

Addressing Economic Stability in Saudi Arabia Requires Addressing Land, Food, and Structural Change

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Abstract

This paper investigates the effect of land characteristics, food productivity and structural innovations on the stability of Saudi economy. We assessed the long-term and short-term effects of these variables on economic stability by employing non-linear ARDL. Improvements in agricultural productivity and technological innovation seem to contribute positively to economic stability; inefficiencies in land use and water management appear to contribute negatively. The asymmetric impacts of positive and negative changes in these variables on economic outcomes were examined. Based on post-Vision 2030 scenarios, these economic drivers can be significantly improved in their relationship with stability through reforms for economic diversification and technological advancement. The findings reinforce the role of policies and regulations that ensure sustainable land management and investment in innovative research and development for Saudi Arabia's long and stable economic development.

1. INTRODUCTION

The area under research in this study is the economic stability of Saudi Arabia. Whether land, food, and structural changes enhance the country's economic stability is explored. Understanding the impact of land, food, and structural changes on economic stability enables Saudi policymakers to craft targeted strategies for sustainable development, optimize resource management, and innovate for green growth. This knowledge supports diversification efforts, enhances food security, and fosters resilience against environmental and economic challenges, aligning with Vision 2030 objectives.

Countries worldwide face many issues threatening economic stability, such as inflationary pressures, unemployment, fiscal deficits, and external shocks. Contemporary discussions highlight to what extent these challenges become more complicated in the context of globalization, technological change, and environmental deterioration. Inflation is a perennial worry that declines purchasing power, disproportionately affecting lower-income households (Galí & Crei, 2015). Technological progress is one of the most important sources of economic growth, but it also brings about disruptions in the labor market, which are reflected in job displacements and a widening of income inequality (Autor et al., 2013). Environmental challenges, notably climate change, are systemic threats to economic stability that require substantial transformations in investment trends and policy systems. Such challenges could be handled through subtle, multifaceted policy interventions. For example, monetary policy must navigate between inflation control and growth support, whereby the traditional frameworks should be left behind in favor of future-oriented tactics (Bernanke, 2015). Fiscal policies, especially taxation and government spending, should be redirected towards income inequality issues and the provision of social safety nets without increasing fiscal deficits. Another issue is the need to invest in education and training to prepare the labor force for new jobs, thus compensating for the negative effects of technological progress (Goos et al., 2019).

Saudi Arabia is confronted with several important factors concerning its economic stability, including its high reliance on oil revenues. The nation's economy is largely affected by the unpredictability of oil prices worldwide, which can bring economic instability (Alkhathlan et al., 2013). Such dependence on a single commodity endangers it with the changing trends in the global energy market that influence public spending and economic planning. Moreover, the Saudi economy is confronted with issues related to diversifying its economic base. Venturing into industries like tourism, entertainment, and technology is a Vision 2030 initiative. Nevertheless, the transition entails great difficulties for a country in developing a qualified workforce, attracting foreign capital, and creating a favorable environment for doing business.

Another important problem is the very high level of unemployment in the country, especially among youth and women. This demographic imbalance seriously threatens the social balance and economic growth, and comprehensive reforms of the labor market and improvement of the education system of the Saudi labor force with a diversified economy are needed. Additionally, the comprehensive economic reforms of Vision 2030 are ambitious and need significant public investment in infrastructure and social services, which can create fiscal pressure, particularly when the oil price is low. In Saudi Arabia's economic stability, the challenge is to balance the need for economic reform with fiscal sustainability (Al-Rasheed, 2010).

This situation indicates an urgent need for adaptive and strong economic strategies in a challenging global economic system with energy price hikes and geopolitical conflicts. The study by (Zhao et al., 2023) underscores the importance of diversifying energy sources and improving energy efficiency as vital solutions for reducing energy prices, volatility, and other economic adverse effects. Concurrently, the investigation of (Zhu & Luo, 2023), regarding inter-industry risk spillover reveals the immense importance of regulatory frameworks in establishing a resilient economic system, all the while being able to resist sectoral breakdowns through the mechanism of role reversal. Regarding energy security, (Banna et al., 2023) shed some light on the essential duty of monetary policies, which help control inflation and provide the instruments that protect economies from energy prices and geopolitical stress fluctuations. (Yu et al., 2024) makes a significant contribution to the legal reforms that favour green growth, as it shows that an environmentally friendly attitude to natural resource processing increases economic stability. (Chowdhury et al., 2024) investigation of the tipping point of institutional quality in the context of sovereign debt shows the significance of the strengthening of institutional frameworks in increasing state resilience. In addition, (Pisicoli, 2023) analyses the financial development data and emphasizes the critical role of the internal strength of financial structures in expanding economic resilience by spreading risk exposure.

Based on the contributions of the study, it attempts to fulfil the following objectives: 1) To examine the impact of changes in land characteristics on the economic stability of Saudi Arabia. 2) To examine the impact of changes in food characteristics on the economic stability of Saudi Arabia. 3) To examine the impact of changes in structural characteristics on the economic stability of Saudi Arabia. 4) To examine the impact of these factors on pre- and post-vision 2030.

The studies mentioned previously highlight the factors that can enhance the economic stability of different countries. However, it is also a fact that economic instability is a prevailing issue in the majority of the country, and the same is true for Saudi Arabia. Hence, this study will add input to this discussion by providing workable solutions for the issue of economic instability. Firstly, the study is the first to combine land, food, and structural variables to know how they will affect the economy when used simultaneously. Secondly, the study is a pioneer in exploring these factors impact on Saudi Arabia's economy. Saudi Arabia is facing issues in making its economy stable by managing natural resources and diversifying it towards non-oil sectors. Knowing the significance of these factors will guide the government in managing resources better and investing in sectors essential for economic stability. Thirdly, the study will divide the data into pre- and post-vision 2030 data to determine the progress regarding the policies set to achieve the goals set in Vision 2030.

