship and short-run dynamics between green trade and green economic growth in Saudi Arabia from 1995 to 2023. Using the Dynamic ARDL simulation approach, the current study aims to improve the accuracy and depth of understanding regarding how green trade influences green economic growth, and to highlight the significance of balanced and sustainable policy participation.

3. METHODOLOGY

The present research investigates the impact of green economic growth, green trade, and natural resources using two analytical tools: the Autoregressive Distributed Lag (ARDL) Model and Dynamic ARDL Simulation. The ARDL approach is used to examine long-run and short-run relationships between these variables, and the Dynamic ARDL forecasting enables a more accurate analysis of these dependencies. The general purpose of these methods is to detect and to measure the nature of the long-run relationship between natural resources and green economic growth. When we study natural energy resources, oil and gas effect are used as proxies. The two approaches are meant to capture the interconnections between green economic growth, green trading and natural resources. Therefore, based on Xu (2022), the following factors are included in the development of the evaluation and economic model.

$$GrE = f(\text{Oi,Ga,Tr,PG}) \quad (1)$$

Where GrE represents green economic growth, and Oi and Ga are oil and gas reserve respectively, Tr represents green trade and PG for population growth. the econometric model can be expressed as follows.

$$GrE_t = \beta_0 + \beta_1 Oi + \beta_2 Ga + \beta_3 Tr + \beta_4 PG + \mu_t \quad (2)$$

This study empirically employs the Autoregressive Distributed Lag (ARDL) to analyze the inter-relationships of variables. Before undertaking the ARDL methodology, some pre-testing is required to assure dataset appropriateness. The model definition consists of:

$$dGrE_t = \beta_0 + \sum_{i=1}^{a}\beta_1 dGrE_{t-1} + \sum_{i=0}^{b}\beta_2 dOi_{t-1} + \sum_{i=0}^{c}\beta_3 dGa_{t-1} + \sum_{i=0}^{d}\beta_4 dTr_{t-1} + \sum_{i=0}^{e}\beta_5 dPG_{t-1} + \alpha_1 GrE_{t-1} + \alpha_2 Oi_{t-1} + \alpha_3 Ga_{t-1} + \alpha_4 Tr_{t-1} + \alpha_5 PG_{t-1} + \mu_t \quad (3)$$

The ARDL model presented above uses *d* to denote the difference operator, with the optimal lag lengths (*a, b, c, d,* and *e*) selected using the Schwarz Information Criterion (SIC). Short-term coefficients are denoted as β_1 to β_5, while long-term coefficients are represented by α_2 to α_5. The error term is symbolized as μ_t.

In order to perform valid regression analysis, we first verify the stationarity of the time series data using Augmented Dickey-Fuller (ADF) and Phillips-Perron (PP) unit root tests. Such tests check whether variables are stationary, which is indispensable for obtaining reliable results with ARDL modeling. The use of both strategies serves to check for data consistency and reinforces the validity of the results for regression.

Testing for cointegration is vital for ARDL bounds test. The F-bound test assess the long run relationships tendency among variables. The optimal lag length must be estimated prior to which the maximum lag index is determined because the F-bound test is presented. One then tests whether the statistical F-value is greater than critical value I(1) and less than critical value I(0). If the statistical F value is more likely than not the hysteresis critical value, then the null hypothesis is rejected suggesting that there is cointegration.

But there are also some other tests that need to be conducted before we proceed to regrad other parameters in the ARDL analysis. These tests. are proposed to detect multicollinearity, autocorrelation, heteroscedastic, normality test and Ramsey test, CUSUM and CUSUM square test. The durbin-watson test attacks the problem of "auto-correlation" where as the breusch-pagan proper procedure for comparing heteroskedasticity and violation of normalcy. These holes keep the marging boundary where the tests performed are relevant.

