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ORIGINAL PAPER

Determining the impact of economic indicators on water, energy and food nexus for sustainable resource security

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Abstract

Water, energy, and food are economic resources whose security and sustainability affect human livelihood. This paper is dedicated to exploring the influence of economic indicators on the security and sustainability of these resources within the water–energy–food (WEF) nexus. The research employed a quantitative approach, gathering data through a structured questionnaire from 282 WEF management professionals in South Africa. The collected data were subjected to statistical analyses, including mean score ranking, exploratory factor analysis (EFA), confirmatory factor analysis (CFA), and structural equation modeling (SEM) using EQS and SPSS software. The results of this study highlight the significant impact of economic indicators on the sustainable security of WEF resources. The mean ranking revealed that there is a need to understand people's economic power for resource sustainability. The CFA and SEM analyses identify four key economic indicators that influence resource security: WEF resource pricing mechanisms, employment rates in the WEF sectors, WEF resource importation, and WEF resource exportation. In conclusion, managing economic indicators within the WEF nexus calls for strategic investment based on comparative advantage. The study provides valuable policy recommendations to support this approach.

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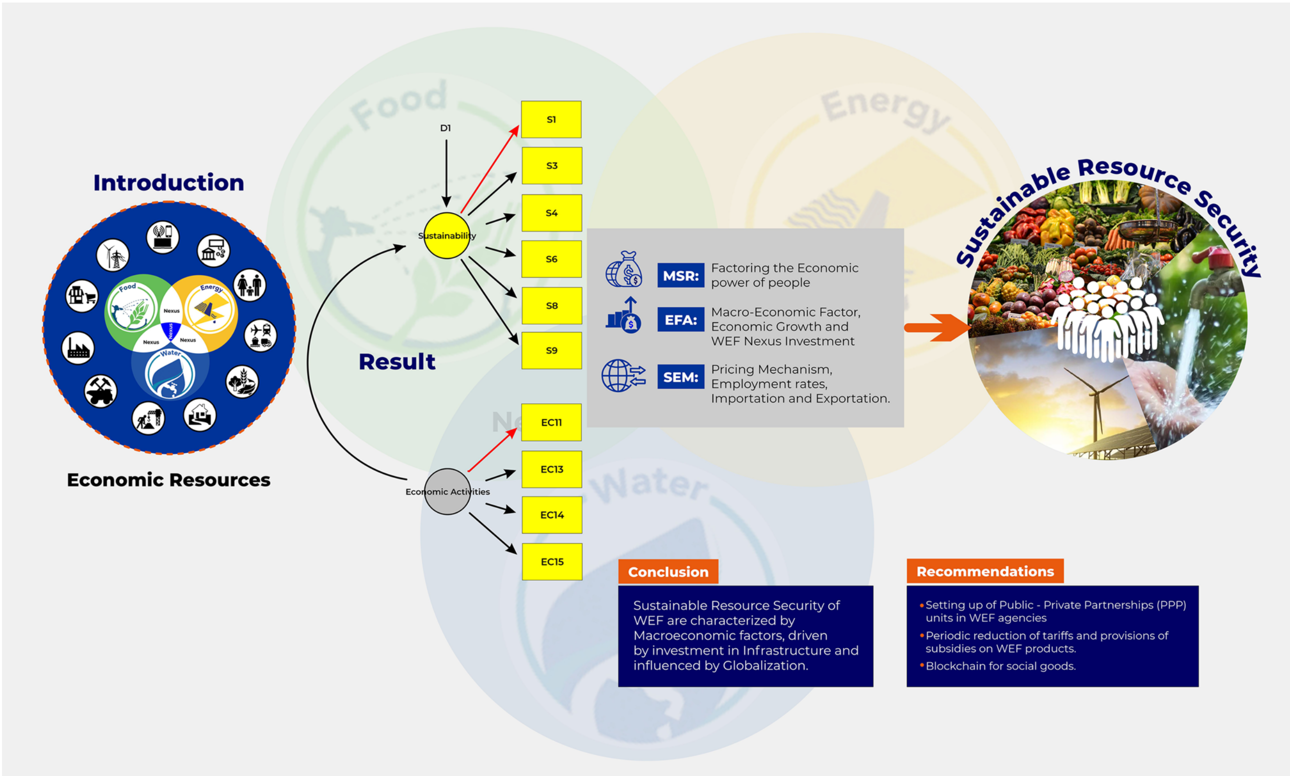
Graphical Abstract



Keywords Economic indicators · WEF nexus · Economic growth · Sustainable resource security

Introduction

The trio of water, energy, and food resources stands as indispensable resources that determine the economic trajectory of any nation. The interrelationship, synergies, and trade-offs among these resources have given rise to the integrated concept known as the water, energy, and food nexus, as elucidated by various scholars (Hoff 2011; Qi et al. 2021; Sun et al. 2021; David et al. 2022). Rakitskaya's (2021) research delves into the interconnectedness of the WEF nexus and its pivotal role in fostering sustainable economic development within a nation. Failure to manage these interlinkages could potentially result in the insecurity of water, energy, and food resources, casting a shadow on their long-term sustainability. A failure to manage the nexus sustainably could disrupt the availability and stability of these resources, both of which are indispensable inputs for all economic processes. Conway et al. (2015), in their exploration of the inter-regional economic implications of WEF resources, shed light on the potential for countries in Southern Africa to contribute to WEF stability in regions grappling with resource shortages due to climate change anomalies. This underscores the significant influence of macroeconomic indicators on an economy, particularly concerning aspects such as resource importation, exportation, prices of WEF goods/products, inflation rates, and the dimensions of international trade. Additionally, Conway et al. (2015) research brings to limelight the role of microeconomics in shaping the dynamics of supply and demand for water, energy, and food resources and highlights how these dynamics directly affect household consumption patterns.

Moreover, Markantonis et al. (2019) explained the relationship between the WEF nexus and economic indicators stating that through the perspective of the nexus, economic growth is possible, as the nexus can ensure fair distribution of WEF resources, reduced transactional costs among the nexus sectors, enhance pricing mechanism within environmental, cultural, and social values, increased investment on technological Research and Development (R & D) in the nexus thereby creating employment opportunities and strengthening institutional arrangement, which leads to sustainable resource security. Blandford (1990) expressed the view that agriculture plays a pivotal role in propelling a nation's economic growth. It achieves this through several means, including supplying essential food for human sustenance, furnishing vital raw materials for various industrial sectors, contributing significantly to the Gross Domestic Product (GDP), and generating employment opportunities. According to the authors, the nexus between Agri-Food resources and economic growth serves as a vital input of environmental performance in areas such as air quality, biodiversity, forestry, and land use. The United Nations (2013) and Mpundu and Bopape (2022) opined that Agriculture is an essential economic activity ensuring the security of food production, income provision, and livelihood sustenance. The Agri-Food resource of the WEF nexus is the foundation of economic activities as the source of all raw materials in producing varieties of products. This economic activity also drives the WEF nexus in determining the production level and consumption rate of different resources and, through various micro- and macro-economic tools, balances the supply and demand of Agri-Food resources. In their review of forty-six (46) articles, the research of Bhuiyan et al. (2022) noted that energy resources, either renewable or non-renewable resources, contribute to and drive economic growth. Also, energy has always been a source of economic growth, as opined by the research of Asghar (2008), which showed an instrumental relationship between economic growth and energy resources via GDP. Energy resources are the fulcrum of economic activity. It is a major economic lubricant that aids in the conversion of other resources and raw materials into finished products of other sectors of the economy. Also, the variations, market forces, and international trades affect the resources' prices, demand, stability, and supply. Also, due to the energy mix and power generation mix, economic activities differ from one country to another. Moreover, the research of Berry (2008) compared the wealth of a nation to the availability of water, which thus stimulates economic activities due to the indispensability of usage to all forms of life. Mukherjee (2016) corroborated in UNESCO (2019), in assessing the relationship between economic development and water resources, opined that the challenges of water scarcity, water pollution, level of water utilization, and increase in water demand have an impact that is opposed to economic growth. Water resources are a resource stabilizer that is indispensable in producing other resources, thereby exercising both intrinsic and physical value on economic activities.