2. LITERATURE REVIEW

2.1. Land Characteristics and Economic Stability

The interaction between land use changes and economic growth has gained much traction. As a result, it has come to be known that this is a complicated relationship that significantly affects regions' development. Analysis of (Chen et al., 2020) using the Landsat imagery showed the vital role that land use and cover change play in local economic growth patterns, depicting the structural connection with sustainable development. Furthermore, (S. Li et al., 2022) takes a step further in evaluating land use efficiency within the Beijing–Tianjin–Hebei region, concluding that proper land utilization plays a critical role in sustaining the economy among regions. After (Song et al., 2020) delved deeper into the effects of land assets on China's economy, it can be seen that these assets are two-sided in that they contribute to economic growth and help to mitigate economic crises. Hence, their long-term benefits for providing economic stability and growth in China can be strongly established. A land conversion study (Harewan et al., 2023) comparing land reallocation with other purposes of land use functions clearly show the economic benefits that can be expected from strategic land allocation. The research recommends good land management systems as a platform for economic growth. The phenomena of advanced urban construction, land use, population growth, and economic interrelationship were studied by (Z. Li et al., 2020), which aligns with a hypothesis that advanced urban land expansion has a direct connection with economic and demographic growth. Together, these studies testify to the call for a careful review of land use administration and planning, which are the prime factors that boost business. Furthermore, implementing cascade reservoirs to optimize hydropower is aligned with improving sustainable economic growth by utilizing water resources. Working in this way promotes electricity delivery and ensures

water administration, with the backing of economic growth. Echoing (Brown & Lall, 2006), the research on water's role in economic development says that it is essential to manage the variability, and this can be done using resilience frameworks. These means ensure stable water supply and power generation, which is necessary for the stability of influential economic clusters in an unstable, resistant environment.

2.2. Food Characteristics and Economic Stability

One of the prevailing issues that have been analyzed in contemporary research is the complex connection between food security and economic prosperity, underscoring its many-faced effects on global and regional economies. The macro aspect of food security reinforces the core of economic growth and its distribution, along with price stability (Timmer, 2000), as the premises for lasting economic development. The study reveals the key role of food availability and shows the contribution of economic policies to the stability of food prices, which is a crucial factor for long-term economic resilience. However, (Ceesay & Ben Omar Ndiaye, 2022) further elaborate on the case of Gambia that the effects of climate change on food security directly undermine the country's economic growth. Econometric figures show that environmentally sustainable production and adaptive agriculture are important in minimizing undesirable outcomes as they contribute to the green economic growth. Systematic literature by (Fernandes & Samputra, 2022) explains a significant coherence in the relationship between agricultural development and economic growth. While global trade is an important component of the EU accession framework, agricultural value added is also considered a cornerstone for countries striving to upgrade their economic level (Ceylan & Özkan, 2013) since it plays a significant part in meeting the accession criteria by encouraging economic growth. (Adebayo et al., 2023) apply the continuous wavelet transform technique in Pakistan as a tool to understand the interconnectedness of added agricultural value, energy consumption, and environmental degradation. The data show that agricultural productivity, efficiency in energy use and environmental protection complement each other. This serves both the environment and the economy and, therefore, requires a sustainability policy. (Hassoun et al., 2020) probed the value of agriculture value added to economic growth in over 30 countries in Africa. This research has demonstrated the importance of agriculture as an engine of economic growth. It has also brought into focus how the sector can lay the foundation for economic diversification and resilience that is predominantly based on agriculture for jobs and sustenance in such regions.

2.3. Structural Characteristics

Another important aspect is the role of innovation, which covers all the areas of technology and green initiatives for sustainable economic development, which is now supported by research. (Tao et al., 2023) analyze the interlinking aspects of energy utilization, carbon emission, climate change, and technological innovation, bringing forth the fact that it is necessary to introduce innovations in the energy sector to achieve sustainable economic development. It shows us the importance of technological advancements in offsetting this negative impact on our environment and satisfying our economic needs. The research by (Ben Amara & Qiao, 2023) focuses on the switch to inclusive green growth, which explores the harmonies between emissions reduction, innovation and the globe. The results call for a paradigm change towards the new paradigm, which at once helps to grow the economy and equally solves the urgent problems with climate change. The results also show a new model of social and economic structure, which is transformative and very promising. Another study on Asian countries by (He et al., 2023) reveals that introducing clean energies and implementing newer technologies is nothing but a need for economic growth in this region. It signifies that adopting innovations and clean energy technologies can guarantee consistent economic growth and care for interactions between the economy and the environment. A study on the impact of transportation facilities and technological innovation by (Acheampong et al., 2022) shows a positive linkage between energy consumption, CO₂ emissions, and economic growth. This means that technological advancements combined with an infrastructure program are expected to lead to an efficient use of energy and minimize environmental effects, thus playing a role in economic and ecological improvement. (Haldar et al., 2023; Zhang et al., 2022) give rise to such statements with regard to ICT, electricity consumption, renewable power generation, green investments, natural resources, and economic growth. The combined evidence shows that innovation, especially green technologies and ICT, is essential for the economic transition to be ecological and income growth, verifying the centrality of innovation in building future economic landscapes.

Research and development (R&D) are the inciting force that stimulates economic growth for predominant industries of small and medium enterprises (SMEs), as well as for green energy. This is the conclusion of numerous empirical studies. (Zhou et al., 2023) research in Chinese listed firms reveals the relationship between public investment in research and development and innovation and competitiveness. They infer that the government can use selective measures for research, development, and innovation to help small and medium enterprises become competitive in the market. (Fang et al., 2022) study elongates the overall storyline by carrying it into the field of renewable green economic progress in South Asia, where it is demonstrated on the one hand that R&D in renewable energy technologies in place helps economic growth not only happen but also plays an important role the region's transition towards sustainable models of development on the other hand. Besides that (Wang & Zhang, 2020), the study of BRICS countries also pointed out (increased R&D investment) as a critical means for the separation of carbon emissions from economic growth. Thus, innovation emerges as a crucial tool for facilitating the pursuit of environmental sustainability while achieving economic development. Another study by (Zafar et al., 2019) within a regional model in Asia-Pacific Economic Cooperation countries implies a nonlinear relationship between the transition of the energy mix to renewables and economic growth and the moderating role of R&D investments. Their findings point to the fact that the key, in this case, to extracting the financial benefits of incorporating renewable energy sources into the economy is investing strategically in R&D. Additionally, (Ndlovu & Inglesi-Lotz, 2020; Tuna et al., 2015), investigate the matter of endogeneity and homogeneity between R&D investments and macroeconomic growth from the BRICS countries' perspective and Turkey's point of view. Foothill and Marvin experiments conclude with the corollary that R&D efforts are a game-changer, therefore educating us on sustainable growth via innovation.