Dynamic ARDL simulation, which is proposed as a novel method in this paper, helps discern prospective shocks to the socioeconomic variables and the climate variables. Prediction charts with both optimistic and pessimistic scenarios for several variables are used to demonstrate the simulation procedure. It considers both cointegrating relationships and short-run dynamics of the variables and hence improves the accuracy and the interpretation of ARDL results. Furthermore, the method also deduces trends of important potentials and study their contribution to results. The ARDL Dynamic Simulation model used in this study is based on the procedure of Sarkodie and Owusu (2020), augmented with Addendum: ARDL Dynamic Simulation model used in this study The ARDL Dynamic Simulation model employed in this study is listed below as:

$$dGrE_t = \delta_0 + \emptyset_0 GrE_{t-1} + \varphi_1 Oi_{t-1} + \varphi_2 Ga_{t-1} + \varphi_3 \mathrm{Tr}_{t-1} c\varphi_4 PG_{t-1} + \eta_1 Oi_t + \eta_2 Ga_t + \eta_3 Tr_t + \eta_4 PG_t + \mu_t \quad (4)$$

Where, δ_0 is the value of constant term and $\emptyset_0$ is the value of coefficient for the term of error correction. For the short term coefficient, it will be φ_1 to φ_4. In comparison, for the long term it is η_1 to η_4. In this case, the error term is given as μ_t.

The most efficient application of the Dynamic ARDL (DYNARDL) simulation is to review long run relationships for the two variables in the time period and over the history of the integrated variables. To this end, It examines the rela- tion between the used natural resources and growth of the green economy over an additional Zeitraum. As well, it helps the decision makers prepare the actions that will have impacts beyond 1 year. The first stage in bound test of the DYNARDL simulation is to ascertain whether there is a long-run association among the predetermined variables. In this DYNARDL simulation approach, Shockvar indicates the nature of the hypothetical shocks, while Shockval represents the magnitude of the shock for the target variable. For instance, the use of non-renewable sources of energy increases drastically although these sources of energy are not renewable, while the energy quality deteriorates owing to the output of carbon dioxide. The objective of this research is to estimate the effects of 1-unit GT targeted raise in last year of study (2022) towards green growth projection by year of 2030.

Finally, we also use the Kernel-based Regularized Least Squares (KRLS) method in this work. KRLS helps in cause and effect discovery by taking derivative with negative points (Sarkodie and Owusu, 2020). In this regard, the green trade variable is examined to measure it's impact on the green economic growth in Saudi Arabia. The mechanism to be used in achieving sustainable green economic growth in Saudi Arabia will be to intensify its green trade and take its serious obligation toward limiting carbon dioxide emission, and natural resource put on sustain use. The anticipated negative (−) or positive (+) impact of the variables in the model are: (i) Green Trade is expected to contribute positively to green economic growth. Some green trade types of trade such as trade in solar panels (a renewable resource) can add to national income or GDP growth by reducing carbon dioxide emissions from all sources of energy; (ii) The reserves of oil and gas will pose a negative influence on the green economic growth. Dado que de produce y se consume (utiliza) tales recursos no-renovables más a menudo se esta disminuyendo la calidad del medio ambiente lo que provoca externalidades negativas a terceros; (iii) Population increase is projected to have favourable effects on green economic growth. An enlarged pool of workers within the economy can be used to generate "green" products and services which in turn increase the demand for "green" products, thus economically expanding the green economy. But sustainable economic growth is much more elusive when resource use is highly inefficient. This is based on a green growth and green trade theory with focus on natural resources. It studies how natural resources influence green economy growth in order to facilitate effective green growth and transformation.

The investigation was South-Western Saudi Arabian based and only the data for Saudi Arabia was employed. The data consists of 29-year from 1995 to 2024. This range of dates was selected because of the exponential growth that the Saudi Arabian economy underwent as well as the harm done to the environment, resources, and contamination. Data was obtained from reputable sources including the World Bank, the International Monetary Fund (IMF) and the King Abdullah Petroleum Studies and Research Center (KAPSARC). Used variables are presented in the summary statistics of the Table 1.

Table 1: Variable ınformation and data sources

Variables	Unit	Sources
Green economics (GrE) = GDP−NRD−CO_2 • GDP=Gross domestic product (annual %) • NRD=National resources depletion (% of GNI) • CO_2=Carbon dioxide (% GNI)	% growth	World Bank (2024)
Green trade (Tr)	% growth	International Monetary Fund
Oil reserve (Oi)	% growth	King Abdullah Petroleum Studies and Research Center (KAPSARC)
Gas reserve (Ga)	% growth	King Abdullah Petroleum Studies and Research Center (KAPSARC)
Population growth (PG)	% growth	World Bank (2024)

Table 2: Descriptive statistics

Indicator	GrE	Oi	Ga	Tr	PG
Mean	0.0614	0.1987	0.2662	0.0209	0.0379
Median	0.0734	0.1584	0.0003	0.0098	0.0332
Maximum	0.2047	0.8906	0.7843	0.2593	0.0895
Minimum	−0.4458	−0.3416	−0.3964	−0.2162	−0.0088
Standard deviation	0.1002	0.2006	0.1099	0.0659	0.0338
Skewness	−1.9217	0.9825	2.9747	0.4525	1.9654
Kurtosis	8.2025	6.0792	12.5818	5.0282	7.0413