However, there is a paucity of research on the association between the indicators of an economy and the nexus of the three resources of water, energy, and food. Previous studies, exemplified by the works of Rakitskaya (2021), Al-Riffai et al. (2017), Conway et al. (2015), and Markantonis et al. (2019), predominantly regarded the WEF nexus as a contributing factor, a stabilizing force, and an environmental influencer on the economy. However, this study unveils a critical research lacuna pertaining to the influence of economic indicators on the water, energy, and food nexus, with a particular emphasis on sustainable resource security. Prior research primarily concentrated on elucidating how these resources contribute to the economy while largely overlooking the role played by economic indicators. This observation forms the foundation for the following research questions:

a. What are the economic indicators that affect water, energy, and food nexus sustainable resource security?
b. What is the impact of economic indicators on water, energy, and food nexus for sustainable resource security?

To address these research inquiries, the study employed two distinct statistical methodologies. The first research question was resolved through mean score ranking, while the second question was answered through more intricate inferential statistics employing structural equation modeling (SEM). Consequently, tackling these research questions has the capacity to trigger economic solutions dedicated to establishing and preserving sustainable resource security. This involves protecting these three vital resources, not only for the current generation but also for future generations, to ensure their stability, affordability, and availability. It is worth noting that the instability of these resources has been recognized as a global risk by the United Nations (Walker 2020). Moreover, achieving sustainable resource security for water, energy, and food resources plays a significant role in addressing a wide range of urgent global challenges. These challenges include but are not limited to, eliminating hunger, mitigating water scarcity, preventing energy depletion, enhancing public health, and promoting a sustainable economy (Shannak et al. 2018).

Moreover, comprehending the impact of various economic indicators on the nexus between these three resources aids in effectively managing the escalating demand for them. For instance, considering the accelerating global population growth, the impacts of climate change on resources, and the expanding consumption habits of the middle class, the United States National Intelligence Council (USNIC 2012) issued a forecast in December 2012 concerning global trends in 2030. According to this projection, by 2030, global water demand is anticipated to rise by 40%, energy demand by 50%, and food demand by 35%. Also, the United Nations anticipates a 60% surge in food production to accommodate an estimated global population of 9.8 billion people by 2050 (Da Silva 2012). This is as energy consumption on a global scale is expected to increase by nearly 30% by 2040 (IEA 2017). Additionally, the Food and Agricultural Organization (FAO 2015) projects that between 2000 and 2050, food demand in Africa will triple due to improved dietary habits and population growth in the region. Furthermore, energy demand in Africa is expected to double from 500 million tons of oil equivalent (mtoe) in 2000 to 1000 mtoe by 2030. Given the projected population increase in Africa, which is set to rise by nearly 50% of its current population by 2030, water demand in the region is expected to nearly quadruple, surpassing the growth rates observed in other parts of the world (Jacobsen et al. 2013). In essence, addressing these demands and challenges constitutes a response to sustainability questions for future generations, encompassing the security and well-being of the three vital resources, as we are seven (7) years into 2030, seventeen (17) years into 2040 and twenty-seven (27) years into 2050. Thus, this study seeks to contribute to managing the three resources with cognizance to their nexus, thus achieving the various resource security definitions put forth by IEA (2014) for energy, UN-WATER (2013) for water, and FAO (2014) for food.

Moreover, understanding the influence of economic indicators, as well as the nature of these indicators, on the three critical resources, plays a pivotal role in ensuring the sustainability of food, energy, and water resources. Vagsholm et al. (2020) and Helland and Sörbö (2014) assert that sustainable food security encompasses various facets, including ensuring an adequate supply of food, its availability, accessibility, affordability, nutritional adequacy, and stability—all while safeguarding environmental integrity. Prasad et al. (2019) contend that sustainability in the realm of energy is contingent upon increasing energy generation from renewable sources, which do not adversely impact the environment through carbon emissions, thus catering to the needs of both current and future generations. Similarly, Mejia et al. (2012) and the American Society of Civil Engineers (ASCE 1999) posit that water sustainability revolves around the capacity of water resources and services to meet current and future water demands without degrading the overall system. These diverse perspectives on the sustainability of water, energy, and food resources collectively underscore the significance of economic indicators. That is, the better the economic indicators, the higher the sustainable resource security of the three resources. This is because only a booming economy can assure WEF sustainability and security. In other words, when a country's economy is performing well and its economic indicators are positive, it is more likely to achieve higher levels of security and sustainability for its water, energy, and food resources.

The cardinal objective of this paper is to determine the impact of economic indicators on the water, energy, and food nexus for sustainable resource security and to determine the type of economic indicators that affect the WEF nexus for sustainable resource security. Achieving these objectives led to the following contribution from the study:

a. Established the need for friendly economic policies to ensure sustainable resource security.
b. Highlighted impactful economic indicators that affect water, energy, and food resources.
c. Established the role of macro-economic factors on the interaction of the three resources.
d. Highlight and promote water, energy, and food resources that need investment commitment.
e. Highlight the need for an increase in the economic power of people for sustainable resource security.
f. Established the statistical mechanism of EFA, CFA, and SEM as it relates to resource sustainability.

As a result, the paper is organized into six distinct sections. In the second section, we provide an overview of the water, energy, and food nexus concept, emphasizing its role in ensuring sustainable resource security. Moving on to the third section, we delve into economic indicators and their measurement methods. The fourth section outlines our research methodology, encompassing the quantitative study's nature, sample size, and data analysis approach. Section five is dedicated to presenting our study's findings, where we thoroughly discuss both descriptive analysis and inferential statistics. In the sixth section, we embark on a detailed exploration of the findings' implications, including an examination of respondents' demographic characteristics and the impact of economic indicators on the WEF nexus for sustainable resource security. Concluding our paper, the seventh section encapsulates the study's findings and policy recommendations.

Water, energy and food (WEF) nexus for sustainable resource security

The WEF nexus are adequately described in Fig. 1, by Endo et al. (2015), whereby an individual resource is an input for another resource. According to the authors, the nexus relationship is seen in utilizing one resource for the production and efficiency of the other resources. Also, Bhaduri et al. (2015) stated that these interactions are now driven by joint demand, price development, resource constraints, and technology. This further shows that the consumption of one resource stimulates the consumption of other resources. Moreover, from the viewpoint of economics, it means that the resources are both competing and complementary resources affected by the law of demand and supply. Moreover, Hoff (2011) at the Bonn conference opined that the interlinkages and interdependencies between these developmental resources bring about nexus thinking. Also, Weitz et al. (2014) opined that nexus interactions are "*about how we use and manage resource systems, describing interdependencies (depending on each other), constraints (imposing conditions or a trade-off), and synergies (reinforcing or having a shared benefit).*" In projects involving any of the