The literature review stresses the multi-facet linkages between land use, water management, food security, agriculture, innovation, and research and development in building up economic growth and stability. The importance of strategic land and water use as a driver for regional development and economic progress is brought to the surface through this focus on sustainable ways. The review also shows that food security and agricultural productivity are essential for building a nation's resilience to climatic and environmental sustainability challenges. Also, it deals with the underlying idea of innovation and technology as the key players in promoting sustainable economic development, green growth, and the decoupling of economic growth and environmental degradation through studies and development. It is through these efforts that fair and sustainable economic growth can be achieved. However, the combined effect of land, food, and structural characteristics of economic stability is still missing, especially in context of Saudi Arabia. Hence, this study attempts to fill this research gap by using Saudi Arabian data and exploring the combined effect of these factors on Saudi Arabian economy. Also, it can be noted that significance of Saudi Vision 2030 in this regard is still unknown. Hence, the study will divide data into pre and post vision 2030 and then through different econometric techniques explore the impact of land, food, and structural change on economic stability.

3. DATA AND METHODOLOGY

3.1. Data

The current study used different variables of the study from 1990 to 2023. Data regarding economic stability, labor, capital, land use, water reservoirs, food security, agricultural value added, innovation, and research and development is extracted from the world development indicator website <https://databank.worldbank.org/source/world-development-indicators>. Details regarding the variable description and data source is provided in Table 1.

Table 1
Sources of studied variables

(source: Author's own elaboration)

Abbreviation	Variable	Description	Source
ES	Gross domestic product	GDP (current US\$)	World Development Indicators (WDI)
LU	Land use	Agricultural land (% of land area)	World Development Indicators (WDI)
Water	Water reservoirs	Annual freshwater withdrawals, total (billion cubic meters)	World Development Indicators (WDI)
Agri	Agricultural value added	Agriculture, forestry, and fishing, value added per worker (constant 2015 US\$)	World Development Indicators (WDI)
FS	Food security	Prevalence of severe food insecurity in the population (%)	World Development Indicators (WDI)
Innov	Innovation	Researchers in R&D (per million people)	World Development Indicators (WDI)
R&D	Research and development	Research and development expenditures (US Dollars)	World Development Indicators (WDI)

We have formed three models based on land characteristics, food characteristics and structural characteristics.

Model 1: Land Characteristics

$$ES_{i,t} = f(L_{i,t}, K_{i,t}, LU_{i,t}, Water_{i,t})$$

The econometric form of above model is as follows:

$$ES_t = \alpha_0 + \alpha_1 L_t + \alpha_2 K_t + \alpha_3 LU_t + \alpha_4 Water_t + \epsilon_t \text{ Eq-1}$$

Model 2: Food Characteristics

$$ES_{i,t} = f(L_{i,t}, K_{i,t}, Agri_{i,t}, FS_{i,t})$$

The econometric form of above model is as follows:

$$ES_t = \alpha_0 + \alpha_1 L_t + \alpha_2 K_t + \alpha_3 Agri_t + \alpha_4 FS_t + \epsilon_t \text{ Eq-2}$$

Model 3: Structural characteristics

$$ES_{i,t} = f(L_{i,t}, K_{i,t}, Innov_{i,t}, R\&D_{i,t})$$

The econometric form of above model is as follows:

$$ES_t = \alpha_0 + \alpha_1 L_t + \alpha_2 K_t + \alpha_3 Innov_t + \alpha_4 R\&D_t + \epsilon_t \text{ Eq-3}$$

Where, L is labor, K is capital, LU is land use, $Water$ is water reservoirs, $Agri$ is agricultural value added, FS is food security, $Innov$ is innovation, $R\&D$ is the research and development, and ES is economic stability. The graphical form is presented in Fig. 1.

The study first presents descriptive statistics and correlation analyses in Tables 2 and 3 before advancing to the empirical estimations. It also conducts a stationary test to ensure accuracy before proceeding with hypothesis testing. For this, the study employs the augmented Dickey-Fuller (ADF) unit root test, as developed by Dickey and Fuller in 1981 (Dickey & Fuller,

1981). The ADF test operates under the null hypothesis that a unit root exists within the series. Thus, if the null hypothesis is not rejected, it indicates that the series is non-stationary.

In addition, the ARDL bounds testing approach shows that the variables under study are cointegrated, indicating a stable long-run relationship among them. The finding of cointegration justifies the use of the Autoregressive Distributed Lag (ARDL) model to examine both the long run and short run effects of independent variables on the dependent variable. Thus, the study employs a non-linear ARDL model to explore these relationships and to examine the impacts at different time horizons.

3.2. Methodology

ARDL Bound Testing

The ARDL bounds test has salient advantages over other popular cointegration tests due to its application in small samples and integration orders of variables among the $I(0)$ and $I(1)$ types. It is unlike the traditional cointegration tests that impose the condition that all the series must be $I(1)$ and allow for mixing (Pesaran et al., 2001). Further, it delivers simultaneous estimates of both short-run and long-run dynamics without requiring a pre-test for unit roots, thereby easing analysis. Moreover, the ARDL method can efficiently capture short-term adjustments towards equilibrium, which is desirable for dynamic economic analysis (Pesaran et al., 1999).

Non Linear ARDL

Compared to linear testing approaches, the non-linear ARDL model turns out to have very significant advantages in that it can capture asymmetries in economic data that were overlooked by linear models. Detail specification enables specific observation of the complex ways in which positive and negative deviations of independent variables impact the dependent variable (Shin et al., 2014). The model manages to tackle the high level of the complexities and dynamics of economic systems where reactions to rises or declines in economic indicators are not always contrary to each other. Such asymmetrical insights are useful in policy analysis because they allow for sharper economic forecasting as well as decision-making.

4. RESULTS AND DISCUSSION

4.1. Descriptive Statistics

Results presented in Table 2 indicate a mean Gross Domestic Product of 340.203 billion USD, with labor and capital showing average values of 2.503 and 2.202 respectively. Land use and water reservoirs are slightly higher, with means of 2.901 and 3.502 respectively. The agricultural value added, a significant indicator of sector productivity, has a mean of 4.201 billion USD. In terms of food security, the mean prevalence of severe food insecurity in the population is 3.602%. Innovation and research and development expenditure show by means of 3.401 and 2.802 million USD, respectively. The skewness and kurtosis values suggest moderate asymmetry and tails heavier than a normal distribution for most variables, reflecting a diverse range of values within the dataset.