4. RESULTS

This section deals with the applied findings substantiated by the simulation models (ARDL, DYNARDL) on the green economic growth dynamics of Saudi Arabia during 1995-2023. The models catch the short-run dynamics, as well as the long-run equilibrium relationships among the elements – the Green GDP (GrE) to the Oil and Gas Reserves (Oi and Ga, correspondingly), Green Trade (Tr), and Population Growth (PG). Below is a summary of GT and RO, RG factors by Table 2 for the Mean, Median, Max value of RG and RO and Standard deviation for the study.

It is clear that below blue lines, i.e., green trade activities, represented by Tr, have very huge and stable values, which means there had been large number of green trade activities throughout the whole period of the study. This is confirmed in Table 1 where Tr (303) has the highest mean and median while Oiand Gi have the smallest large difference showing low reinvested growth rate in reserve oil and reserve gas respectively. It is also noted that Tr with the maximum tr vale of 0.2593 depicts the significant trade green peak increase from the time of study till now in the past and since GrE with its minimum value of −0.4458 indicates that a deteriorating green GDP throughput in those years. So it can be concluded that the minimum green GDP represents a reduction of throughput during the period of the study.

All other variables have less data spread in terms of standard deviation so GrE is justifying with its argument that Tr is having higher value. All the other variables, besides GrE showed that right-skewed behavior more distinctly than the other variables. All variables with a kurtosis > 3 (leptokurtic distribution). Leptokurtic distribution would give more of intensive peaks with central value observed crow value so variance would be close to zero bringing all other variable value to closer than estimation. In this case, the method of Tr may be larger than expected. The robustness checks will includee changing the unit root tests for every modification to the data series of Autgd Dickey-Fuller to Phil|ips-Perron, as well as switching from first level to zeroth for all other variables. The ADF test indicates the significance at 1% level of GrE and PG and 5% level of Ga and Tr.

From Table 3, it can be concluded that the variables under consideration are properly selected for ARDL modeling. We must note, however, that if the dependent variable was non-stationary at first difference and the independent variables were also non-stationary at second difference, then ARDL would have been an unfit model for this research. This requirement makes ARDL method applicable for investigating the relationships among the variables. Hence, the data are stationary according to the stationarity test and hence ARDL can be used. We will first test an existence of relationships before the application of (ARDL) analysis using a F-bound test for long run association. Table 4

Table 3: Unit root test results

Variable	Phillips-Perron		Augmented Dickey-Fuller	
	Level	First difference	Level	First difference
GrE	−5.0893***	−17.6746***	−5.3891***	−3.7211**
Tr	−8.7430***	−12.7018***	−6.0953***	−4.6873***
Oi	−6.9445***	−24.2402***	−5.0439***	−8.8736***
Ga	−3.3513***	−15.8092**	−3.5801**	−4.9802***
PG	−5.0094***	−11.5717***	−4.9332***	−7.8841***

*,**,*** denote significant level at 10%, 5%, and 1% respectively

Table 4: Bound test results

F-statistics	Significance level	I (0)	I (1)
7.6266***	10%	2.3	3.26
	5%	2.78	4.01
	1%	3.92	4.97

*,**,*** denote significant level at 10%, 5%, and 1% respectively

presents the F-bound test that comprises both I(0) and I(1) being the lower and upper critical values, respectively. The table provides that the 1 I(1) critical value of stock 4.97 is less than the F-statistic value of 7.6266 that is based on a lag-length of 1% significance level. This indicates that the study's variables are related in the long run indicating that the natural resources and green trade influence the green growth in the case of Saudi Arabi. The results of the ARDL estimations for short-run and long-run relationships are presented in Table 5.

