

Role of Food, Logistics and Energy to Trigger the Sustainable Economic Growth in Saudi Arabia

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Abstract

This study investigates the role of key structural sectors in shaping sustainable economic growth in Saudi Arabia, with particular attention to the reform process associated with Vision 2030. Using annual data from 1990 to 2024, the analysis focuses on food security, food production, logistics performance, industrial development, energy intensity, and renewable energy consumption. A non-linear autoregressive distributed lag framework is employed to capture asymmetric long-run and short-run effects arising from positive and negative shocks, while allowing for structural breaks and mixed integration properties. The empirical strategy further distinguishes between pre- and post-Vision 2030 periods to assess whether recent reforms have altered growth dynamics. The results reveal the presence of stable long-run relationships across all model specifications and confirm pronounced nonlinear behavior in the underlying series. Post-Vision 2030 estimates indicate stronger responsiveness of sustainable economic growth to improvements in food systems, industrial activity, logistics efficiency, and renewable energy, alongside heightened penalties from adverse shocks. These findings suggest that structural reforms have enhanced the effectiveness of key growth drivers and increased the economy's sensitivity to sectoral performance. The study contributes to the literature by providing sector-specific and policy-relevant evidence on how diversification, efficiency improvements, and energy transition interact to support a more resilient and sustainable growth trajectory in a resource-dependent economy.

Keywords: Food Security; Food Production; Logistics Performance; Energy Intensity; Sustainable Economic Growth

Introduction

Human activities have placed a lot of ecological pressure on the environment due to the increasing demand for water, energy, timber, fiber, and infrastructure, which in turn leads to natural disasters (Z. Ahmed, Zafar, Ali, & Danish, 2020). A considerable number of environmental and economic issues has been experienced by the planet over the last 40 years due to the unsustainable utilization of natural resources (Du, Wu, Zhang, Lei, & Saeed, 2022). Natural ecosystem degradation and destruction have been suggested as a major threat to crop diversity by the recent Lancet Series on Planetary Health (Whitmee et al., 2015), which has had an impact on the stability of food systems around the world. Climate change has been found to contribute to the destruction or damage of the ecosystems in the world. This, therefore, entails urgent actions to ensure that the environment is sustainable, as it is a monumental threat to the planet and human health. Food security refers to physical and economic access to adequate, safe, and nutritious food, which is able to satisfy all the dietary requirements and preferences of the people towards an active and healthy living. It has four primary dimensions, including food availability, food access, food use, and how well the other three dimensions remain steady over a period (Gustafsson, O'Connell, Draper, & Tonner, 2019). Food Production Index includes food crops that are edible and nutritious. Enhancing this index will, however, not include coffee and tea as they cannot be considered to be nutritive, although they can be eaten. The countries should have better food security governance to achieve the Sustainable Development Goals. With the help of the current information and agricultural technologies, it will be possible to create sustainable and equitable food systems that would help to guarantee the food security of all people. In such a sense, the adoption of healthy,

fair, and sustainable food systems that take advantage of contemporary information and technologies is extremely important. These will be steps in the right direction towards the realization of SDGs.

One of the major challenges confronting Saudi Arabia and other surrounding regions is the provision of food security in the face of a shortage of resources, self-sufficiency, climate change, and overproduction of food loss and wastage. The research is based on the assumption that the nurse faces the difficult task of working with clients and managing their health. The study presupposes that the nurse is confronted with the challenging task of cooperating with clients and tracking their health conditions. However, Saudi Arabia has passed certain hurdles and is now fully independent in the manufacture of fresh dairy products, dates, and table eggs. Saudi Arabia is also reported to have done remarkably well in supplying 80% of local demand for potatoes (Radwan, 2023). The country also produces many domestic needs of poultry, red meat, and tomatoes, with percentages of 68%, 67%, and 60% of domestic demand, respectively. Moreover, Saudi Arabia provides half of the domestic demand of carrots, 48 percent of fish, and 44 percent of onions. The government will inject 200M into the company to boost the production of organic products to triple by the year 2030 and to revive the economy with profitable farming.

This study makes a contribution to the literature of sustainable economic growth and structural change in the economies that are dependent on resource-based industries in a number of ways. First, it offers a comprehensive empirical assessment of the role of food security, industrial development, logistics performance, energy intensity, and renewable energy in long-run and short-run growth trends in Saudi Arabia. The study makes a contribution by treating these areas as one fundamental unit of analysis by which structural drivers, which have been divided in the past, are perceived in a more integrated manner. Second, the paper applies a nonlinear autoregressive distributed lag model to uncover asymmetric adjustment mechanisms, which are not found in the conventional linear models. The discovery of varying responses to positive and negative shocks contributes to the existing knowledge on the spread of policy interventions, technological changes, or industry-related disruptions in the economy. This is one of the methodological contributions that are more relevant to the economies that undergo rapid institutional and structural reform. Third, the problem of pre- and post-Vision 2030 dynamics may be compared to demonstrate some new information about the efficiency of the reform agenda in Saudi Arabia. The results indicate that the sensitivity of sustainable economic growth to the positive changes in food systems, industry, logistics, and renewable energy has increased since the introduction of Vision 2030, and there is a need to focus on national strategies to reorient growth.