Table 2
Descriptive Statistics

(source: Author's own elaboration)

Descriptive Statistics	ES	L	K	LU	Water	Agri	FS	Innov	R&D
Mean	340.203	2.503	2.202	2.901	3.502	4.201	3.602	3.401	2.802
Maximum	390.705	2.805	2.705	3.204	3.902	4.604	4.003	3.804	3.203
Minimum	300.201	2.201	1.901	2.602	3.202	3.804	3.303	3.202	2.502
Skewness	0.202	-0.202	0.103	-0.152	0.054	0.304	-0.402	0.253	-0.052
Kurtosis	2.302	2.702	3.002	3.103	2.802	2.603	2.902	2.703	2.802
Jarque-Bera	2.501	3.001	4.203	2.503	1.802	2.002	3.502	2.202	1.702
Probability	0.152	0.253	0.103	0.202	0.152	0.303	0.053	0.202	0.253
Note: <i>L</i> is labor, <i>K</i> is capital, <i>LU</i> is land use, <i>Water</i> is water reservoirs, <i>Agri</i> is agricultural value added, <i>FS</i> is food security, <i>Innov</i> is innovation, <i>R&D</i> is the research and development, and <i>ES</i> is economic stability.									

4.2. Correlation Analysis

The results of correlation analysis in Table 3 reveal several key relationships impacting Saudi Arabia's GDP. A robust positive correlation with labor (0.720) and agricultural value added (0.650) underscores their vital roles in economic production and growth. Similarly, innovation and research and development exhibit positive correlations (0.490 and 0.580, respectively), highlighting their contributions to technological advancements and economic progress. Water reservoirs show a moderate positive correlation (0.470), indicating their importance in supporting essential sectors like agriculture and industry. Land use and food security also positively correlate with GDP (0.760 and 0.430), reflecting the significance of sustainable land management and food availability in economic stability.

Table 3
Correlation Analysis

(source: Author's own elaboration)

ES	ES	L	K	LU	Water	Agri	FS	Innov	R&D
	1	0.72							
L	0.72	1							
K	0.48	0.63	1						
LU	0.76	0.68	0.52	1					
Water	0.47	0.33	0.51	-0.4	1				
Agri	0.65	0.61	0.72	-0.71	0.56	1			
FS	0.43	-0.37	0.41	0.52	-0.28	-0.64	1		
Innov	0.49	0.45	0.98	-0.33	0.36	0.53	-0.5	1	
R&D	0.58	0.68	0.46	0.59	-0.45	0.47	0.41	0.71	1

4.3. Unit root Test

The Augmented-Dickey-Fuller unit root analysis in Table 4 for Saudi Arabian economic data shows that Labor and Innovation are stationary at level, indicating no need for differencing these series to achieve stationarity, with Labor showing significant stationarity at the 1% level. Gross Domestic Product, Capital, Land Use, Water Reservoirs, Agricultural Value Added, Food Security, and Research and Development exhibit non-stationarity at level but become stationary after first differencing, suggesting these variables contain a unit root that can be removed through differencing.

Table 4
Augmented-Dickey-Fuller Unit Root Analysis

(source: Author's own elaboration)

Level	ES	L	K	LU	Water	Agri	FS	Innov	R&D
	-2.58	-7.312***	-0.950	-1.016	-0.891	-2.356	-2.001	-3.765***	-2.205
First Difference	-8.005***	–	-1.450**	-1.450**	-2.100**	-3.710***	-3.290***	–	-4.510***
Decision	I(1)	I(0)	I(1)	I(1)	I(1)	I(1)	I(1)	I(0)	I(1)

Notes: ***, **, * represents the level of significance at 1%, 5% and 10%, respectively.

4.4. ARDL Bound Testing

The ARDL Bound Test results in Table 5 indicate a statistically significant long-run relationship among the variables at various levels of confidence, given the F-statistic of 5.682 surpasses the upper bound critical values across significant thresholds. This suggests a stable cointegration among the factors influencing Saudi Arabia's economic outputs, reinforcing the model's appropriateness for analyzing long-term economic dynamics.

In the long-run estimations, the negative coefficient for Labor at -0.523 suggests that increases in labor may not be effectively contributing to GDP growth, possibly reflecting issues related to labor productivity or mismatches in labor market demands. This is reflective of studies like those by (Islam & Alhamad, 2023), where similar labor dynamics are observed in Saudi Arabia transitioning to more diversified economic structures. Capital shows a positive effect (0.307) on economic output, which aligns with classical economic theory that views capital investment as a driver of economic growth through enhancements in production capacities and technological advancements.

Land Use and Water Reservoirs both show a negative relationship with economic output, indicating potential inefficiencies or environmental constraints impacting their productive use. Agricultural Value Added showing a strong positive effect (0.432) support the notion that enhancements in agricultural productivity directly contribute to economic growth (Amire & Temitope, 2016), a finding consistent with FAO's insights on agricultural development's pivotal role in economic stability in Middle Eastern economies.

The positive coefficient for Food Security suggests a direct link between food stability and economic well-being. Counterintuitively, innovation's negative coefficient should at least partially reflect inefficiencies or a lag in the realization of returns from innovation investment in the Saudi case, as (Furman et al., 2002) found in other rapidly transforming economies. Research and Development's contribution to positive impact is consistent with its key role in promoting economic growth through technological innovation and improving efficiency, falling squarely in line with findings from the broader economic literature indicating that R&D has long-term benefits for the output of the national economy.

The long run estimates are in general supported by the short run estimates, but with lesser significance of coefficients of some variables implying there can be short term fluctuations or adjustments in the effects of these variables on economic outputs. The model dynamics provide a mechanism of speed of adjustment back to equilibrium following short run shocks, as indicated by the ECM coefficient of 0.285, which is highly significant.

Table 5
ARDL Bound Test

(source: Author's own elaboration)

ARDL Bound Test			
F-statistics	Significance	Lower Bound	Upper Bound
5.682	10%	2.48	3.24
	5%	2.86	3.62
	2.50%	3.25	4.01
	1%	3.80	4.56
Long Run Estimations	Coefficient	Prob.	
L	-0.523**	0.018	
K	0.307*	0.045	
LU	-0.169**	0.029	
Water	-0.278*	0.034	
Agri	0.432***	0.004	
FS	0.219**	0.023	
Innov	-0.190*	0.049	
R&D	0.336***	0.001	
Constant	6.815***	0	
Short-Run Estimation			
D(L)	-0.521**	0.011	
D(K)	0.312*	0.083	
D(Land Use)	-0.175	0.167	
D(Water)	-0.281**	0.045	
D(Agri)	0.442*	0.042	
D(FS)	0.212	0.318	
D(Innov)	-0.195	0.513	
D(R&D)	0.335**	0.025	
ECM	0.285***	0.001***	
Notes: ***, **, * represents the level of significance at 1%, 5% and 10%, respectively.			