Over the short-term, the problematic lagged differences for gas reserves are seriously negatively and at 10% level the value gas reserves have is a negative effect on the green economy. With respect to the short-run equilibrium, the error correction term shows the expected negative and very significant at 1% sign, signaling a strong recovery tendency to the equilibrium after being hit by a shock. In other words, the variables display mean-reverting behavior after the occurrence of disturbances. The adjustment speed is 87.74%, which indicates very fast. In the long term, green trade has proven to a positive effect on green economic growth, which is consistent with our previous speculation and complementary researches (Xu, 2022). Empirical analysis Diagnostic tests Diagnostic tests confirm the results obtained by the ARDL model. The test for heteroscedasticity by Breusch-Pagan-Godfrey shows no evidence of heteroscedasticity, residuals are non-normally distributed since the Jarque-Bera test fails, there is no evidence of serial correlation as indicated by the Serial Correlation LM Test and the DW test is within the range of no serial correlation. The model robustness was presented in Figure 2 (CUSUM, CUSUM of Squares tests). Bad news is that Ramsey's RESET Test favours an omitted variables/model specification. To have more applicable and accurate results by having an accurate assessment of the short- and long-run relationship of all independent variables with the dependent variable, the DYNARDL simulation is utilized. For this reason, Table 6 also can represent these relationship in more details.

Dynamic ARDL simulation is used to examine short and long run relationships among the variables. As can be seen from the table, the variable of green trade (Tr) is significant in the short

Table 5: ARDL estimation results

Variable	Coefficients	Standard error
Short run		
	−0.5583*	0.3405
	−0.8774***	0.2367
Long run		
	0.3433**	0.0864
	0.2956	0.2250
	0.2488	0.4864
	0.9412	0.7378
	−0.0252	0.0386
Diagnostic results		
Breusch-Pagan-Godfrey	0.8145	
Jarque-Bera	14.2596	
Serial correlation LM test	0.6233	
	25.6503***	
CUSUM	Stable	
CUMUM square	Stable	

*,**,*** denote significant level at 10%, 5%, and 1% respectively

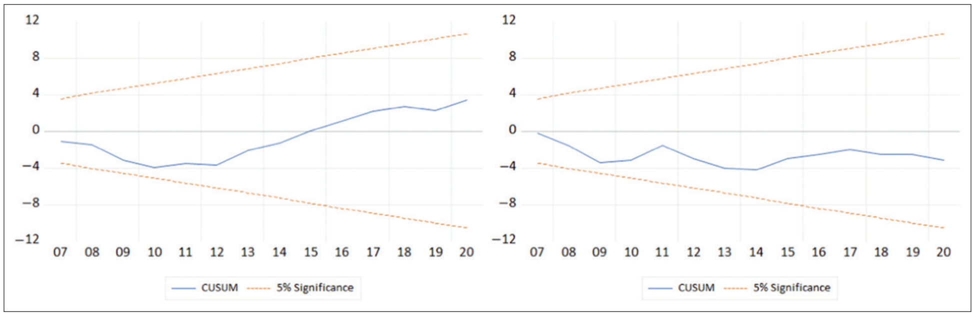
Table 6: Dynamic ARDL estimation results

Variable	Coefficients	Standard error
Short run		
	0.2961**	0.0465
	0.2754***	0.2111
	−0.5718	0.4187
	0.8535	0.6629
	−0.9041	0.3287
Long run		
	0.2773**	0.1163
	0.1758	0.1053
	0.1614	0.4157
	0.5463	1.0308
	0.3258	0.0386
Constant	−0.0301	0.0408
Prob>F	0.0019***	
	0.6941	
	0.0938	

*,**,*** denote significant level at 10%, 5%, and 1% respectively

and long terms. More clearly, in the short term, 1% growth in green trade implies 0.2961% growth in green economic growth (GrE). This positive correlation is exaggerated even further in the long run as a 1% increase in green trade raises a 0.2773% change in the green economy sector. These findings support the increasing global practices to embed sustainability in trade and the argument that the more engaged in green trade, the more sustainably growing the economy will be. On the other hand, for the other variables, in either the short or the long run, no major associations were found. This indicates that, in the scope of the present study, green trade stands out as the most influential promoter of green economic growth and other determinants are found not to statistically influence GrE over the period under review. This finding also suggests that green trade may act as a driving force behind sustainable economic development, which may be the prime concern for the policy makers who are committed to promoting green economic development. Strong overall significance is confirmed by the model diagnostics with Prob > F = 0.0019 (significant at 1% level), R^2 = 0.6941 (indicating that the model explains around 69.41 % of variation in GrE) and a Root Mean Square Error (RMSE) = 0.0938, which estimates the average magnitude of error.