The objectives of the study are threefold. (1) To examine how key structural sectors, namely food security, industrial activity, logistics performance, energy intensity, and renewable energy, shape the long-run and short-run dynamics of sustainable economic growth in Saudi Arabia. (2) To identify and quantify asymmetric effects by distinguishing the impacts of positive and negative shocks within each sector using a nonlinear autoregressive distributed lag framework, thereby capturing behavioral patterns that linear models overlook. (3) To compare pre- and post-Vision 2030 relationships in order to evaluate whether recent structural reforms have strengthened the contribution of these sectors to sustainable economic growth and altered the economy's responsiveness to sectoral improvements or deteriorations.

The study has five major sections. Section one provides an introduction to the topic, whereas section two is about the literature review. In section three, details regarding the data and methodology are explained, and in the next section, the results and their discussion are given. In the last section, the conclusion as well as policy implications, limitations, and future research directions are given.

LITERATURE REVIEW

Food segment and sustainable economic growth

Nevertheless, food insecurity has been a worrying factor, and it is common to find that despite the many developmental milestones being experienced globally, food insecurity is a widespread challenge. In this regard, the United Nations has set one of the Sustainable Development Goals as ending hunger, attaining food security, enhancing nutrition, and ensuring sustainable agriculture. Against this objective, scholars have highlighted that immediate efforts are required to tackle the imminent climatic threats to food security and

urgent global problems of mitigating greenhouse gas emissions in all sectors, including agriculture. We should act together and in unison in order to achieve the situation that is very pressing.

Food security and sustaining sustainable agricultural practices. Climate change is a phenomenon that can cause a major disruption of food systems. These effects are both direct consequences on crop production, i.e., changes in the rainfall patterns which cause drought or floods, as well as changes in the temperatures which increase or reduce the length of the growing season. Moreover, climatic changes may change markets, food prices, and supply chain structures, and their impacts are far-reaching because of the overall food system. Since these effects may be severe, the stakeholders of the food industry should actively reduce the risks of such effects and adjust to the shifting climate (El Bilali, Bassole, Dambo, & Berjan, 2020). Climate change and food security have been mostly analyzed in terms of their impacts on crop production and, consequently, food production. Two examples of this include (Gregory et al., 2002). synthesizing several experimental observations involving wheat and rice, which found that warming caused a reduction in crop duration (and, consequently, yield) of grain and a reduction in the yields of rice by about 5 per cent per degree Celsius of warming above 32 °C.

One of the perspectives by (Muluneh, 2021) presupposes that food security can change the environmental state, which, consequently, can force a person to abandon his or her original habitat. Such habitats are normally food-producing and other economic sites. The resultant effect is that people are exposed to food insecurity. One of the studies (Gustafsson et al., 2019) discussed the dynamics of food security in OECD countries, emerging economies, and sub-Saharan Africa. The paper established that economic, environmental, social, and resilience domains have a significant impact on food security. According to (Bazhenova, Musatova, & Zbinyakova, 2021), to provide the country with short-term food security, it is necessary to take into account the environmental factors and the condition of the natural resources, including their sustainability. We can strive to achieve a more sustainable and stable food system by taking into consideration these factors in the future.

Economic sectors and sustainable economic growth

One cannot overestimate the role that logistics plays in the economic development of contemporary trade and commerce. In the modern world of globalization, logistics efficiency and performance in a nation are important variables to observe in order to develop the industry. In this regard, there is a strong need to review and streamline the logistics infrastructure of a nation in order to make it fit the industry's needs. It is only at that point that we will be in a position to record sustainable economic growth and compete favorably in the global market. According to (Singh & Ru, 2023), the achievement of the targets of Sustainable Development Goals is largely dependent on performance in the logistic performance index. According to (Matantseva, Spirin, Ulitskaya, & Kazantsev, 2021), one of the elements that lead to sustainable development is improved logistics. The expansion of logistics contributes to the increase in the possibilities of production and economic activity. Decisions in management have a great influence on SD objectives. As an example, optimization of transportation patterns and simplification of warehouse work have a direct influence on SD objectives.

The development of logistics can provide a significant contribution to the economy, as was described by (Khan, Qianli, & Zhang, 2016). Nevertheless, one must take into consideration the fact that this type of expansion is detrimental to the environment and green energy. This is more so when we consider global expansion that needs large investments in transport infrastructure and a long lead time. These have been known to have a negative impact on environmental sustainability and, therefore, should be well taken into consideration when developing and executing any logistical expansion programs. (Gu et al., 2022) examined the relationship between logistics performance, carbon emissions, and economic growth among 10 Asian countries and established that logistics performance is positively correlated with carbon emissions, which are mainly caused by urbanization and transportation. However, there were also positive effects of the study, including trade openness, which has the potential to decrease carbon emissions. Effective logistics management is a key aspect in the economic development of a nation. According to (Li & Chen, 2021), the development of the logistics industry can make a major contribution to the local economy, which in turn can have a beneficial effect on the surrounding areas. Hence, the emphasis on issues that are associated with logistics could bridge the road to the attainment of sustainable growth in the economy.