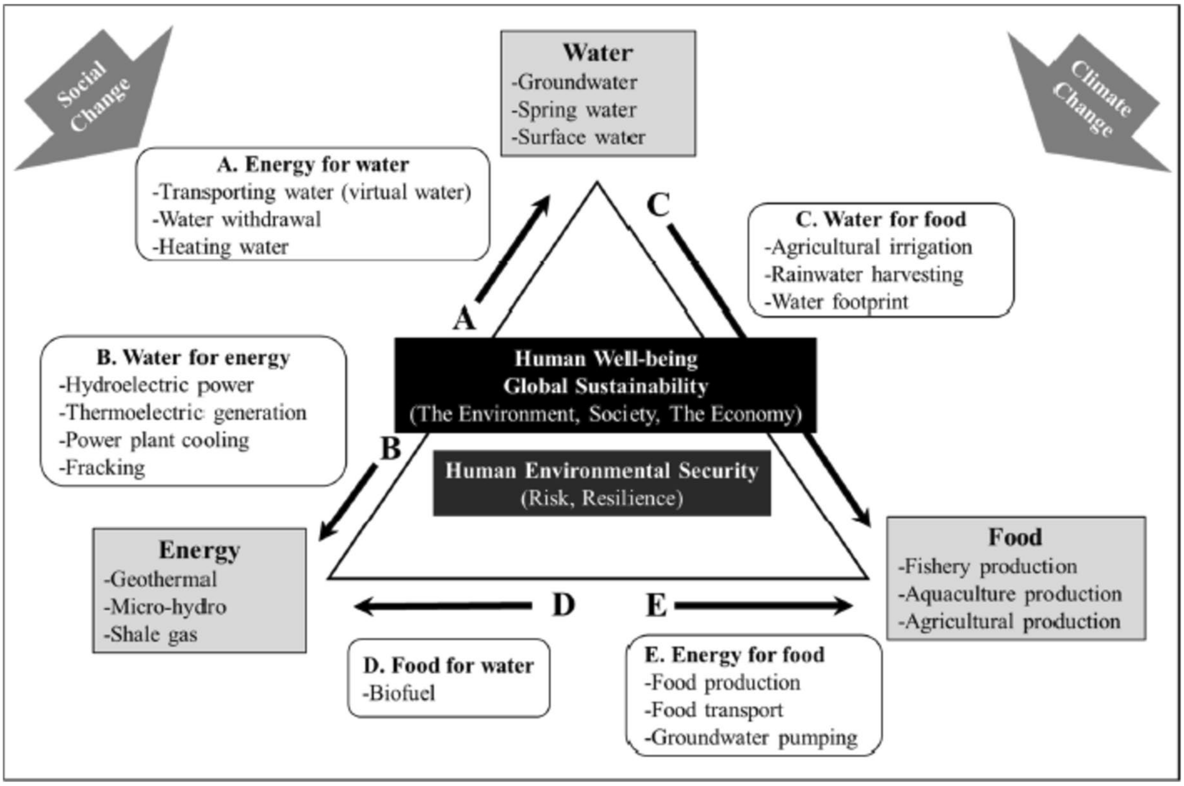


Fig. 1 WEF project dynamics of RHIN project (Endo et al. 2015)

resources, nexus has brought about the need not to consider the resources as separate entities but as being complex, and inextricably entwined (European Commission 2018).

The World Economic forum (2011) opined that nexus presents a better approach to understanding the relationship between resource security, economic disparity, and environmental pressures, highlighting the economic and social dimensions of development. Bazilian et al. (2011) stated that the nexus would contribute to developmental goals in deforestation, energy access, biofuels, irrigation, hydropower, food security, and provision of water through desalination. The WEF nexus entails understanding the tradeoffs, interrelation, and resource struggle associated with WEF for Sustainable Development (Cansino-Loeza and Ponce-Ortega 2021; Abulibdeh and Zaiden 2020). Pueppke (2021) pronounced that the WEF nexus is about the expansion of the benefits of the synergies among the three resources while avoiding the drawbacks of WEF trade-offs by transferring attention from the resource competition to their shared benefits. Ogbolumani and Nwulu (2021) also stated that the WEF nexus ensures resource allocation doesn't have catastrophic consequences on the resources and the consumers. David and Adepoju (2021) posit further that the nexus is a global action for uniting the mechanisms of achieving the security of the resources. Also, Zarei et al. (2021) stated that the nexus encompasses economic, social, environmental, and political factors that must address infrastructural planning as WEF activities have ecological impacts such as declining groundwater levels, degradation of rivers, water pollution, carbon emission, deforestation, air pollution, raising the water temperature, killing aquatic animals, and GHG emission. The ADC (2015) also explained that the nexus entails the development of stakeholders' capacity at all levels, including specific technical assistance, training, and efforts to strengthen analytical and system thinking in WEF project complexity. The United Nations avers that the WEF nexus is a policy tool for managing the joint demand for the three resources and the attendant challenges of allocation (FAO 2014).

The WEF nexus has shown that it is a resource security mechanism that can be sustainable, which implies that the major outcome of the nexus approach is the sustainability of the resources. This entails the equitable availability of resources inter-generationally and intra-generationally with the promotion of socio-economic activities and ensuring environmental integrity (Stoddart 2011). This sustainability dynamics can be measured using the three dimensions of sustainability: economic, social, and environmental sustainability (Khan 1995; Mensah 2019). According to the authors, economic sustainability deals with achieving economic prowess without altering or causing ecological disturbances, whereas social sustainability entails the effect of decisions on the people and their cohesiveness, whereby environmental sustainability focuses on the preservation of the ecosystem.

So, within the context of sustainable resource security related to the water, energy, and food nexus, as deduced from the studies by Rakitskaya (2021), Al-Riffai et al. (2017), Conway et al. (2015), and Markantonis et al. (2019), the dimensions of sustainability were aligned with the WEF nexus, marking this as the first paper on the subject matter. Therefore, the economic sustainability measures entail conversion and recycling of WEF resources to waste, environmentally friendly production, eco-friendly supply chain, utilization of cleaner production mechanism, sustainable production mechanism, accounting value of WEF resources, a friendly import–export ratio, potentiality of increasing employment opportunities and production of more innovative products. WEF nexus in social sustainability entails training employees on nexus thinking, eco-friendly location of the production factory, enhancement of competent leadership, a stable political environment, promotion of stakeholder consultation, promotion of good working conditions, promotion of health and safety codes, optimization of labor laws, re-organization of societal norms, and digitalized procurement mechanism. Environmental sustainability measures from the WEF nexus include adequate environmental impact assessment, recycling, and reusability of food waste, reduction of greenhouse gas emission, enhancement of waste management, enhancement of energy efficiency, water sustainability, promotion of climate change management strategies, reduction of biodiversity loss, promotion of afforestation, and promotion of green investment.

Economic indicators

The Bonn Conference of 2011, where Hoff (2011) first proposed the WEF Nexus, was a conference about improving the standards of living of people of the world from a green economy perspective, highlighting the symbolic effect of economic growth of a nation and the sustainable security of water, energy and food resources. The WEF resources, considering their critical roles as economic boosters, economic stabilizers, and economic stimulants, necessitate understanding the extent of the role of economic indicators, which can be determined via the level of economic growth of a nation beyond its gross domestic product.

Generally, economic growth has been perceived and conceptualized as the increased rate of producing economic goods and services over time. According to the research of Haller (2012), economic growth is a long-run phenomenon that is complex in measurement, the performance of an economy, and subjected to constraints such as population, resource constraint, inadequate infrastructure, difficulties from the institutional framework, and government. According to the author, economic growth is determined by the efficiency in the utilization of resources and the increase in the production capacity of a country, facilitating the redistribution of wealth between the society and the population. According to the Department for International Development (2007), economic growth aids in moving people out of poverty, increases employment opportunities, optimizes human development endeavors, improves education and health, and transforms society.