Figure 2: Cumulative sum (CUSUM) and cumulative sum of squares (CUSUMQ)



Before the diagram in the right, a positive shock to green trade is a good thing, which means the green trade has positive effect on the sustainable growth of the green economy of Saudi Arabia. This beneficial effect may be correlated with the assumption that over the long term the green trade could possibly reduce the growth of the green economy. This finding is consistent with the anticipations of the dynamic simulation from the ARDL model, given that the coefficient on green trade is negative (−0.3773). Validation of this conclusion is confirmed by prior studies, which have demonstrated that a green trade can help to significantly promote green economic growth and effectively results in environmental sustainability (Xu, 2022). An appropriate strategic focus on green trade can provide a very strong stimulus to promoting green economic growth. This highlights the importance of acting to prioritise green trade in the context of economic policy, so that such initiatives are better integrated with wider environmental and economic objectives – and perform their function of being on balance good for the economy.

The Table 7 results represent average marginal effects of the variables of interest where GrE, Oi, Ga and PG takes the values of 0.2018, −0.0274, 0.0327 and 0.6282, respectively. Like the linear regression coefficients, these values reflect the average effect in the dataset. Heterogeneity occurs across the distribution of effects by percentiles (P25, P50, P75).

This positive relationship between green trade and green economic growth shows that green trade is a potential pathway to sustainable economic development. However, since the data indicates considerable variation, the influence of green trade and related resources can vary immensely in different scenarios. Therefore, it is essential for policymakers to design green trade policies that are likely to maximize the benefits while cushioning themselves against the potential adverse impacts. This kind of design will entail a fine balance among green trade initiatives and broader environmental and economic objectives to promote sustainable green economies in the actual sense. As shown in Table 7 below, the average pointwise marginal effects for GrE, Oi, Ga, and PG are 0.20, −0.03, 0.03 and 0.62, respectively. The average pointwise marginal effect plays a role similar to the expected coefficient in linear regression in the sense that it represents the average of the marginal effects. Variability in relation to these figures can be determined from the 25th, 50th and 75th percentiles. Moreover, the histogram of the pointwise marginal effects above, as shown in Figure 3 below, offers a quick and straightforward graphical interpretation of these heterogeneities. The graph, in

Figure 3: Pointwise differentiation in green trade

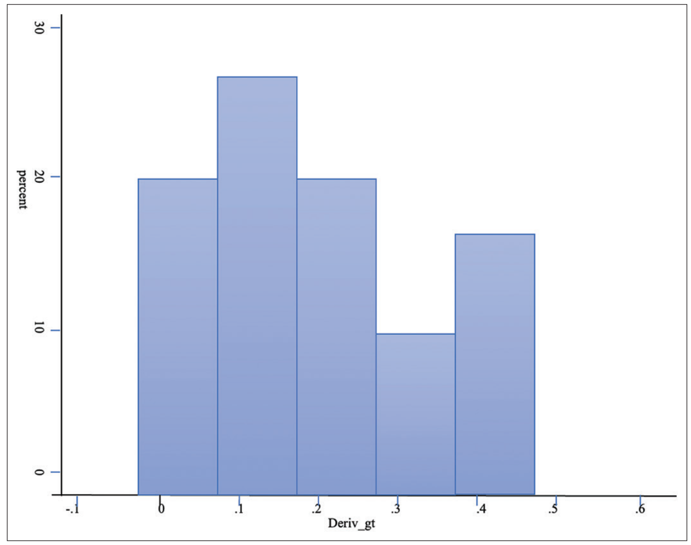


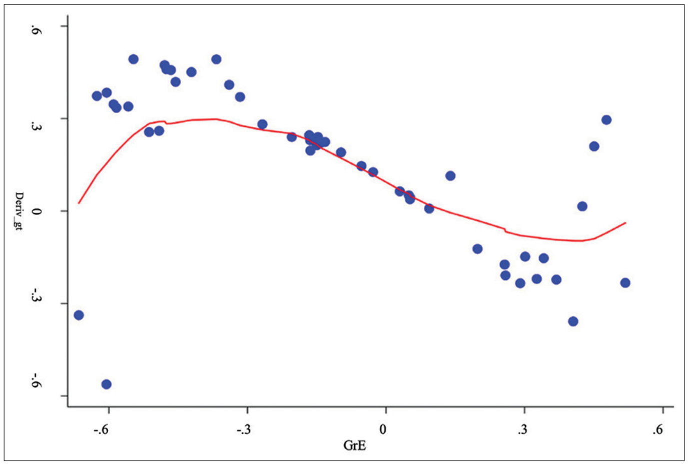
Table 7: Pointwise derivatives from KRLS