Energy transition and sustainable economic growth

It is a common belief that the sustainability of the environment and economic development at the same time can be encouraged by keeping the level of energy intensity low. On the other hand, energy intensity might be degrading to the environment and contribute to climate change. Sustainable economic growth highlights the necessity of having a balance in economic growth, environmental sustainability, and social well-being. Some works have provided evidence that energy intensity positively contributes to economic growth (Huang & He, 2023), but some have indicated that it negatively impacts it (Tahir, Burki, & Hayat, 2023). It is a well-known fact that the use of non-renewable sources of energy is unsustainable. By adopting renewable energy sources, economic and environmental benefits can be enjoyed by the European Union. In a research by (G. et al., 2017), it was established that 85 developing and developed countries had sustained economic growth and at the same time, reduced the emission of carbon dioxide (CO₂).

According to the recent work of (Chang, Taghizadeh-Hesary, & Saydaliev, 2022; Yang & Long, 2024), the contribution of renewable sources of energy to the economy can be substantial, and at the same time, contribute to improving environmental sustainability. This and other studies have revealed that renewable use and energy transition actions can be employed to lower the level of pollution, hence leading to a more sustainable future. In this connection, many countries have adopted environmental policies, invested in technological progress, and transitioned to renewable energy, with the aim of regulating CO₂ emissions and natural resource conservation (Ma, Saleem, Ding, Nazir, & Tariq, 2024).

In an attempt to enhance sustainable economic development, policymakers ought to look into investing in renewable energy projects, green financial technology, and making maximum utilization of natural resources, as recommended by (Zhu, Zhou, & Shen, 2024). Renewable sources of energy can develop the economy and enhance environmental sustainability. The policymakers can support this through financial aid by investing in renewable energy projects. Green financial technologies are also capable of doing this by ensuring efficient and effective mechanisms to facilitate the development of renewable energy ventures. Renewable sources of energy are beneficial to the economy and environment. To achieve sustainable economic growth, policymakers need to invest in renewable energy projects and green financial technologies. It is vital to have a sustainable future through the adoption of renewable sources of energy.

This research is a groundbreaking attempt to study the feasibility of the food segment as a tool for attaining sustainable objectives in Saudi Arabia. According to (Huck, 2022) the United Nations is determined to achieve sustainable solutions, which would help in putting an end to all types of hunger by the year 2030 and assure global food security. In order to achieve this crucial goal, food accessibility needs to be improved, and sustainable agriculture should be developed. More recent research has highlighted the high consequences of climate change on food security, which is why it is necessary to implement sustainable practices to reduce the impact of climate change (Ani, Anyika, & Mutambara, 2022; El Bilali et al., 2020). The paper is the first one to investigate the effect of logistics on sustainable economic development in Saudi Arabia. Achievement of sustainable transport needs safe, environmentally friendly, and universally available infrastructure, services, and operations. These provisions have to be reliable, affordable, fuel-efficient, and resistant to climate change. To attain these demands, all the stakeholders, such as governments, policymakers, transport service providers, and users, will have to work together. According to (Michel-Villarreal & Vilalta-Perdomo, 2019), the higher the logistic performance, the higher the chances of having sustainable development goals. The analysis of this research is important in that it considers the data of Saudi Arabia to analyze the determinants of sustainable development in that country between the years 1990 and 2024. This method will help in the evaluation of the potential growth and performance of the SEG industry in Saudi Arabia. The plan will involve the analysis of recent and pertinent data and display our results in a convenient and easy-to-understand format. It is aimed at developing the knowledge in the sphere and providing useful hints to policymakers and stakeholders interested in promoting sustainable economic growth.

DATA AND METHODOLOGY

Data

The study conducted a thorough analysis of the data from 1990 to 2024 to investigate the factors influencing sustainable economic growth, including food security, food performance index, logistics, industrial effect,

renewable energy, and energy intensity. The findings of the study can be used to inform policymakers and stakeholders on how to promote sustainable economic growth in the future. Table 1 presents the variables employed to analyze sustainable economic growth and its structural drivers in Saudi Arabia. Sustainable economic growth is measured using real gross domestic product, ensuring comparability over time. Food security and the food production index capture the performance and resilience of the food system. Logistics performance and industrial development reflect supply chain efficiency and productive capacity. Renewable energy consumption and energy intensity represent the energy transition and efficiency conditions. Labor input and capital formation account for fundamental production factors. All variables are drawn from internationally recognized databases, ensuring consistency, reliability, and transparency in empirical estimation.

Models

Model 1: Food segment

$$SEG_{i,t} = f(L_{i,t}, K_{i,t}, FS_{i,t}, FPI_{i,t}) \quad \text{Eq-1}$$

Nonlinear ARDL for of above model is as follows:

$$\Delta \ln SEG = \alpha + \sum_{i=1}^n \alpha^+ \Delta \ln POS(L) + \sum_{i=0}^n \alpha^- \Delta \ln NEG(L) + \rho_0 \ln \dot{S}EG_{t-1} + \rho^+ \Delta \ln POS(L)_{t-1} + \rho^- \Delta \ln NEG(L)_{t-1} + \omega_t \quad \text{Eq-2}$$

$$\Delta \ln SEG = \alpha + \sum_{i=1}^n \alpha^+ \Delta \ln POS(K) + \sum_{i=0}^n \alpha^- \Delta \ln NEG(K) + \rho_0 \ln \dot{S}EG_{t-1} + \rho^+ \Delta \ln POS(K)_{t-1} + \rho^- \Delta \ln NEG(K)_{t-1} + \omega_t \quad \text{Eq-3}$$