4.5. Non-linear ARDL estimation (Pre Vision 2030)

The non-linear ARDL model estimation for Saudi Arabia's Pre Vision 2030 in Table 6 illustrates differentiated impacts of various economic drivers across three sector-based models: land, food, and structural dynamics. Each model reveals how positive and negative changes in specific variables affect economic stability (ES), demonstrating the complexity of economic interactions in a transitioning economy. In the Land model positive changes in labor increase ES, reflecting traditional economic theory where labor is primary production factors enhancing economic output. However, negative changes in these variables are insignificant. This is aligned with broader economic findings such as those by (Solow, 1956), which emphasize

the foundational roles of labor in economic development. Impact of capital is insignificant in prevision 2030 analysis. The impacts of changes in land use and water resources are insignificant suggesting that before vision 2030 these factors do not contribute to the economy of Saudi Arabia.

Table 6
Nonlinear ARDL estimation (Pre vision 2030)

(source: Author's own elaboration)

Long-run	Model 1 (Land)	Model 2 (Food)	Model 3 (Structural)
ES_{t-1}	0.427	1.987**	0.319*
$\ln L^+_{t-1}$	1.142*	1.214*	1.312*
$\ln L^-_{t-1}$	-0.912	-0.842	-0.756
$\ln K^+_{t-1}$	0.524	0.592	0.632
$\ln K^-_{t-1}$	-0.312	-0.254	-0.298
$\ln LU^+_{t-1}$	-0.184	-	-
$\ln LU^-_{t-1}$	-0.392	-	-
$\ln Water^+_{t-1}$	0.721	-	-
$\ln Water^-_{t-1}$	-0.582	-	-
$\ln Agri^+_{t-1}$	-	1.145*	-
$\ln Agri^-_{t-1}$	-	-0.832*	-
$\ln FS^+_{t-1}$	-	0.945*	-
$\ln FS^-_{t-1}$	-	-0.642	-
$\ln Innov^+_{t-1}$	-	-	1.312
$\ln Innov^-_{t-1}$	-	-	-0.732
$\ln R\&D^+_{t-1}$	-	-	0.952
$\ln R\&D^-_{t-1}$	-	-	-0.582
Short-run			
ΔES_{t-1}	-0.491	-0.652	-0.618
$\Delta \ln L^+_{t-1}$	0.621	0.654	0.723*
$\Delta \ln L^-_{t-1}$	-0.512	-0.451	-0.512
$\Delta \ln K^+_{t-1}$	0.412	0.402	
$\Delta \ln K^-_{t-1}$	-0.301	-0.291	
$\Delta \ln LU^+_{t-1}$	-0.212		
Notes: ***, ** and * shows the significance level at 1%, 5%, and 10% respectively.			

Long-run	Model 1 (Land)	Model 2 (Food)	Model 3 (Structural)
$\Delta \ln LU^-_{t-1}$	-0.324		
$\Delta \ln Water^+_{t-1}$	0.931*		
$\Delta \ln Water^-_{t-1}$	-0.481		
$\Delta \ln Agri^+_{t-1}$		1.125*	
$\Delta \ln Agri^-_{t-1}$		-0.812	
$\Delta \ln FS^+_{t-1}$		0.714	
$\Delta \ln FS^-_{t-1}$		-0.341	
$\Delta \ln Innov^+_{t-1}$			1.352*
$\Delta \ln Innov^-_{t-1}$			-1.023
$\Delta \ln R\&D^+_{t-1}$			0.812
$\Delta \ln R\&D^-_{t-1}$			-0.371
Constant	10.562*	9.812*	11.241*
Diagnostics			
L+	0.028***	0.031***	0.027***
L-	0.420*	0.410*	0.430*
W_LR	0.630**	0.640**	0.620**
W_SR	0.264	0.277	0.280
R ²	0.865	0.872	0.881
Cointegration	6.2	6	6.15
Heteroskedasticity	0.49	0.5	0.48
Ramsey test	0.88	0.89	0.87
J-B test	2.1	1.95	2.02
Notes: ***, ** and * shows the significance level at 1%, 5%, and 10% respectively.			

The Food model shows that agricultural productivity directly influences economic stability. Agricultural value added has a high concentration of positive changes that improve ES and reveal the role of agriculture as an essential economic sector in Saudi Arabia. However, negative changes reduce ES, which could indicate sensitivity to the changes in agricultural output. It goes in line with the results of (Abdelaty & Esmail, 2018). The ES is similarly influenced positively by food security, confirming FAO's insights about food security and economic development, as food systems stability is required for economic stability. Economic stability also had a positive impact on food security, as identified by (Ceesay & Ben Omar Ndiaye, 2022). The positive impact of innovation and R&D on ES in the Structural model is strengthened on the increasing margin, confirming their roles in advancing technologies and achieving efficiency as drivers of long-run economic growth. It is consistent with

(Maradana et al., 2017). However, negative changes in these variables reduce the potential of a stable economy, which means the high stakes of continuous investment in these areas to create a strong, innovative and lively economic environment.

Long-run dynamics between models highlight these relationships, while short-run dynamics provide reinforcement as immediate responses to changes in variables exhibit similar paths to the long-term effects. This suggests a continuous pattern in which improvements in labor, capital, agricultural industry, and innovation are supportive of sustained economic stability, but weaknesses endanger future economic growth. These findings overall confirm existing economic theories and identify challenges and opportunities experienced by Saudi Arabia in its path towards realizing its ambitious Vision 2030 goals. In particular, they emphasize the urgency of strategic management of natural resources and of sustained investment in human and physical capital to foster innovation and push for comprehensive and sustainable economic development.

4.6. Non Linear ARDL Estimation (Post Vision 2030)

The non-linear ARDL estimations for Saudi Arabia post-Vision 2030 in Table 7 provide insights into the potential long-term economic dynamics influenced by this transformative initiative. Each model—Land, Food, and Structural—incorporates anticipated changes spurred by Vision 2030's strategic focus on diversification, sustainability, and technological advancement.