In research, various methodologies have been employed to evaluate economic growth, with gross domestic product (GDP) often taking precedence as a fundamental measure. However, Skare and Rabar (2017) introduced a set of distinctive economic indicators used to assess the underpinnings of economic growth within Organization for Economic Cooperation and Development (OECD) countries. These economic indicators encompass multiple facets of the economy pertinent to the WEF nexus. According to the authors, these indicators can be broadly categorized into two main groups. The first category is constituted by macro-economic indicators, encompassing parameters such as real per capita GDP, inflation rates, unemployment rates, and the exports/imports cover ratio. The second category encompasses social, institutional, and environmental indicators, such as public health expenditures, scientific research publications, CO_2 emissions, and the representation of women in national parliaments. However, for the purposes of this study, the aforementioned Skare and Rabar (2017) eight (8) economic indicators were adapted and contextualized based on the works of Hoff (2011), Haller (2012), and the Department of International Development (2007). This led to the indicators used for measuring and analyzing the relationship between economic factors and resource security in the WEF nexus. They are Citizens' standards of living, Government subsidies, Availability of labor (skilled and unskilled), Investment in WEF infrastructure, Importation of WEF resources, Exportation of WEF resources, Price mechanism of WEF resources, Employment rate in WEF sectors, Economic incentives, Gross domestic product index, Inflation rate affecting WEF interactions, Carbon emission tax, Taxes on WEF resources production, private company's activities, Taxes on WEF resources distribution, tax relief initiatives and taxes on WEF resources consumption rate.

Methodology

This paper employed a quantitative research approach to examine the influence of economic activities on the water, energy, and food nexus. Data for this study were collected through the distribution of a questionnaire to management personnel in South Africa's water, energy, and food departments. The questionnaire employed a five-point Likert scale, in line with recommendations from Sekaran (2003) and Aaker et al. (2009). The Likert scale consisted of two categories: the first category (1—To no extent, 2—Small extent, 3—Moderate extent, 4—Large extent, and 5—Very large extent) assessed the degree of impact of economic activities on the water, energy, and food nexus. The second category (1—Strongly disagree, 2—Disagree, 3—Neither, 4—Agree, and 5—Strongly Agree) gauged respondents' agreement levels regarding how the nexus can contribute to sustainable resource security in terms of economic, social, and environmental sustainability.

The study population consisted of management personnel within South Africa's water, energy, and food resource sectors, as outlined in Table 1, sourced from the annual reports for 2018/2019, 2019/2020, and 2020/2021. The sample size, determined using Yamane's (1967) formula and Bowley's Proportional Allocation Formula (1962), was calculated to be two hundred and eighty-two (282), with allocation details presented in Table 1.

The research analysis encompasses both descriptive and inferential statistics, employing techniques such as percentages, frequencies, Mean ranking EFA, CFA, and SEM. The first objective was achieved using EFA, CFA and SEM, while the second objective was analyzed using Mean ranking. These analytical tools were chosen to construct a comprehensive model for a detailed examination of the relationship between economic indicators and sustainable security measures within the WEF nexus. This selection is grounded in recommendations derived from Aigbavboa (2014), Bentler (2006), and Kline (1998). To conduct the analysis, two statistical software packages were utilized: Statistical Package for the Social Science (SPSS) version 27 and Equations (EQS) version 6.4. It is noteworthy that before engaging in SEM, an EFA is routinely performed, aligning with the methodology outlined by Aigbavboa (2014) and Ogunbayo (2021). EFA serves as a preliminary step in SEM, as further affirmed by Rehbinder (2011), who emphasized its role in identifying underlying factors that explain correlation patterns among observed variables, thereby streamlining data.

Following the EFA, confirmatory factor analysis (CFA) is carried out for the remaining variables. Notably, during the CFA, the variables are subjected to Satorra-Bentler statistics (S-Bχ^2), accessible within EQS, as it offers greater accuracy compared to conventional Chi-Square test statistics, as highlighted by Byrne (2006) and Bentler (2006). Furthermore, the EQS software employed in this research offers a robust maximum likelihood (RML) estimation method, as mentioned by Kline (2005) and Musonda (2012), to ensure the robustness of fit indexes, as displayed in Table 5, prior to establishing a model between the variables.

Findings

Descriptive statistics findings

Table 2 illustrates that the study garnered responses from a total of 254 respondents, resulting in an impressive response rate of 90.07% in comparison with the designated sample size of 282. This response rate aligns with the criteria established by Kline (2005), Aigbavboa (2014), and Ogunbayo (2021) as acceptable for conducting structural equation modeling.

Inferential statistics findings

Table 3 displays the hierarchical ranking of different economic indicators within the WEF nexus, with the top three indicators being Citizens' standards of living (4.15), Government subsidies (4.08), and Availability of labor (4.06), all reflecting a pronounced and substantial impact on the nexus. In contrast, the lowest-ranked indicators include taxes on WEF resources on consumption rate (3.42), Tax relief initiatives (3.48), and Taxes on WEF resources on distribution (3.59), indicating comparatively lesser effects within the nexus.

Table 4 presents the preliminary analysis, depicting the significant findings related to the attributes of economic indicators, with a *p* value of 0.000 from Bartlett's test of sphericity and a KMO (Kaiser–Meyer–Olkin) value of 0.884. This statistical evidence underscores the appropriateness of the conducted EFA (Explanatory Factor Analysis), aligning with the recommendations of Field (2005) and Kline (2005). Moreover, the correlation values of the indicators in Table 4

Table 1 Population and sample size allocation

S/N	Agencies, Ministry/Departments	Population	Proportion	Sample size allocation
1	Ministry of Agriculture, Land Reforms, and Rural Development	406	0.426*281.7	120
2	Ministry of Mineral Resources and Energy	254	0.266*281.7	75
3	Ministry of Water, and Sanitation	293	0.307	87
	Total	953 Population		282 Sample size

Source: Researcher survey (2022)

Table 2 Respondents' demographic characteristics

Features	Frequency	Percentage (%)
Gender		
Male	100	39.4
Female	154	60.6
Age group		
20–30 years	94	37.0
31–40 years	82	32.3
41–50 years	78	30.7
Years of experiences		
< 5 years	95	37.4
5–10 years	36	14.2
11–15 years	68	26.8
16–20 years	3	1.2
Above 20 years	52	20.5
Educational qualification		
B.Sc/B. Tech/B. Eng	106	41.7
Honors	58	22.8
Masters	41	16.1
PhD	34	13.4
Others	15	5.9
Sector of operation		
Water	99	39.0
Energy	70	27.6
Food/ Agriculture	85	33.5
Designation		
Low Level Management	51	20.1
Middle Level Management	162	63.8
Top Level Management	41	16.1
Familiarity with WEF Nexus		
Yes	191	75.2
No	63	24.8
Total	254	100%

Source: Researcher survey (2022)

exceed the recommended threshold of 0.3, as suggested by Somiah (2019), confirming the robustness of the measured elements. Additionally, the calculated Cronbach's Alpha value of 0.875 surpasses the minimum threshold of at least 0.7, as advised by Nunnally and Bernstein (1994), affirming the accuracy of the factor analysis and its suitability for further analysis, specifically CFA.

The EFA pattern matrix in Table 4 extracted three distinct components: Component 1 comprising 5 items, while Component 2 and Component 3 each included one item. The loading factors for these items exceeded the recommended value of 0.4, as per Field (2005), justifying their retention for subsequent investigations. Notably, Component 1 exhibited an eigenvalue of 4.121 (% of the variation of 58.872), Component 2 had an eigenvalue of 0.917 (% of the variation of 13.098), and Component 3 had an eigenvalue of 0.709 (% of the variation of 10.122). These combined eigenvalues explained a substantial 82.092% of the variance in the data, as outlined in Table 4, providing compelling evidence for convergent validity. Furthermore, examining the interrelationship of these components in Table 4 along with their indicators, Component 1 was labeled as "WEF Nexus Macro-economic Factors," Component 2 as "Economic Growth of WEF Nexus," and Component 3 as "WEF Nexus Investment."