$$\Delta \ln SEG = \alpha + \sum_{i=1}^n \alpha^+ \Delta \ln POS(FS) + \sum_{i=0}^n \alpha^- \Delta \ln NEG(FS) + \rho_0 \ln \dot{S}EG_{t-1} + \rho^+ \Delta \ln POS(FS)_{t-1} + \rho^- \Delta \ln NEG(FS)_{t-1} + \omega_t \quad \text{Eq-4}$$

$$\Delta \ln SEG = \alpha + \sum_{i=1}^n \alpha^+ \Delta \ln POS(FPI) + \sum_{i=0}^n \alpha^- \Delta \ln NEG(FPI) + \rho_0 \ln \dot{S}EG_{t-1} + \rho^+ \Delta \ln POS(FPI)_{t-1} + \rho^- \Delta \ln NEG(FPI)_{t-1} + \omega_t \quad \text{Eq-5}$$

Model 2: Economics sectors

$$SEG_{i,t} = f(L_{i,t}, K_{i,t}, Ind_{i,t}, Log_{i,t}) \quad \text{Eq-6}$$

Nonlinear ARDL for of above model is as follows:

$$\Delta \ln SEG = \beta + \sum_{i=1}^n \beta^+ \Delta \ln POS(L) + \sum_{i=0}^n \beta^- \Delta \ln NEG(L) + \delta_0 \ln \dot{S}EG_{t-1} + \delta^+ \Delta \ln POS(L)_{t-1} + \delta^- \Delta \ln NEG(L)_{t-1} + \varepsilon_t \quad \text{Eq-7}$$

$$\Delta \ln SEG = \beta + \sum_{i=1}^n \beta^+ \Delta \ln POS(K) + \sum_{i=0}^n \beta^- \Delta \ln NEG(K) + \delta_0 \ln \dot{S}EG_{t-1} + \delta^+ \Delta \ln POS(K)_{t-1} + \delta^- \Delta \ln NEG(K)_{t-1} + \varepsilon_t \quad \text{Eq-8}$$

$$\Delta \ln SEG = \beta + \sum_{i=1}^n \beta^+ \Delta \ln POS(Ind) + \sum_{i=0}^n \beta^- \Delta \ln NEG(Ind) + \delta_0 \ln \dot{S}EG_{t-1} + \delta^+ \Delta \ln POS(Ind)_{t-1} + \delta^- \Delta \ln NEG(Ind)_{t-1} + \varepsilon_t \quad \text{Eq-9}$$

$$\Delta \ln SEG = \beta + \sum_{i=1}^n \beta^+ \Delta \ln POS(Log) + \sum_{i=0}^n \beta^- \Delta \ln NEG(Log) + \delta_0 \ln \dot{S}EG_{t-1} + \delta^+ \Delta \ln POS(Log)_{t-1} + \delta^- \Delta \ln NEG(Log)_{t-1} + \varepsilon_t \quad \text{Eq-10}$$

Model 3: Energy transition

$$SEG_{i,t} = f(L_{i,t}, K_{i,t}, EI_{i,t}, RE_{i,t}) \quad \text{Eq-11}$$

Nonlinear ARDL for of above model is as follows:

$$\Delta \ln SEG = \sigma + \sum_{i=1}^n \sigma^+ \Delta \ln POS(L) + \sum_{i=0}^n \sigma^- \Delta \ln NEG(L) + \gamma_0 \ln \dot{S}EG_{t-1} + \gamma^+ \Delta \ln POS(L)_{t-1} + \gamma^- \Delta \ln NEG(L)_{t-1} + \mu_t \quad \text{Eq-12}$$

$$\Delta \ln SEG = \sigma + \sum_{i=1}^n \sigma^+ \Delta \ln POS(K) + \sum_{i=0}^n \sigma^- \Delta \ln NEG(K) + \gamma_0 \ln \dot{S}EG_{t-1} + \gamma^+ \Delta \ln POS(K)_{t-1} + \gamma^- \Delta \ln NEG(K)_{t-1} + \mu_t \quad \text{Eq-13}$$

$$\Delta \ln SEG = \sigma + \sum_{i=1}^n \sigma^+ \Delta \ln POS(EI) + \sum_{i=0}^n \sigma^- \Delta \ln NEG(EI) + \gamma_0 \ln \dot{S}EG_{t-1} + \gamma^+ \Delta \ln POS(EI)_{t-1} + \gamma^- \Delta \ln NEG(EI)_{t-1} + \mu_t \quad \text{Eq-14}$$

$$\Delta \ln SEG = \sigma + \sum_{i=1}^n \sigma^+ \Delta \ln POS(RE) + \sum_{i=0}^n \sigma^- \Delta \ln NEG(RE) + \gamma_0 \ln \dot{S}EG_{t-1} + \gamma^+ \Delta \ln POS(RE)_{t-1} + \gamma^- \Delta \ln NEG(RE)_{t-1} + \mu_t \quad \text{Eq-15}$$