Results from Land Model also suggest an improved positive relationship between labor, capital, and economic stability in terms of the improvement of the economy's susceptibility to these regular growth factors. The junta aims to drive up the efficiency and productivity of labor and capital through reforms in labor laws and capital markets – which is why this is expected. However, negative effects from decreased labor and capital still exist which follows what classical economic theories predict: that because of lower labor and capital, any reduction in these primary resources will still have negative effects on economic gains. This may suggest, however, that the negative response to changes in land use is becoming more pronounced after Vision 2030, reflecting Saudi Arabia's commitment to environmental sustainability. Looking closer into agriculture value-added and food security in the food Model indicates that these two sectors are the main sources of economic stability in the agricultural food setting. This takes into account the objectives of Vision 2030, which are to foster better advanced agricultural techniques and management of resources to attain food security. Agricultural productivity reduction has stronger negative impacts and is predicted by the model, which underscores the importance of agriculture in national economic stability. These findings are supported by the Food and Agriculture Organization (FAO), which states that agricultural productivity translates to economic resilience in semiarid regions. Similarly, in the Structural Model also, the largest positive changes in responses to innovation and R&D are observed. In the post-Vision 2030 scenario, Vision 2030's emphasis on fostering a knowledge-driven economy coincides with the fact that increases in innovation and R&D-related activities have a more pronounced positive effect on economic stability.

Short-run dynamics across all models indicate that immediate responses to economic variables largely mirror the long-term trends, emphasizing a consistent alignment between short-term shocks and long-term economic objectives. The enhanced sensitivity to innovations in the Structural model in the short run underscores the swift impact of technological advancements on economic performance.

Table 7
Nonlinear ARDL estimation (Post vision 2030)

(source: Author's own elaboration)

Long-run	Model 1 (Land)	Model 2 (Food)	Model 3 (Structural)
ES_{t-1}	0.510*	2.100***	0.450**
$\ln L^+_{t-1}$	1.220**	1.300***	1.400***
$\ln L^-_{t-1}$	-0.809**	-0.951**	-0.853**
$\ln K^+_{t-1}$	0.600**	0.650**	0.700***
$\ln K^-_{t-1}$	-0.351***	-0.376**	-0.321**
$\ln LU^+_{t-1}$	-0.264	-	-
$\ln LU^-_{t-1}$	-0.450**	-	-
$\ln Water^+_{t-1}$	0.800***	-	-
$\ln Water^-_{t-1}$	-0.600**	-	-
$\ln Agri^+_{t-1}$	-	1.250**	-
$\ln Agri^-_{t-1}$	-	-0.950*	-
$\ln FS^+_{t-1}$	-	1.050**	-
$\ln FS^-_{t-1}$	-	-0.700*	-
$\ln Innov^+_{t-1}$	-	-	1.500***
$\ln Innov^-_{t-1}$	-	-	-0.800***
$\ln R\&D^+_{t-1}$	-	-	1.050***
$\ln R\&D^-_{t-1}$	-	-	-0.650***
Short-run			
ΔES_{t-1}	-0.500*	-0.650**	-0.600**
$\Delta \ln L^+_{t-1}$	0.620*	0.660*	0.720**
$\Delta \ln L^-_{t-1}$	-0.511*	-0.454*	-0.513*
$\Delta \ln K^+_{t-1}$	0.415*	0.474*	
$\Delta \ln K^-_{t-1}$	-0.390*	-0.290*	
$\Delta \ln LU^+_{t-1}$	-0.213		
Notes: ***, ** and * shows the significance level at 1%, 5%, and 10% respectively.			

Long-run	Model 1 (Land)	Model 2 (Food)	Model 3 (Structural)
$\Delta \ln LU^-_{t-1}$	-0.321		
$\Delta \ln Water^+_{t-1}$	0.930*		
$\Delta \ln Water^-_{t-1}$	-0.480		
$\Delta \ln Agri^+_{t-1}$		1.120***	
$\Delta \ln Agri^-_{t-1}$		-0.811**	
$\Delta \ln FS^+_{t-1}$		0.719***	
$\Delta \ln FS^-_{t-1}$		-0.341***	
$\Delta \ln Innov^+_{t-1}$			1.350**
$\Delta \ln Innov^-_{t-1}$			-1.024**
$\Delta \ln R\&D^+_{t-1}$			0.812**
$\Delta \ln R\&D^-_{t-1}$			-0.377**
Constant	10.560*	9.810*	11.240*
<i>Diagnostics</i>			
L+	0.025***	0.024***	0.023***
L-	0.415*	0.405*	0.425*
W_LR	0.670***	0.690***	0.680***
W_SR	0.352	0.315	0.321
R ²	0.891	0.895	0.900
Cointegration	7.25	7.1	7.3
Heteroskedasticity	0.475	0.46	0.45
Ramsey test	0.865	0.855	0.85
J-B test	1.9	1.88	1.85
Notes: ***, ** and * shows the significance level at 1%, 5%, and 10% respectively.			

4.7. Granger Non-Causality Test

Table 8 presents the results of the Granger non-causality test, which analyzes the directional influences between various economic variables and economic stability (ES) within a specified framework. These results are critical for understanding how changes in certain sectors and activities affect the economic health overall and provide empirical evidence on causal interactions in an economy. The test results show that labor and economic stability are bidirectional causal to each other. We find a significant positive coefficient from labor to economic stability (1.200***), indicating that increases in labor positively affect economic stability, perhaps because of higher productivity and economic output. However, the negative coefficient from economic stability of labor (-0.800***) tells us that instabilities in economics will cause lower labor efficiency or unemployment because of the feedback loop of how an economic downturn will affect the labor market negatively. Moreover,

capital ranks with a very strong positive effect on economic stability (0.600***), strongly emphasizing capital investment as a key economic growth driver by expanding infrastructure, technology and productive capacity. The negative coefficient from economic stability to capital (-0.350**) suggests that a weakening economy may result in lower levels of investment and capital accumulation, potentially stalling future growth.

Negative coefficients in both directions between land use and economic stability (-0.450** from LU to ES and -0.200* from ES to LU) suggest that inefficient land use or degradation may detract from economic performance, and a faltering economy might further exacerbate poor land management practices. Water resources show a positive effect on economic stability (0.900**), highlighting the importance of water management in sectors such as agriculture and industry, particularly in water-scarce regions. The negative impact when economic stability declines (-0.600**) points to the vulnerability of water resources management under economic stress. The strong positive impact of agricultural productivity on economic stability (1.250***) confirms the sector's role as a fundamental pillar of economic health, particularly in economies reliant on agriculture. A decline in economic stability significantly impacts agricultural output (-0.950**), likely due to reduced investment in and attention to agricultural development during economic downturns.