Structural equation modeling

Confirmatory factor analysis of the variables

(i) Economic activities for CFA

Following the initial EFA to assess variable correlations, we proceeded to conduct CFA. In this phase, we incorporated the responses from the 254 questionnaire participants into the EQS software, encompassing 18 observed variables related to economic indicators. However, after a comprehensive review using the Satorra-Bentler analysis, we determined that 14 of these indicators were redundant and subsequently removed, resulting in the retention of 4 key economic indicators. This selection was made in accordance with the guidelines established by Byrne (2006) and Joreskog and Sorbom (1988), which stipulate that CFA variables should exhibit symmetry and be centered around zero. Subsequently, the four retained indicators yielded a residual covariance matrix exceeding the critical threshold of 2.58, affirming their convergent validity, consistent with the insights of Aigbavboa (2014) and Byrne (2006). These remaining indicators are identified as EC11, EC13, EC14, and EC15, as visualized in Fig. 2.

The four dependent indicator variables for economic indicators construct were the prices mechanism of WEF resources, the employment rate in WEF sectors, the importation of WEF resources, and exportation of WEF resources.

(ii) WEF Nexus sustainable resource security CFA.

Additionally, the analysis extended to the sustainable resource security indicators within the WEF nexus. After completing the EFA, this set of indicators underwent CFA separately from the economic indicators. Initially comprising 31 observed variables, this group was refined to just 6, as 25 variables were deemed unnecessary and subsequently excluded. This reduction was made in accordance with the criteria for symmetry and convergent validity of the Satorra-Bentler analysis as advised by Aigbavboa (2014), Byrne (2006), and Joreskog and Sorbom (1988). The final selection yielded 6 essential variables, denoted as S1, S3, S4, S6, S8, and S9, as depicted in Fig. 3.

Table 3 Features of economic indicators

Features/Indicators	Mean ($\bar{x}$)	SD (σx)	Mean score ranking (R)
Citizens standards of living	4.15	0.843	1
Government subsidies	4.08	0.925	2
Availability of labor (skilled and unskilled)	4.06	1.065	3
Investment in WEF infrastructure	3.96	0.811	4
Importation of WEF resources	3.88	0.979	5
Exportation of WEF resources	3.83	0.960	6
Prices mechanism of WEF resources	3.83	0.975	7
Employment rate in WEF sectors	3.76	0.967	8
Economic incentives	3.72	0.861	9
Gross domestic product index	3.72	0.957	10
Inflation rate affects the interaction of WEF	3.72	0.973	11
Carbon emission tax	3.69	1.161	12
Taxes on WEF resources production	3.66	0.792	13
Private company's activities	3.62	0.928	14
Taxes on WEF resources distribution	3.59	0.878	15
Tax relief initiatives	3.48	0.965	16
Taxes on WEF resources consumption rate	3.42	0.866	17

Source: Researcher survey (2022)

Table 4 EFA pattern matrix for economic indicators

Pattern matrix[a]	Component			% of variance	Cronbach's Alpha	Number of Items
	1	2	3			
Government subsidies	0.689			58.872	0.875	7
Prices mechanism of WEF resources	0.842					
Employment rate in WEF sectors	0.936					
Importation of WEF resources	0.918					
Exportation of WEF resources	0.891					
Gross domestic product index		0.996		13.098		
Investment in WEF infrastructure			0.990	10.122		
Extraction method: principal component analysis Rotation Method: Promax with Kaiser normalization						
Kaiser–Meyer–Olkin (KMO) measure of sampling adequacy				0.884		
Barlett's test Sig				0.000		

Source: Researcher survey (2022)

The six dependent indicator variables for sustainability construct are environmentally friendly production, conversion & recycling of WEF resources waste, eco-friendly supply chain, reduction of CO_2 in the transportation of WEF resources, local production in a friendly import–export ratio, and increased employment opportunities.

(iii) CFA and structural model of goodness of fit for both economic activities and WEF nexus sustainability.

Thus, subsequent to conducting the CFA for both economic activities and WEF nexus sustainability factors, a comprehensive CFA model was constructed using EQS, as presented in Fig. 4. This model visually represents the relationship between these two sets of variables. In Fig. 4, it becomes evident that economic activities exert a significant influence on WEF nexus sustainability.

The hypothesis test involving the relationship between economic indicators and WEF nexus sustainability, as depicted in Fig. 4, resulted in a robust likelihood ratio test

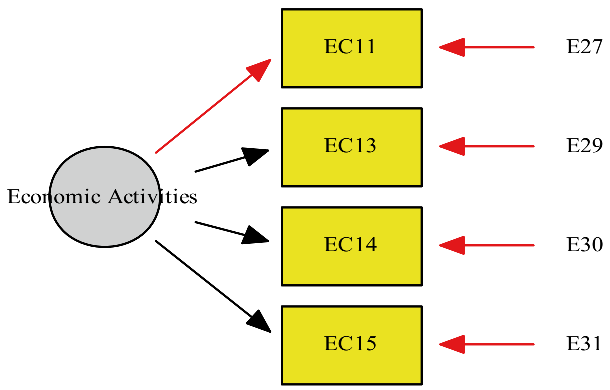


Fig. 2 Measurement model of economic activities

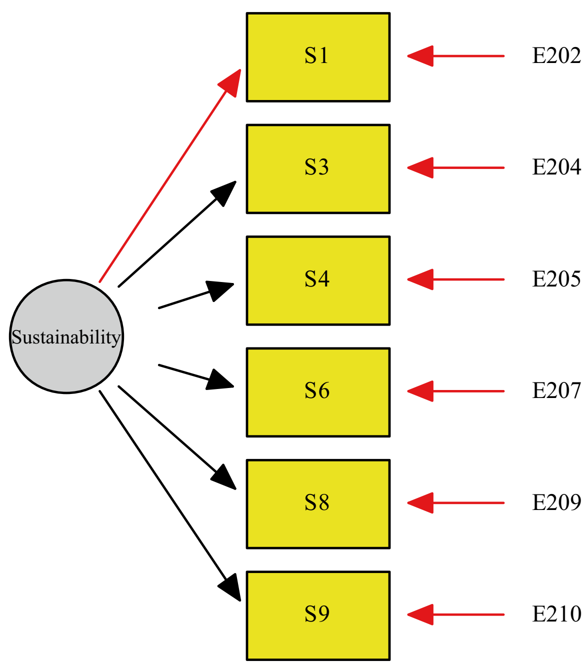


Fig. 3 Measurement model of the sustainability

using Satorra-Bentler (S-Bχ^2) statistics, yielding a value of 137.1491 with 34 degrees of freedom. This outcome indicated an insignificant chi-square value, indicative of an acceptable fit. It is worth noting that Kline (2005) highlights that the chi-square test is sensitive to sample size, hence, we employed the normed chi-square (χ^2/df) for developing Fig. 4 model in this research. The normed chi-square is obtained by dividing the chi-square value by the degrees of freedom, and it must be less than or equal to 5.0. In this study, this division resulted in a value of 4.03, which falls below the threshold of 5.0, in line with recommendations from Kline (2005), Ogunbayo (2021), and Agumba (2013).