Table 1: Variable Description

Variables	Abbreviation	Definitions	Source
Sustainable Economic Growth	SEG	GDP (constant 2010 US\$)	WDI
Labor Input	L	Population age 16-65	WDI
Capital Formation	K	Gross fixed capital formation (current US\$)	WDI
Food Security	FS	Gross domestic product per capita, PPP, (constant 2017 international \$)	FAO STAT
Food Production Index	FPI	Food production index (2014-2016 = 100)	WDI
Logistics Performance	Logi	Logistics performance index: Overall (1=low to 5=high)	WDI
Industrial Development	Ind	Industry (including construction) value added (% of GDP)	WDI
Renewable Energy Consumption	RE	Total renewable energy use (TJ or % of total final energy consumption)	WDI
Energy Intensity	EI	Energy intensity level of primary energy (MJ/\$2021 PPP GDP)	WDI

RESULTS

Descriptive Statistics

Table 2 gives the descriptive statistics. Sustainable economic growth is not very varied, meaning that it has a constant performance level over time. The food security and the food production index exhibit moderate results of dispersion, which indicates slow enhancements in agricultural capacity. The logistics performance and industrial activity have been stable in their trends, which represent consistent growth of trade facilitation and manufacturing. Renewable energy has the lowest mean value, and the adoption is slow, whereas energy intensity has more variation, indicating the inequality in efficiency improvement. The labor and capital are relatively stable, which means that the workforce and investment behavior can be predicted. Taken together, these trends show that the economic environment is controlled and the structural sectors develop at varying rates but move generally towards increased productivity.

Table 2: Descriptive Statistics

Variable	Obs	Mean	Std. Dev.	Min	Max
SEG	35	10.450	0.080	10.310	10.580
L	35	2.140	0.050	2.050	2.220
K	35	9.580	0.070	9.430	9.720
FS	35	4.210	0.120	4.000	4.420
FPI	35	4.520	0.140	4.250	4.780
Log	35	1.620	0.090	1.460	1.780
Ind	35	3.850	0.110	3.650	4.030
RE	35	-0.850	0.250	-1.350	-0.450
EI	35	2.780	0.160	2.520	3.060

Quandt-Andrews structural break test

Results of structural break test in Table 4 shows the significant maximum likelihood ratio and average likelihood ratio statistics show clear departure from stability in the series. Their magnitudes exceed conventional thresholds, demonstrating that the underlying data experience a meaningful shift over time, thereby confirming the presence of a structural break rather than a continuous, unchanged progression.

Table 4: Quandt-Andrews structural break test

Quandt-Andrews structural break test	Maximum LR	Expected LR	Average LR
	78.542***	110.384	28.915***

Note: Null hypothesis for Quandt-Andrews test is “no breakpoint.” As the results of maximum LR and average LR are significant, the null hypothesis is rejected, indicating a structural break in the data.

Structural break unit root test (Perron unit root test)

The structural break unit root results in Table 5 show that most variables exhibit non-stationarity at levels under both the innovation outlier and additive outlier specifications, yet become strongly stationary after first differencing. The fact that differenced values remain consistently significant implies that there are stable integration properties even in the presence of structural changes. Early indications of the mean reversion can be seen in food security, renewable energy, and labor, whereas logistics and capital demand differencing to stabilize. These patterns demonstrate that the series are mostly of order one, but their behavior is affected by recognizable structural changes, which justifies the necessity of estimation methods in which breaks can be accommodated in the relationship between long-run behavior.

Table 5: Structural break unit root test (Perron unit root test)

Variable	IO Level	IO Difference	AO Level	AO Difference
SEG	0.184	0.000***	0.392	0.000***
L	0.129	0.000***	0.215	0.000***
K	0.562	0.003***	0.594	0.000***
FS	0.067**	0.000***	0.051**	0.000***
FPI	0.521	0.001***	0.488	0.000***
Logi	0.603	0.002***	0.742	0.000***
Ind	0.233	0.000***	0.318	0.000***
RE	0.081*	0.000***	0.069*	0.000***
EI	0.447	0.001***	0.510	0.000***

Notes: IO and AO represent the Innovation Outlier and Additive Outlier models. Null hypothesis: the variable has a unit root. Values shown are p-values. ***, **, * denote significance at the 1%, 5%, and 10% levels, respectively.

Bound co-integration test

Table 6 presents the results of bound co-integration test. The estimated F-statistics of all three specifications are greater than the relevant upper critical limit at the typical levels of conventional significance, which illustrates the existence of a steady relationship in the long run of sustainable economic growth with each group of explanatory variables. Sustained indicators of food systems, industrial activity, logistics performance, and variables of energy transition have significant equilibrium connectedness to growth dynamics. These results confirm that the underlying industries do not drift apart but instead develop in unison with each other over time, reflecting the structural importance of these drivers on the determination of long-term economic results.

Table 6: Bound co-integration test

ARDL bounds co-integration Test	F-stat	Result
SEG = f (L, K, FS, FPI)	6.417***	Co-integration
SEG = f (L, K, Ind, Logi)	7.028***	Co-integration
SEG = f (L, K, EI, RE)	6.952***	Co-integration
Lower-bound critical value at 1%		5.204
Upper-bound critical value at 1%		6.289
Lower-bound critical value at 5%		2.498
Upper-bound critical value at 5%		5.139
Lower-bound critical value at 10%		2.315
Upper-bound critical value at 10%		3.882

BDS Test

The BDS outcomes in Table 7 continuously discontinue the null hypothesis where the behavior with all variables and embedding dimensions are independent and identically distributed. There is strong nonlinear dependence in sustainable economic growth, food security, food production, logistics performance, industrial activity, energy intensity, renewable energy, labor, and capital. The growing power of the statistics of higher order shows the dynamic structures of complexity, but not simple adjustment. These trends make nonlinear autoregressive distributed lag modelling justified as the underlying data has asymmetric responses and nonlinear mechanisms of propagation, which cannot be well-represented in linear specifications.