GrE	Avg.	SE	P25	P50	P75
Tr	0.2018***	0.0542	0.0935	0.0873	0.1702
Oi	−0.0274	0.0564	−0.0346	−0.0354	−0.0024
Ga	0.0327	0.0407	−0.0886	0.0653	0.1737
PG	0.6282*	0.4352	0.3471	0.8003	1.2677
Diagnostic					
Lambda	1.854	Sigma	3.9562		0.6734
Tolerance	0.052	Eff.Df	6.0221	Looloss	2.855

Figure 3 below displays the distribution of the derivatives for green trade, reflecting the extent to which green trade exerts a marginal effect on green economic growth. The distribution is predominantly positive, with most of the values being between 0 and 0.4, emphasizing that green trade generally exerts positive pressure on the GDP. The distribution also suggests that there is no heterogeneity problem in the marginal effects presented, enhancing the reliability and validity of the data used for this study.

Figure 4 displays the pointwise marginal effects which highlight the long-run behavior of the green trade variable and its impact on green economic growth. We see then from the figure that the effect of the green trade enters differently in the various levels of Gre. The marginal impact of green trade is also relatively positive at low GrE levels, suggesting the promotion of economic growth in the early stages by green trade. However, as GrE increases, the marginal effect gradually decreases, and even becomes negative

Figure 4: The contribution of green trade to advancing the green economy



at higher GrE levels. It is also a reflection of the fact that in the initial period economic growth is facilitated through green trade, but when the economy gets developed, the benefit of green trade begins to diminish and, in the more developed economic structure, it may place a little negative impact. The gains of green trade are not evenly distributed, they depend on the level of economic development, which means a subtle policy should be adopted to foster green trade in order to achieve sustainable economic development.

5. CONCLUSION AND POLICY IMPLICATIONS

The present study investigates the natural resource consumption impact on green economic development in Saudi Arabia through the period of 29 years from 1995 to 2023, which incorporates green economic growth, green trade, oil and gas reserves, and demographics. Most of the analysis is carried out through ARDL and new DYNARDL models. It has been proved that green trade is highly conducive to the green economic growth, particularly in the long-run ARDL models. DYNARDL also supports the persistence of such an effect in the short and in the long run. These observations are in agreement with Ahmed et al. (2022) findings about the effect of trade on green economic transition in the countries of the Gulf Cooperation Council. One of the main challenges in conducting this study was the unavailability of reliable and complete data about the green economic growth construct. It needed a very large number of data set combinations, which made the research very challenging. The short length of the trial added to these difficulties. We hope that future studies will overcome these confounders through better data availability and increased study duration, leading to increased accuracy and relevance of future research. In addition, so as to explore the beneficial effect of green trade on the green economic growth, there is reason to believe that green trade may have relatively higher green economic growth, which might provide some implications to the government to find suitable strategies to achieve sustainable and better environmental. By tackling these restrictions and highlighting the positive aspects of green trade, future studies can provide insightful results that can help in the sustainable development and environmental improvement.

The results of this study have some implications as a guide for the policy makers in Saudi Arab and other countries which aim to harmonize economic growth with sustainable environmental behaviour. It needed to be embedded in national economic strategies by policy makers, and is critical for sustainable economic growth. The green technology and sustainable practice is more than offset by positive environmental gain – more competitive manufacturing – innovation, efficiencies– simply because it led and put resources into them." transitioning industry Nothing will drive innovation and efficiencies like governments investing large on technology and sustainable practices that make manufacturing more competitive globally. The advantages of trade in the green can scale up when companies get paid (fiscally) for the implementation of such practices and laws that reward them for implementation speed up the shift to sustainability on the economic level since eco-friendly operations can be economic.

Establishing a lasting policy framework for renewable and non-renewable resource management is needed. Policy makers must reach the goal of economic prosperity with the minimum environmental damage by means of resource utilization and conservation activities. Green trading strategies should be considered and developed for long-term prospects and in line with broader economic and environmental targets for them to prevent success derailing sustainable outcomes. Enhancing green trade benefits in the public understanding while educating enterprises and consumers in the sustainable means will cultivate an environmental sustainability ambience. And policy makers must support initiatives that promote well-informed choices and sustainable consumerism. When it implements these policies with a measure of environmental responsibility as well as economic development, Saudi Arabia will be on course to sustainable economic growth through green trade.

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