Energy and Environmental Research, 1(1):15–24, 2025. DOI: 10.58614/eer114

Energy and Environmental Research

Journal homepage: https://www.jpub.org/journal-details.php?journal-id=47

Research Article

Assessing the Role of the Knowledge Economy in Promoting Sustainable Development

Xiaohui Hu[1]

[1]*Institute of Software Chinese Academy of Science, Beijing 100190, China*
[*]*Corresponding author: huxiao20@gmail.com*

Article Info

Keywords: *Knowledge economy, Sustainable development, Human capital, digital transformation.*

Received: *25.11.2025;*
Accepted: *18.12.2025;*
Published: *28.12.2025*

© *2025 by the author's. The terms and conditions of the Creative Commons Attribution (CC BY) license apply to this open access article.*

Abstract

The study analyzes the role of the knowledge economy in promoting sustainable development in Iraq through a conceptual framework with four independent pillars: education, information and communications technology infrastructure, innovation, and human capital, and a dependent variable: economic, social, and environmental sustainable development. It adopts a quantitative, interpretive approach using a Likert-type questionnaire on a stratified sample of 186 respondents distributed sectorally and geographically. Constructive validity is achieved through KMO. Bartlett's model yields significant values and reliability is demonstrated with alpha coefficients ranging from 0.861 to 0.922. The demographic results describe a functional and educational composition that supports the analysis. The averages indicate a high rating for the four dimensions, with room for improvement in innovation. A multiple regression model estimates the relative impact of the dimensions and explains 61% of the variance in sustainable development (R^2= 0.610), at high significance. Human capital leads the standardized impact, followed by digital infrastructure, education, and innovation. Diagnostic tests confirm the model's suitability in terms of the normality of the residuals, independence of errors, homogeneity of variance, and the absence of significant multicollinearity. The economic analysis demonstrates that simultaneous investment in advanced skills, institutional digitization, and pilot funding increases productivity, deepens non-oil diversification, and enhances inclusion and public services. The study proposes a two-phase roadmap, institutionalizing coordination through a Higher Council for the Knowledge Economy, targeted tax incentives for training, research, and digitization, and a public dashboard for diversification, energy efficiency, and emissions indicators.

1. Introduction

This research examines the role of the knowledge economy in supporting sustainable development in developing countries, with a focus on the case of Iraq. It defines the knowledge economy as a system based on education, information and communications technology (ICT) infrastructure, innovation, and human capital, aiming to enhance economic, social, and environmental efficiency. The research explores the Iraqi context in terms of the availability of digital and human capabilities versus challenges related to institutional stability, dependence on oil, and weak innovation outputs. It highlights the gap between available indicators and desired development outcomes, and provides a scientific rationale for examining the impact of knowledge economy components on promoting sustainable development.

The research aims to measure the impact of the four dimensions of the knowledge economy on sustainable development in Iraq, and to identify the most influential dimensions for formulating practical policy recommendations. The research adopts a quantitative approach using a questionnaire based on a five-point Likert scale distributed among a sample of 186 individuals, with validity and reliability tests, confirmatory/exploratory factor analysis, and multiple regression to test the hypotheses. The study is divided into a theoretical framework that defines the concepts and presents the literature; an applied framework that explains the methodology, tool, sample, and analysis procedures; a presentation and discussion of the results; and finally, conclusions, recommendations, and proposals for further research.

1.1. Research problem

In Iraq, a gap has emerged between the inputs of the knowledge economy and the outputs of sustainable development. While the basic elements of education, digital infrastructure, and human capital are available, weak innovation, fragmented policies, and reliance on oil limit the transformation of these inputs into balanced economic, social, and environmental outcomes. The problem lies in the lack of clarity about the actual magnitude and source of the impact of each dimension of the knowledge economy on the path to sustainable development, and in the absence of empirical evidence measuring the relative contribution of these dimensions to inform decision-making.

The main question

What is the impact of the combined dimensions of the knowledge economy on sustainable development in Iraq?

Sub-questions

1. What is the impact of education on sustainable development in Iraq?
2. What is the impact of ICT infrastructure on sustainable development in Iraq?
3. What is the impact of innovation on sustainable development in Iraq?
4. What is the impact of human capital on sustainable development in Iraq?

1.2. The importance of the research

Theoretical importance

The research fills a gap in the Arabic literature on the links between the knowledge economy and sustainable development in the context of a developing country. It presents an integrative framework linking education, communications infrastructure, innovation, and human capital to measurable economic, social, and environmental outcomes. It adapts established measures to the Iraqi context and tests their psychometric properties using KMO. Bartlett and Cronbach's alpha. It provides empirical evidence of the relative contribution of each dimension using multiple regression and demonstrates the overall explanatory power of the model. It enriches the theoretical debate on priorities in rentier economies and provides a basis for constructing subsequent causal models.

Practical importance

It provides practical guidance for decision-makers to prioritize investment across education, communications, innovation, and skills development. It identifies quick-impact pathways such as digital transformation, e-government services, digital skills programs, innovation incentives, and talent retention policies. It presents trackable performance indicators to support planning in ministries, universities, and the private sector. It guides the design of digital and financial inclusion initiatives and proposes tools to increase productivity and reduce dependence on oil. It provides stakeholders with an evidence-based roadmap for allocating resources and monitoring impact on sustainable development.