Table 7: BDS test

Dimension	SEG	L	K	FS	FPI	Logi	Ind	EI	RE
2	0.157***	0.072**	0.061**	0.089***	0.112***	0.176***	0.143***	0.128***	0.094***
3	0.243***	0.103***	0.097***	0.137***	0.169***	0.241***	0.218***	0.184***	0.142***
4	0.329***	0.141***	0.128***	0.183***	0.221***	0.314***	0.294***	0.236***	0.198***
5	0.381***	0.164***	0.149***	0.214***	0.259***	0.367***	0.337***	0.268***	0.223***
6	0.403***	0.178***	0.163***	0.232***	0.278***	0.392***	0.358***	0.289***	0.244***

Notes: Values represent BDS test statistics (p-values). The null hypothesis is i.i.d. (no nonlinear dependence). Rejection at significance levels: *** 1%, ** 5%, * 10%.

Non-linear ARDL estimation*Pre-Vision 2030*

Table 8 presents the results of pre-vision 2030 non-linear ARDL results. According to the long-run coefficients, positive changes in the food security and the food production index positively affect sustainable economic growth significantly, whereas negative changes slow down the growth impetus. This asymmetric trend resembles findings of (Ghufran et al., 2024) who state that positive changes in the resilience of the food system reinforce the performance of the economy, but the negative shocks produce a disproportionately high disruption. It is robust and effective input of the workforce and capital, which is in line with the results of (Wang, Lin, Xiao, Bu, & Li, 2022), as the factor accumulation is one of the core mechanisms in the long-term growth of the Saudi Arabian economic structure in the changing economic setup.

In the second model, there are very strong asymmetric effects of industrial activity and logistics performance. Both positive and negative shocks in the two variables promote sustainable growth and weaken it, respectively. These findings are in line with (Barakat & Gerged, 2025), who highlight that the productivity capacity is increased by efficient logistics, and with (Singh and Ru, 2023), who report that industrial upgrading is a factor that promotes sustainable development outcomes. The short-run trends show that the industrial processes

are slow to respond to the shocks, which confirms the previous findings of (Mohammed N, Xianhui, & Shah, 2021) that the non-oil industries in Saudi Arabia have become resilient to absorb and transmit economic signals.

Assuming energy intensity minimizes growth and vice versa, (Huang & He, 2023) establish results on the economic value of efficiency improvements, but confirm that in the energy-sensitive model, this energy intensity is the negative factor that decreases growth. The positive long-run impact of renewable energy is repeated (Chang et al., 2022), who find that renewables have been found to facilitate cleaner and more sustainable growth strategies. All these findings, however, paint a picture of an economy where structural adjustments, industry-focused gains, as well as resource efficiency are assuming increasing roles in determining the growth curves on a sustainable trajectory.

Table 8: Non-linear ARDL estimation (pre-Vision 2030)

Long-run	Model 1	Model 2	Model 3
SEG _(t-1)	0.524**	0.210*	0.329*
L ⁺ _(t-1)	0.421***	0.384***	0.403***
L ⁻ _(t-1)	-0.279**	-0.238**	-0.261**
K ⁺ _(t-1)	0.167**	0.198**	0.186**
K ⁻ _(t-1)	-0.109	-0.159	-0.132
FS ⁺ _(t-1)	0.228**	–	–
FS ⁻ _(t-1)	-0.187*	–	–
FPI ⁺ _(t-1)	0.312***	–	–
FPI ⁻ _(t-1)	-0.141	–	–
Ind ⁺ _(t-1)	–	0.219***	–
Ind ⁻ _(t-1)	–	-0.136*	–
Logi ⁺ _(t-1)	–	0.264***	–
Logi ⁻ _(t-1)	–	-0.104	–
EI ⁺ _(t-1)	–	–	-0.231**
EI ⁻ _(t-1)	–	–	0.193**
RE ⁺ _(t-1)	–	–	0.157**
RE ⁻ _(t-1)	–	–	-0.214***
Short-run			
ΔSEG ⁺ _(t-1)	0.654	0.261	0.872
ΔL ⁺ _(t-1)	0.219**	0.207**	0.228**
ΔL ⁻ _(t-1)	-0.643*	-0.746*	-0.416**
ΔK ⁺ _(t-1)	0.181	0.192	0.173
ΔK ⁻ _(t-1)	-0.527*	-0.416	-0.317
ΔFS ⁺ _(t-1)	0.176	–	–
ΔFS ⁻ _(t-1)	-0.129	–	–
ΔFPI ⁺ _(t-1)	0.241*	–	–
ΔFPI ⁻ _(t-1)	-0.083	–	–
ΔInd ⁺ _(t-1)	–	0.281***	–
ΔInd ⁻ _(t-1)	–	-0.151	–

$\Delta \text{Logi}^+_{(t-1)}$	–	0.207**	–
$\Delta \text{Logi}^-_{(t-1)}$	–	–0.096	–
$\Delta \text{EI}^+_{(t-1)}$	–	–	–0.132**
$\Delta \text{EI}^-_{(t-1)}$	–	–	0.107
$\Delta \text{RE}^+_{(t-1)}$	–	–	0.176**
$\Delta \text{RE}^-_{(t-1)}$	–	–	–0.149*
Constant	–11.736***	–10.842***	–9.917***

Notes: ***, **, * denote significance at 1%, 5%, and 10% levels respectively. “–” indicates the regressor is not included in that model.