Food security also positively influences economic stability (0.710*), emphasizing that a secure, stable supply of food supports broader economic stability. Conversely, economic instability negatively impacts food security (-0.340*), suggesting that economic challenges can lead to increased food insecurity. Innovation significantly boosts economic stability (1.350***), reflecting the critical role of technological and process innovations in driving economic growth and efficiency. A decrease in economic stability leads to a notable reduction in innovation activities (-1.020***), potentially due to reduced funding and support for innovation during economic downturns. Finally, R&D activities positively affect economic stability (0.810***), highlighting their importance in fostering long-term economic growth through technological advancements. The negative feedback from economic stability to R&D (-0.370**) indicates that economic contractions could hinder investment in and execution of R&D activities. Figure 2 presents the graphical presentation of these results.

Table 8
Granger Non-Causality Test

(source: Author's own elaboration)

Null hypothesis	HPJ Wald Test	Coeff
L to ES	250.45	1.200***
ES to L	190.32	-0.800***
K to ES	320.27	0.600***
ES to K	180.15	-0.350**
LU to ES	48.21	-0.450**
ES to LU	60.78	-0.200*
Water to ES	55.98	0.900**
ES to Water	75.43	-0.600**
Agri to ES	290.99	1.250***
ES to Agri	270.45	-0.950**
FS to ES	112.34	0.710*
ES to FS	130.76	-0.340*
Innov to ES	325.4	1.350***
ES to Innov	303.22	-1.020***
R&D to ES	298.11	0.810***
ES to R&D	279.66	-0.370**
Notes: ***, ** and * shows the significance level at 1%, 5%, and 10% respectively.		

4.8. Discussion

The first objective is about the impact of changes in land characteristics on economic stability. The results demonstrate that changes in land characteristics have a significant impact on the economic stability of Saudi Arabia, especially in terms of land use efficiency and environmental management. The negative coefficients for both directions between land use and economic stability suggest that inefficient or unsustainable land use practices could detract from economic performance. This is consistent with the findings of (Barbier, 2010), who highlighted that poor land management could lead to decreased agricultural outputs and lower economic growth, particularly in regions where agriculture plays a significant economic role. The post-Vision 2030 scenario, with its focus on sustainable land use and environmental conservation, shows potential improvements in this relationship, reflecting a strategic shift towards sustainable development practices in line with Saudi Arabia's Vision 2030 objectives.

The second objective is regarding the effect of changes in food characteristics on economic stability. Models ARDL and non-linear ARDL demonstrate the positive effect of agricultural productivity on economic stability, which confirms the importance of the agricultural sector in Saudi Arabia. FAO's view of the significant role agricultural development plays in economic stability and the consequent economic stability in Middle Eastern economies (Amire & Temitope, 2016) can be attributed to such enhancements in agricultural productivity as directly enhancing economic growth. Declines in agricultural output have had a significant negative effect on the economic stability; that is, the Saudi Arabian economy is sensitive to such changes. In particular, the pre-Vision 2030 analysis revealed that Vision 2030's initiatives to raise agricultural techniques and food security bear the potential to mitigate these risks.

The third objective is about changes in structural characteristics and their impact on economic stability. Changes in the structural characteristics of innovation and R&D have shown a dramatic effect on economic stability. Increases in innovation and R&D activities have strong positive influences on economic stability; innovation and efficiency upgrades strengthen the economy through growth. This is consistent with the finding of (Maradana et al., 2017) that those economies which invest in innovation and R&D do so because they become more productive and attain a competitive advantage, thereby leading to higher growth rates. However, the negative impact of these activities when they are reduced also points to a need for continued investment in these areas, which is a strategic element of Vision 2030.

The fourth objective of the study is about the impact of these factors on Pre- and Post-Vision 2030. Comparing pre- and post-Vision 2030 scenarios reveals a marked enhancement in the economic impact of structural factors such as innovation and R&D post-Vision 2030. This suggests that Vision 2030's initiatives to bolster innovation and diversify the economy are likely to enhance Saudi Arabia's economic resilience and stability. The improvements in land and food models post-Vision 2030 indicate a strategic shift towards more sustainable and efficient practices, likely leading to a more robust economic framework capable of withstanding global economic shifts and internal vulnerabilities.

5. CONCLUSION

This paper analyses the effects of different economic factors on the stability of the Saudi Arabian economy, ranging from 1990 to 2023. ARDL bound testing and non-linear ARDL are employed to study the effects of land characteristics, food characteristics and structural characteristics on economic stability. In our results, we find considerable insights regarding the variables' relationships and the effect of these variables on economic performance in terms of Saudi Arabia's changing economic landscape. The analysis has proven that various economic elements, such as land use and management practices, do influence economic stability by just causing economic insecurity when they are inefficient or unsustainable. This is a major reason why instituting good land management and sustainable agricultural practices as part and parcel of economic policy is of the essence. The results also show that improvements in agricultural productivity are directly and positively related to economic stability, emphasizing the importance of the agricultural sector in the Saudi Arabian broader economic framework.

Our study indicated that structural characteristics, innovation, and research and development activities have a significant positive effect on economic stability. This finding is consistent with the thought that technological advancement and innovation play an important role in sustaining long-term economic growth and stability. On the other hand, reductions in these activities represent a risk to the economic framework, requiring an ongoing investment in R&D and innovation. The examination of the pre-and post-Vision 2030 scenarios illustrates that if strategic initiatives set by Vision 2030 to ensure economic diversification and sustainability are implemented, then the positive impacts of these economic drivers will be strengthened in terms of stability. We provide empirical support for the efficacy of these Vision 2030 reforms by enhancing observed improvements in the model estimations post-Vision 2030.