Additionally, the model, as presented in Fig. 4, which illustrates the influence of economic indicators on WEF

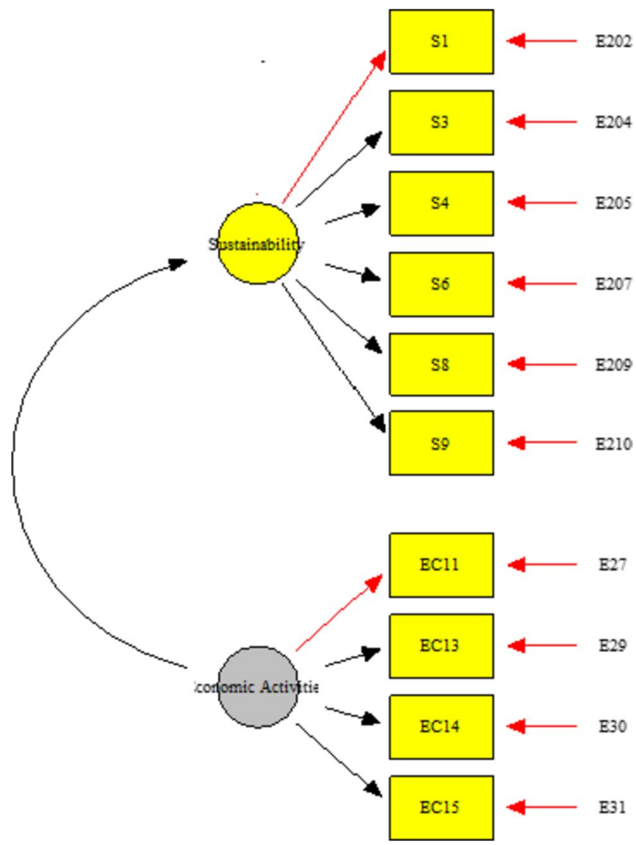


Fig. 4 CFA for both WEF nexus sustainable resource security and economic activities

nexus sustainability, adheres to the robust goodness-of-fit criteria of Aigbavboa (2014) and Bentler (2006). The comparative fit index (CFI) attains a commendable value of 0.940, meeting the acceptable range of 0.90–0.95, indicating a well-fitting model. Furthermore, the values for the 90% confidence interval of the root-mean-square error of approximation (RMSEA) stand at 0.051, which is below the cutoff value of 0.08, signifying a good fit. Overall, Fig. 4's model meets the criteria for both good and acceptable fits of Table 5, aligning with the recommendations of Ogunbayo (2021), Aigbavboa (2014), Agumba (2013), Rehbinder (2011), Kline (2006), and Joreskog and Sorbom (1988).

(iv) Internal reliability and construct validity.

Furthermore, when assessing the score reliability within the structural equation model presented in Fig. 4, we examined both Cronbach's Alpha and Rho coefficients. The Rho coefficient, which assesses the internal consistency of the values, yielded a robust score of 0.958, surpassing the recommended minimum threshold of 0.70 by Kline (2005). In addition, the Cronbach's Alpha value of 0.893 exceeded the 0.70 benchmark suggested by Nunnally and Bernstein (1994). These values, as displayed in

Table 5 Robust fit indexes

Model fit indices	Threshold/values	Estimate	Comment
S–B		137.1491	
Df		34	
Chi-Square (χ^2/df)	< 5 (acceptable fit)	4.03	Acceptable fit
	< 3(good fit)		
Comparative fit index (CFI)	> 0.90 (Acceptable fit)	0.940	Acceptable fit
	> 0.95 (Good fit)		
Incremental fit index (IFI)	> 0.90 (Acceptable fit)	0.941	Acceptable fit
	> 0.95 (Good fit)		
Normed fit index (NFI)	> 0.90 (Acceptable fit)	0.929	Acceptable fit
	> 0.95 (Good fit)		
Root mean-square error of approximation (RMSEA)	≤ 0.08 (Acceptable fit)	0.051	Good fit
	≤ 0.05 (Good fit)		
RMSEA 90% CI		(0.090, 0.128)	Good fit range

Table 6 Factor loadings and internal reliability

Indicator variable	Standardized coefficients	*Z* statistics	*R* square	Significance	Cronbach alpha	Reliability coefficient
EC11	0.765	–	0.586	Yes	0.893	0.958
EC13	0.818	16.750	0.669	Yes		
EC14	0.947	19.833	0.897	Yes		
EC 15	0.930	19.680	0.864	Yes		
S1	0.855	–	0.731	Yes		
S3	0.893	31.625	0.798	Yes		
S4	0.893	23.253	0.784	Yes		
S6	0.919	35.343	0.845	Yes		
S8	0.961	35.754	0.924	Yes		
S9	0.907	36.842	0.822	Yes		

Source: Researcher survey (2022)

Table 6, reflect a high level of internal consistency and uniformity in respondents' responses regarding the influence of economic indicators on WEF nexus sustainable resource security.

Moreover, factor loadings of the standardized coefficients in Table 6, a measure of the proximity of variables to one another, exhibited values above the recommended range of 0.5–0.7 by Hair et al. (1998). The highest factor loading recorded was 0.961, while the minimum factor loading stood at 0.765. Additionally, the factor loadings were notably high, as indicated by the (R^2), signifying a strong association between the economic indicators and the WEF nexus sustainability variables. Furthermore, the *Z*-statistics surpassed 1.96 for all values in Table 6, signifying their statistical significance.

In summary, Tables 5 and 6 provide compelling statistical evidence that the economic indicators possess significant predictive power in predicting WEF nexus sustainable security.

Discussions

Respondent's demographic characteristics

Table 2 presents a comprehensive overview of the demographic characteristics of the study's respondents, offering insights into their backgrounds and familiarity with the concept of the WEF nexus. This table includes data on gender, age range, years of experience, educational qualifications, sector of operation, designation, and familiarity with the WEF nexus. Notably, the results indicate that approximately 63% of the respondents are aged over 30 years, signifying a level of maturity that likely corresponds to a deeper understanding of water, energy, and food resources. Moreover, Table 2 reveals that most of the respondents possess considerable experience in their respective fields of work, demonstrating their familiarity with the intricate interplay among these three crucial resources.

The data also highlight that more than 80% of the respondents hold at least a first-degree qualification, indicating a high level of comprehension regarding the questionnaire's content and lending credibility to their responses. Furthermore, the table shows that one-third of respondents operate within each of the three sectors related to water, energy, and food resources, mitigating concerns of bias or one-sidedness in the respondent pool.

It is worth noting that Table 2 reveals that many respondents hold middle-level management positions across the three resource sectors, making them a pivotal component of the management structure with a profound awareness of the operations in their respective areas. This lends further assurance that the respondents' feedback is accurate, reliable, and dependable, derived from a place of extensive knowledge and practical experience related to the three resources and their nexus. Consequently, this study's findings carry significant weight and can be valuable for shaping economic policies related to the management of economic activities for WEF nexus sustainability.

Economic Indicators that affect WEF nexus sustainable resource security

The mean ranking scored in Table 3 showed the first three economic indicators that affect the sustainable resource security of the nexus, which are Citizen's standards of living, government subsidies, and availability of labor. This connotes the economic realities of citizens, government support for resource production and consumption, employment, and the socio-economic status of the citizens. This further shows that in understanding the WEF nexus, maximizing the synergies and trade-offs of the nexus for WEF sustainability and security, the economic power of people must be understood. That is, the higher the level of the economic power of people determines their level of consumption and utilization of resources. That is before initiating and executing water, energy, and food projects for sustainable resource security in a particular domain, the economic power of the users or the beneficiaries must be factored in, as it will determine the level of sustainability of the projects and their benefits. Amadeo and Rasure (2022) opined that economic power is a country, business, or individual's ability to improve their living standards and the freedom to make decisions that benefit them. According to the authors, economic power is always measured by purchasing power, income level, quality of life, leisure time, life expectancy, and economic security. This shows a direct relationship between the economic power of users of the WEF nexus project or resources and the sustainability of the project or resources. For instance, Strange (1975) opined that the inequality of economic power of an individual has an adverse effect on the economic outcomes of the resources. The author stated thus: "…*Here it is particularly obvious that the inequality of economic power can and does have a significant effect on economic outcomes. In earlier times, the weakness of unorganized hungry men seeking jobs by which to feed their families in negotiating with long-pocketed employers over the price of labour made nonsense of the equilibrium models showing the interactions of demand and supply. Now, sometimes, the boot is on the other foot and (as in newspaper production) it is the employers producing a perishable commodity who are most vulnerable and the printing unions that have extra bargaining power."* The author's assertion underscores the profound influence of economic inequality on various economic outcomes. This notion is deeply rooted in historical contexts where individuals who were economically disadvantaged, driven by the pressing need to secure employment and provide for their families, often found themselves in a precarious position during wage negotiations with financially affluent employers. This historical reality frequently created a significant disparity between the idealized equilibrium models of supply and demand and the practical dynamics that unfolded in the real world. In the contemporary landscape, we witness situations where the power dynamics have shifted. An illustrative example can be found in certain industries where employers engaged in producing perishable goods are more susceptible to disruptions, while labor unions, acting on behalf of the workers, have gained increased bargaining power. This shift highlights the evolving nature of economic influence within various sectors. Consequently, any strategies, planning, or projects related to the three key resources—water, energy, and food—must consider the economic power of their users and account for the intricate dynamics among different stakeholders. Neglecting this dimension places the sustainability of these resources in jeopardy.