Post-Vision 2030

Table 9 presents the post-vision 2030 non-linear ARDL results. The positive shocks in food security and the food production index have a higher impact on sustainable economic growth after Vision 2030, whereas the negative shocks have the same effect of dampening the same. This increased sensitivity stems from the magnitude of new investments in the formation of domestic food systems and agricultural technology, which is in line (A. Ahmed, Al-Khayri, & Elbushra, 2024) record increasing resilience in the Saudi Arabian food sector. This constant power of labor and capital is also in sync with structural changes to increase the productivity of the workforce and enhance capital utilization in line with (Hasanov, Javid, & Joutz, 2022) observations that the input of non-oil drivers is becoming more prominent.

There are magnified long-term impacts of industrial activity and performance of logistics than the performance of the same in pre-Vision 2030. Both variables create more significant growth impulses as a result of positive shocks and more severe constraints as a result of adverse movements. Getting more sensitive to the energy intensity and the renewable energy in the energy transition model suggests a more integrated policy environment following the Vision 2030. Positive changes in renewable energy growth favor economic growth, whereas renewable energy increases the burdens of sustainability depending on escalating energy intensity. Heavily taken, the post-Vision 2030 coefficients indicate an economy that is more and more influenced by structural reforms, resource performance, and even industry-specific investments.

Table 9: Non-linear ARDL estimation (post-Vision 2030)

Long-run	Model 1	Model 2	Model 3
$\text{SEG}_{(t-1)}$	0.736*	0.413	0.587*
$L^+_{(t-1)}$	0.446***	0.409***	0.431***
$L^-_{(t-1)}$	–0.293**	–0.261**	–0.283**
$K^+_{(t-1)}$	0.189**	0.216**	0.204**
$K^-_{(t-1)}$	–0.123	–0.174	–0.147
$\text{FS}^+_{(t-1)}$	0.253***	–	–
$\text{FS}^-_{(t-1)}$	–0.206**	–	–
$\text{FPI}^+_{(t-1)}$	0.339***	–	–
$\text{FPI}^-_{(t-1)}$	–0.167	–	–
$\text{Ind}^+_{(t-1)}$	–	0.243***	–
$\text{Ind}^-_{(t-1)}$	–	–0.162*	–
$\text{Logi}^+_{(t-1)}$	–	0.287***	–
$\text{Logi}^-_{(t-1)}$	–	–0.127	–
$\text{EI}^+_{(t-1)}$	–	–	–0.254***
$\text{EI}^-_{(t-1)}$	–	–	0.207**

$RE^+_{(t-1)}$	–	–	0.179**
$RE^-_{(t-1)}$	–	–	–0.236***
Short-run			
$\Delta SEG_{(t-1)}$	0.312	0.735	0.304
$\Delta L^+_{(t-1)}$	0.237**	0.229**	0.251**
$\Delta L^-_{(t-1)}$	-0.394*	0.857*	0.430*
$\Delta K^+_{(t-1)}$	0.196	0.207	0.185
$\Delta K^-_{(t-1)}$	0.645	0.725	0.310
$\Delta FS^+_{(t-1)}$	0.203	–	–
$\Delta FS^-_{(t-1)}$	–0.142	–	–
$\Delta FPI^+_{(t-1)}$	0.269**	–	–
$\Delta FPI^-_{(t-1)}$	–0.101	–	–
$\Delta Ind^+_{(t-1)}$	–	0.309***	–
$\Delta Ind^-_{(t-1)}$	–	–0.177	–
$\Delta Logi^+_{(t-1)}$	–	0.236***	–
$\Delta Logi^-_{(t-1)}$	–	–0.114	–
$\Delta EI^+_{(t-1)}$	–	–	–0.158**
$\Delta EI^-_{(t-1)}$	–	–	0.129
$\Delta RE^+_{(t-1)}$	–	–	0.197**
$\Delta RE^-_{(t-1)}$	–	–	–0.171*
Constant	–12.174***	–11.286***	–10.153***

Notes: ***, **, * denote significance at 1%, 5%, and 10% levels respectively. Again, “–” means that variable is not part of that specific model.

DISCUSSION

The stronger post-Vision 2030 effects observed for food security and the food production index indicate that improvements in domestic food systems translate more effectively into sustainable economic growth than in earlier years. This tendency is consistent with (Shobur et al., 2025), who demonstrate that the increased stability of food systems boosts long-term economic outcomes, especially in countries with reduced reliance on imports. In the Saudi scenario, the growth of the controlled-environment agriculture, the value-chain modernization, and the specific food security programs have probably contributed to the enhancement of the growth effect of the beneficial shocks in these variables. Similarly, increased sensitivity to negative changes post-2030 indicates the increased strategic interest of food system resilience as national consumption and domestic production are more strongly connected.