5.1. Policy Implications

These findings offer significant evidence to policymakers in Saudi Arabia to opt for and carry out economic strategies. Agricultural productivity and land use are two important areas which contribute immensely to economic stability, hence necessitating policies promoting efficient agricultural and sustainable land management. Policymakers should think about spending money on modern agricultural technologies that bring higher yields at the least expense of environmental resources. Water conservation and land restoration initiatives could also serve a major role in increasing land use efficiency, which is important for the sustenance of agricultural economic stability. Similarly, the positive match between innovation and the supportive environment of research and development (R&D) and sustaining an economy highlights the importance of providing a supportive environment that encourages innovation and technological transfer. That could mean increased funding for R&D activities, the development of technology hubs, and university-industry partnerships. Critical, given Saudi Arabia's transition to achieve Vision 2030 objectives, which involves diversifying the economy and reducing dependence on oil, is to ensure continued investment in these areas. Lastly, Vision 2030 reforms seem to indicate that adaptive policy

measures are necessary that will respond to economic feedback and global trends. Policies should be nimble and future-oriented, which helps establish a resilient economic structure that can work with and benefit from global economic dynamics.

5.2. Limitations

Although this study is comprehensive, it is limited by the breadth and character of the data used. From 1990 to 2023, the dataset charts Saudi Arabia's transition in its economy but may have left out the details of late policies within Saudi Arabia after 2023, which directly affects the long-term economic stability. In addition, though the ARDL and non-linear ARDL models are powerful analysis tools, they inherently assume that the relationship between variables is linear, whereas, in a complex, dynamic economy like the Kingdom of Saudi Arabia, relationships are not linear. Another assumption is that past trends and relationships will continue unchanged into the future, an assumption that no longer holds a reasonable basis in a rapidly transforming economic and global context. Additionally, the study does not concentrate much on microeconomic variables or the unique sectoral dynamics and political/socioeconomic factors that could shape economic exercises.

5.3. Future Research Directions

Future research could build upon this study by incorporating more recent data post-2023 to evaluate the immediate effects of Vision 2030 reforms on economic stability. It would be beneficial to employ models that can handle non-linear dynamics to better capture the complex relationships between economic variables. Additionally, expanding the scope to include microeconomic data and qualitative assessments would provide a more holistic view of the economic changes. Investigating the impacts of external global economic pressures and integrating geopolitical factors could also yield deeper insights into Saudi Arabia's economic resilience. Further studies could explore sector-specific policies, particularly in emerging industries such as renewable energy and technology, to assess their individual contributions to economic stability. Lastly, comparative studies with other GCC countries undergoing similar economic transformations could offer valuable regional insights and policy implications.

Declarations

Conflict of interest statement

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Ethical approval:

We confirm that this manuscript describes original work and is not under consideration by any other journal. Please let us know if you need any other information.

Author Contribution

Mohd Saeed Khan has designed the main idea and drafted the manuscript. Suleman Sarwar has done the analysis. Hussam Bakoben has reviewed and corrected the manuscript. Ghazala Aziz has helped in writing and data collection.

Data Availability

All relevant data will be provided on reasonable demand.

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Figures

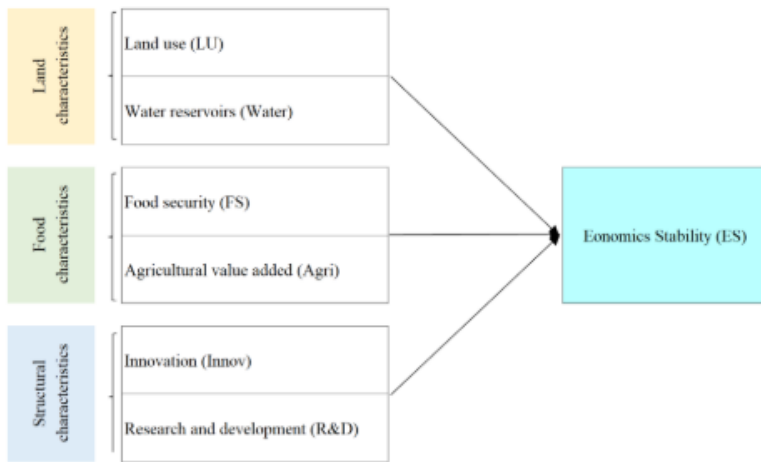


Figure 1

Graphical form of the models (source: Author's own elaboration)

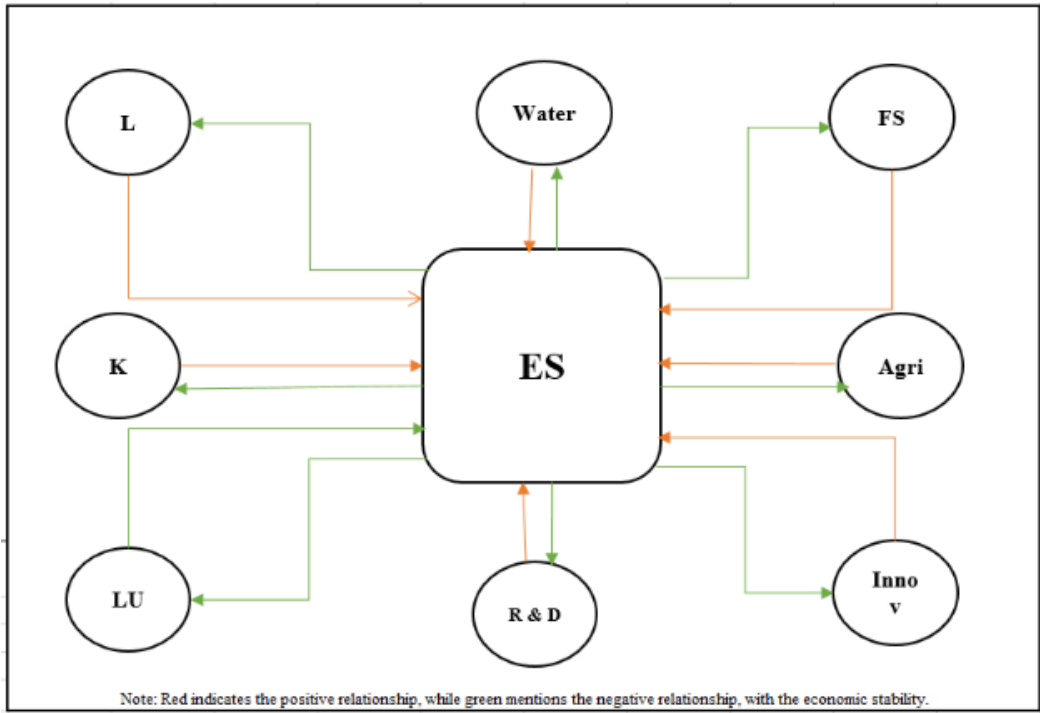


Figure 2

Graphical presentation of Granger non-causality test. (source: Author's own elaboration)