The economic indicators construct emphasizes a fundamental perspective: It asserts that the level of economic influence wielded by resource users and beneficiaries is a crucial factor that must be thoughtfully incorporated when predicting and shaping sustainability outcomes within the WEF nexus framework. This perspective dives deep into the complex interplay of resource interactions, recognizing the pivotal role played by the economic capacities and actions of those reliant on these resources in determining the overall sustainability of the WEF nexus. In essence, it acknowledges that economic power, whether held by individuals or organizations, acts as a linchpin in influencing the equilibrium of these critical resources. This understanding extends to the financial dynamics of all types of stakeholders, whether they are consumers, businesses, or institutions, and acknowledges their profound impact on the delicate equilibrium of sustainability within this nexus. Therefore, these three economic indicators, as they relate to the WEF Nexus, enrich our understanding of this complex interconnection. They underscore the necessity of considering economic forces and incentives when striving for the sustainability of water, energy, and food resources. By recognizing the economic power dynamics at play and the economic strata of beneficiaries, we can develop more effective strategies to achieve long-term resource security and foster prosperity for all.

Impact of Economic indicators on WEF nexus for sustainable resource security

Tables 5 and 6 show that economic indicators have a statistically significant effect on the sustainable resource security of the WEF nexus, as the values suggest a high level of associations, and conformance to statistical criteria, and depict values vital to the measurement model of Fig. 4. Thus, the overall results established statistically that economic indicators have an enormous impact on sustainable resource security of water, energy, and food nexus.

This indicates that economic indicators have a direct and strong influence on the WEF nexus in South Africa, which will lead to the sustainability of water, energy, and food resources in South Africa. This further means that, in any Water, energy, and Food Nexus Project or product, the contribution of economic indicators should be factored in and considered for the sustainability of such project. This aligns harmoniously with the perspectives presented by Hoff (2011) and FAO (2014), who assert that economic growth and development, stemming from diverse economic activities, drive the heightened demand for water, energy, and food, thereby exerting significant pressure on the nexus. It is important to note that this phenomenon is particularly pronounced in urban settings and various industries. This also confirms the research of Petrariu et al. (2021) that economic performance activities influence the understanding of the interaction of WEF nexus, as the authors opined that entrepreneurial prowess and profitability indices provide a direction on how WEF nexus can be structured in policy and for institutional development. This is also reflected in the research of Mohtar and Daher (2016) on how pricing, an economic activity, affected the demand for basic nutritional needs of the populace. Collectively, these insights reinforce the pivotal role of economic indicators in shaping the dynamics of the WEF nexus and underscore the necessity of their consideration in strategies and policies aimed at achieving sustainability.

Furthermore, the results of the EFA conducted on economic indicators, as presented in Table 4, reveal the presence of three distinct factor components: Macro-Economic Factor, Economic Growth, and WEF Nexus Investment. This outcome closely aligns with the research by Al-Riffai et al. (2017), where the authors expounded on how the economics surrounding the three resources fundamentally shape the dynamics of the WEF nexus. As elucidated by Bloomenthal (2022), macroeconomic factors exert a profound influence on a nation's economy, offering a comprehensive overview of its economic performance. These factors encompass elements such as inflation rates, unemployment figures, economic outputs, government expenditures, exchange rates, and more (Sarel 1997). This insight underscores the critical relationship between macroeconomic factors and the nexus of WEF resources, given it profound impact on economic growth and investment. For example, a high inflation rate can disrupt the interaction among these resources, impacting their production capacity and demand in the market, as consumers may adopt a more conservative approach due to weakened purchasing power.

This crucial understanding highlights the fundamental link between macroeconomic factors and the complex dynamics of the WEF nexus. For instance, when the inflation rate (a macroeconomic factor) experiences a sharp increase, it can disrupt the harmonious interactions between these essential resources. This disruption, in turn, has a ripple effect across various aspects of the WEF nexus. One of the immediate consequences is the impact on the production capacities of water, energy, and food resources. The rising costs associated with high inflation can lead to increased production expenses, which, in the case of agriculture, might mean higher costs for inputs like fertilizers, seeds, and fuel. For energy production, inflation can drive up the prices of raw materials such as oil and gas. As a result, producers may need to adjust, potentially reducing output or passing the increased costs on to consumers.

On the demand side, high inflation influences market dynamics. As the prices of everyday goods and services surge, consumers often find their purchasing power diminished. In response, individuals may adopt a more cautious and conservative approach to spending. They might prioritize essential items, cut back on discretionary spending, and look for ways to economize. In the context of the WEF nexus, this shift in consumer behavior can have profound effects. For food resources, a drop in consumer spending may result in decreased demand for certain types of products or brands, which can affect agricultural production and supply chains. In the energy sector, reduced consumer spending could lead to lower energy consumption, impacting the balance of supply and demand. Even in the water domain, changes in consumption patterns can have implications for resource allocation and distribution.

In essence, when macroeconomic factors like inflation exert their influence on the WEF nexus, they can perturb the delicate equilibrium of how these resources coexist and interact. Therefore, it becomes evident that a nuanced understanding of the economic landscape is essential for addressing the multifaceted challenges within the WEF nexus and achieving sustainability in the face of macroeconomic fluctuations.

Moreover, an increase in government expenditures directed toward projects related to water, energy, or food/agriculture within any of the three resource sectors can have a positive ripple effect on the production rates of the other two, thereby contributing to their sustainability. This observation aligns with the findings of Sarel (1997), who posited a direct connection between macroeconomic activities and income distribution. To elaborate further, let's consider how this connection operates. When the government allocates resources to projects in the WEF sectors, it spurs growth, investment, and job opportunities within those areas. For instance, funding renewable energy projects not only boosts energy production but also stimulates job creation in the sector. As more people secure employment and experience economic growth, their income levels tend to rise. With higher incomes, individuals may choose to increase their consumption of resources, such as food, which, in turn, bolsters the agricultural sector. This pattern of development echoes throughout the WEF nexus. Essentially, an individual's income level, driven by macroeconomic factors, determines the type and nature of WEF resources that they are likely to consume.

The findings from Component Two of the EFA pertaining to investment align with discussions held during the 2021 working group on integrated water resources management, specifically the sixteenth meeting on various investment options for the WEF nexus (UNECE 2021a, b). This meeting explored various investment options within the WEF nexus context. It is important to note that projects related to water, energy, and food are typically capital-intensive ventures that demand significant investment. For instance, as indicated by the National Business Initiative (2021), South Africa’s water sector requires an estimated investment of R330 billion over the next decade, averaging R33 billion per year. This significant investment is necessary even though many water institutions in the country are not creditworthy, and there is a water debt of R13 billion. Furthermore, according to a consultation paper by the World Economic Forum, South Africa will need approximately 250 billion USD over the next 30 years to transition from a coal-powered energy system to a low-carbon energy system. This implies that, for a successful transition to renewable energy, an annual investment of nearly 10 billion USD is imperative (Jiyeong 2022).