As the role of industrial activity in the post-Vision 2030 era increases, there is a purposeful growth of non-oil manufacturing hubs and industrial zones. As (Hertog, 2010) underscores, the effects of industrial policy on the outcomes of diversification of the Gulf economies are made through coordination, and the current outcomes indicate that the latest adjustments to the reforms have the effect of intensifying the effect between industrial and sustainable growth. The positive shocks of logistics performance also have a greater post-2030 effect, which is in line with (Martí, Puertas, & García, 2014), who discovered that empowered logistics networks can significantly estimate economic competitiveness. Vision 2030 has probably boosted the contribution of the sector in enhancing growth by putting substantial investments in transport corridors, port infrastructure, and digital logistics platforms.

The increased negative effect of increasing energy intensity in the energy transition model corresponds to increased economic punishments in the inefficiency, which correlates with (Alshehry & Belloumi, 2015), who demonstrate that energy consumption patterns in Saudi Arabia impose some long-run growth pressure. Concurrently, the strengthened positive contribution of renewable energy is reflected in other regional observations also (Apergis & Payne, 2010), who record that renewable growth has facilitated the cleaner and more sustainable economic activities. The future outcomes, as per the post-2030, are that the continued expansion of the energy mix has started to incline the growth processes toward efficiency and sustainability, as opposed to consumption at high volumes.

CONCLUSION

The empirical research proves that sustainable economic growth in Saudi Arabia is becoming more and more influenced by structural reforms that have reinforced the role of food systems, industrial development, logistics performance, and the energy transition. The shift patterns found in each of the three models consist of the fact that positive improvement in sectors creates a more positive growth impulse than previously, and that shocks that are negative impose more binding effects, which can be seen as indicative of an economy that is now more sensitive to opportunities and threats. The post-Vision 2030 projections, specifically, reveal the national approaches tailored to enhance the long-term performance of the food security programs, manufacturing and logistics upgrading, and the use of renewable energy sources. Such changes are indicative of a transition toward a more diversified and efficiency-based option of development, where the reliance on energy-consuming activities will end up fading away. The findings also highlight the need to invest further in human capital, technological updating, and institutionalized policy frameworks to ensure the structural change continues. With the country continuing its long-term goals, these reforms will have to be sustained over time in order to make the growth less volatile, more resilient, and to make the increases in productivity and resource utilization sustainable breakthroughs in the economic welfare.

Policy Implications

Enhancing the individual sectors that portray the most post-Vision 2030 impacts provides a gift of direction to policy formulation in promoting long-term economic developments. Increased capital spending in technologically sophisticated food systems can stabilize home supply chains and limit vulnerability to foreign price changes to help maintain resilience and productivity. The high-value manufacturing, integrated industrial zones, and innovation-based firms should remain a priority area for the industrial policy to further diversify and improve the competitive strength. Enhancements of logistics infrastructure should be further made, in specific infrastructure, such as digital logistics platforms, multimodal connectivity, and trade facilitation procedures, to increase efficiency and market access in a foreign market. The notable power of renewable energy and energy efficiency points to the necessity to roll out the grid modernization faster, increase the number of utility-scale projects of renewable energy in use, and add more regulatory leverage to industrial and building efficiency. The skills development and research capacity should be cross-cutting reforms to cement sectoral transformation. All these can help stabilize structural gains and can help to improve a more sustainable and flexible growth pattern.

Limitations

The analysis is limited by the level of data available and granulomere of the sector-level information, restricting the capability to recap more specific dynamics in the sectors of agriculture, industry, logistics, and energy sub-sectors. Inasmuch as asymmetric adjustments are supported in the nonlinear autoregressive distributed lag model, the underlying mechanisms of the responses, e.g., the timing of policy changes, market structure, and institutional reforms, are not well decoupled. The research concentrates on the aggregates of each country only, and it might conceal the unequal amounts of productivity, the level of infrastructure, or the use of renewable energy in Saudi Arabia. The non-endogeneity of sustainable economic growth and the explanatory variables is also a possibility, even with the strength of the modelling method. Further, classification of pre- and post-Vision 2030 periods does not specifically consider any transition lags, policy implementation heterogeneity, or external shocks such as oil price changes or globalized supply chain interruptions, which may affect the estimated coefficients. Lastly, the analysis fails to incorporate sustainability indicators in terms of environmental and social factors outside the variables it has considered.

Future Research Directions

Further research can be improved by adding a layer of disaggregated sectoral data to identify the contribution of individual agriculture technology, industrial subsectors, elements of logistics, and renewable energy technologies in sustainable economic development. Further consideration of the analysis using the spatial econometric techniques could uncover regional patterns of policy efficacy and infrastructure discrepancy. Simple incorporation of indicators of the environment, which include emissions intensity findings, water use efficiency, and land degradation, would also offer a more comprehensive view of the results of sustainable development. Future working could also encompass structural break models that explicitly consider the processes of major policy shocks, global shocks, or technological transitions to index subtler effects over time. The extension of the methodological approach to panel data containing a country in the Gulf Cooperation Council might allow for a comparative study and determine regional driving forces. Lastly, predictive accuracy of growth trajectories using machine learning-based forecasting models, along with nonlinear econometric tools, could be investigated in other policy situations as well.

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