In addition, investment is also critical in South Africa's Agri-Food system, especially in addressing various challenges like malnutrition, diet-related chronic diseases, undernutrition, obesity, and stunted growth (Thow et al. 2017). This was underscored by the 2022 South African Investment Conference, where pledges of over 2 billion rands were made for agricultural investments, with the African Development Bank committing to R42.5 billion (Manoko 2022). Furthermore, the third component of the EFA corresponds with the research by One Planet (2019), which establishes a direct link between economic growth, primarily driven by investment, and the utilization of resources. Therefore, the level of economic growth, often measured by GDP, is intrinsically connected to the utilization of water, energy, and food resources. This connection implies that the state of a nation's economy, in terms of its economic growth, will significantly manifest in the availability, affordability, stability, security, and sustainability of water, energy, and food resources. In essence, the economic well-being of a nation is intricately tied to the state of its resource utilization within the WEF nexus.

Furthermore, the outcomes of this study, as displayed in Table 6, reveal that the economic indicators model is defined by four key variables: the price mechanism of WEF resources, employment rates in WEF sectors, the importation of WEF resources, and the exportation of WEF resources. These indicators continue to underscore the pivotal role of macroeconomic factors in ensuring the sustainable resource security of the WEF nexus. The results strongly suggest that all the variables incorporated into the model exert a significant influence on sustainability within the context of the WEF nexus, aligning with findings from previous research (Department for International Development 2007; Haller 2012; Skare and Rahar 2017). Furthermore, the findings indicate that the economic indicator constructs serve as a significant determinant of the sustainability of water, energy, and food nexus project delivery. Therefore, a nation that does not consider how economic indicators will shape the interplay, synergies, and trade-offs among these three resources may find it challenging to effectively manage their complex interactions not alone their sustainability. However, it is noteworthy that the combined effect of the four variables that define economic activities is unique to this study.

Additionally, as depicted in Table 6, among the four economic indicator variables, variable EC14 (Importation of WEF resources) boasts the highest standardized coefficient of 0.947. This underscores the insights from Skare and Rahar (2017) regarding how importation contributes to a country's economic activities. Nonetheless, it is worth emphasizing the need to reassess a nation's import dependency, as argued by Lupak et al. (2021). The authors posit that import dependency alone does not guarantee a nation's economic security. The implication of the importation variable is that WEF nexus projects should be viewed as an economic advantage in terms of globalization, comparative advantage, and technological/ knowledge transfer. This means that imports related to the WEF nexus should be strategically oriented toward developing and optimizing resources within South Africa. This can be achieved by leveraging the comparative advantages of countries exporting to South Africa, capitalizing on the benefits of globalization, and ensuring that importation involves knowledge transfer or technological transfer. Such an approach will inevitably contribute to the security and sustainability of resources in both the short and long term.

Conclusion and policy implications

In conclusion, the findings and discussions from this study have underscored that in the pursuit of sustainable resource security, economic indicators are predominantly characterized as macroeconomic rather than microeconomic. They tend to be more driven by infrastructure investment rather than consumption, reliant on the economic power of individuals rather than government largess and influenced by globalization rather than local content. This highlights the importance of prioritizing comparative advantage-driven investments in the three key resources, both at the regional level (regardless of cultural homogeneity) and on the international stage (regardless of heterogeneity). Specifically, for the Republic of South Africa, it is recommended that comparative advantage-driven investments in the WEF nexus should focus on addressing economic water scarcity, optimizing food resource imports, and promoting clean energy initiatives. Furthermore, to fully harness the potential of WEF resource production, it is advisable to implement an optimal decision support system. This can be achieved through the utilization of advanced tools such as artificial intelligence, techno-economic analysis, and benefit–cost analysis. These methodologies can aid in optimizing the production of WEF resources, thereby enabling a more effective and comprehensive management of the WEF nexus for sustainability.

Nevertheless, it is essential to acknowledge certain limitations within the scope of this study, primarily concerning the chosen methodology and the reliance on EQS for analysis. In the pursuit of more comprehensive insights, future research endeavors may explore alternative software tools and analytical approaches, particularly when assessing the statistical significance and the precise quantitative impact of each EFA component as it relates to EQS analysis. The utilization of various analytical tools and software packages can offer a more diversified perspective on the relationships between economic indicators and sustainability within the context of the WEF nexus. By exploring a broader array of analytical methods, researchers can deepen their understanding of the multifaceted dynamics at play and potentially uncover nuances that might remain obscured when using a single analytical framework. This approach would not only enhance the robustness of research findings but also contribute to the refinement of methodologies in the field of WEF nexus studies.

Moreover, this study has significantly and statistically established that economic indicators play a pivotal role in shaping and determining the level of sustainable resource security, impacting both the current generation and those to come in future. However, these findings underscore a critical limitation associated with economic indicators—an omission of essential policy implications. Specifically, if the present generation increases resource security through their economic power and prevailing macroeconomic realities, how will it transform into resource sustainability without considering the economic power and macro-economic realities of future generations. To address this crucial issue, this paper puts forward three policy recommendations:

a. *Setting up public–private partnership (PPP) units in WEF agencies*. Public–private partnerships (PPPs) have historically been utilized as a policy tool for financing, with a strong focus on the built environment, particularly in road infrastructure and construction projects. In contrast, sectors related to water, energy, and food (WEF) have largely relied on government spending or private-sector entrepreneurial initiatives, often burdening citizens with the economic consequences of bureaucratic inefficiencies. To promote favorable macroeconomic conditions and alleviate the economic burden on citizens, it is imperative to establish dedicated PPP units within each of the WEF agencies. These units would serve as platforms for collaboration, facilitating resource contributions from governments as regulatory bodies and private entities as implementing agents. By doing so, they would stimulate the necessary financial, human, and technological investments required for optimizing production in the WEF sectors. The introduction of PPP units within WEF agencies would encourage cooperative competition between small enterprises and large corporations, enabling the production of larger volumes of WEF products. This, in turn, would create favorable dynamics within the supply and demand ecosystem, benefitting citizens by enhancing their economic power. Furthermore, these PPP units would play a crucial role in promoting sustainability by evaluating and refining policies that align with economic, social, and environmental sustainability objectives.
b. *Periodic reduction of tariffs and provision of subsidies on WEF products*. The economic health of a nation is often reflected in key indicators such as its unemployment rates and manufacturing capabilities. Considering the substantial investment required in the water, energy, and food (WEF) sector in South Africa, it becomes essential for the government to implement a policy framework that systematically and periodically reduces tariffs while providing subsidies for WEF-related items or raw materials. This strategic approach aims to stimulate increased production and investment within the sector. When tariffs are introduced or subsidies are revoked haphazardly and without proper timing,

it can have detrimental effects on the overall economy, leading to instability and impeding economic growth. The reduction of tariffs and the provision of subsidies are particularly beneficial for small and medium-sized enterprises (SMEs) as they can expand their production capacities. This, in turn, has a multiplier effect on the nation's employment rates, creating more job opportunities. Additionally, it bolsters the economic power of citizens by ensuring that WEF products remain affordable and accessible to a broader segment of the population.

c. *Blockchain for social goods.* Management and leadership systems within water, energy, and food (WEF) organizations often prioritize profit generation without due consideration for the delicate balance between economic, social, and environmental sustainability. As a remedy, the introduction of blockchain technology, known for its features such as transparency, decentralization, immutability, and digital ledger, can provide valuable guidance to WEF organizations in their decision-making processes. Blockchain technology can be particularly instrumental in shaping various aspects of WEF organizations, including production decisions, public–private partnership (PPP) arrangements—especially those related to finance and resource allocations—and the implementation of policies. By incorporating blockchain technology, these organizations can establish policies that inherently promote resource sustainability. This, in turn, contributes to the preservation of citizens' economic power while fostering equilibrium across sustainability dimensions within the economy.

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Data Availability The datasets generated during and/or analyzed during the current study are available from the corresponding author on reasonable request.

Declarations

Conflict of interest The authors have no relevant financial or non-financial interests to disclose.

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