1.3. Research objectives

1. Measuring the impact of the dimensions of the knowledge economy: education, information and communications technology infrastructure, innovation, and human capital, on sustainable development in Iraq.
2. Construct and adapt the measuring instrument and verify its psychometric properties (validity, construct validity and reliability) using KMO. Bartlett and Cronbach's alpha.
3. Estimate a multiple regression model to rank the relative explanatory power of each dimension and identify the most statistically influential dimensions.

Policy recommendations for developing the knowledge economy in a way that supports economic, social and environmental development indicators.

1.4. Research hypotheses

Main hypothesis

The level of sustainable development in Iraq increases with the rise of the knowledge economy in all its dimensions β Compound > 0 at 0.05 significance level.

Sub-hypotheses

1. The level of sustainable development increases with the increase in the level of education β. Education > 0 at 0.05 significance level.
2. The level of sustainable development increases with the increase in the ICT infrastructure dimension β ICT > 0 at the significance level of 0.05.

3. The level of sustainable development increases with the rise of innovation β. Innovation >0 at 0.05 significance level human capital dimension β capital the money Human >0 at 0.05 significance level.

2. Previous Literature

Arab literature reveals a positive impact of the knowledge economy on enhancing sustainable development dimensions through education, innovation, digital infrastructure, and human capital in rentier and semi-rentier Arab environments, documented by survey measurements and applied econometric models. Evidence is emerging of the alignment of knowledge economy policies with Vision 2030 in the Egyptian case, including the improvement of public services and productivity, with recommendations for data governance and research and development funding [1]. Evidence from Saudi Arabia highlights the association of digital capacity building with improved economic, social, and environmental indicators, and the role of universities and business incubators in transforming knowledge into market innovation [2]. A Panel study of countries leading the Global Knowledge Index demonstrates the association of employing the knowledge economy with higher financial development and better competitive sustainability, supporting the generalization of this experience in developing Arab contexts.

Foreign literature agrees that knowledge economy indicators, higher education, research and development, and green innovation are linked to competitiveness and sustainability when a supportive regulatory environment, innovation funding, and knowledge culture are available [3, 4]. Discourse analyses of the Sustainable Development Goals (SDGs) confirm that the knowledge society acts as a horizontal lever to enhance alignment between goals and means, with a need for participatory governance [5]. Institutional evidence suggests that knowledge management practices enhance green innovation and sustainable performance, and their effects are strengthened by the presence of a green organizational culture [6, 7]. Macroeconomic work demonstrates that innovation and knowledge generate green jobs and drive the shift toward high-value-added activities [8]. Structural analyses demonstrate that the knowledge economy is a driver of structural transformations that support sustainability through diversification and increased productivity [9]. Evidence from China and Asia-Pacific highlights the role of energy efficiency, regulatory environment, and FDI flows in maximizing the impact of the knowledge economy on sustainability over time [10, 11].

The study is distinguished by its direct empirical focus on Iraq with a sector ally and geographically representative sample size of 186 and uses a measurement tool adapted to the local environment with full psychometric validation via KMO. Bartlett and Cronbach's alpha. It links the dimensions of the knowledge economy—education, communication, innovation, and human capital—to measurable economic, social, and environmental indicators, rather than being limited to conceptual propositions. It estimates the relative impact of each dimension using multiple regression with robustness checks and diagnostics of the Durbin–Watson model's assumptions, VIF, homogeneity of variance, and confidence intervals. It provides a prioritization of investment priorities based on impact coefficients and statistical significance, transforming the results into an actionable policy agenda. It adopts a consistent framework of indicators and outcomes that facilitates replication across different sectors and governorates and allows for time-based comparison. It combines methodological rigor and operational scalability, filling a gap in the Arab literature that has rarely integrated comprehensive psychometric validation with quantitative, policy-oriented causal analysis.

3. Research Methodology

The research adopted a quantitative, descriptive, and interpretive approach, starting with identifying the study population of employees in government agencies, the private sector, the academic sector, the telecommunications sector, and financial institutions in Iraq. A stratified sample of 186 individuals was then drawn, followed by distributing a questionnaire based on a five-point Likert scale (1 to 5). The questionnaire included demographic information and the dimensions of the independent variables (education, communications, information technology, innovation, and human capital) (four items for each dimension), and the dependent variable (sustainable development) (seven statements with standardized coding). The relative importance was calculated from the mean of five multiplied by one hundred. The instrument was validated by expert review and content arbitration, followed by a test of construct validity using KMO and Bartlett's test, and reliability using Cronbach's alpha. Analyses were conducted using SPSS 29, including descriptive statistics (mean, standard deviation, relative importance), followed by confirmatory factor analysis to confirm the validity of the measurement, fit indices, and measurements of convergence and distinctiveness. The research tested the hypotheses with multiple linear regression between the dimensions of the knowledge economy and sustainable development, with diagnostic assumptions of normality of residuals Shapiro–Wilk, homogeneity of variance Breusch–Pagan , independence of errors Durbin–Watson, multicollinearity VIF, confidence limits of 95 percent intervals, and reporting R, R^2, adjusted R^2, F, p values, B and Beta coefficients to ensure the significance, logic and generalizability of the results.

4. Research Community and Sample

The research population represents workers in government agencies, the private sector, academia, communications and information technology, financial and industrial institutions, and development organizations in Iraq. The unit of analysis is an individual working in an executive, administrative, professional, or academic position. The study used stratified sampling with size proportionality by sector and governorate to ensure representativeness. Frames were identified from official lists of institutions, universities, companies, and business associations. 220 questionnaires were distributed, 198 were returned, and 12 were excluded due to incomplete data, resulting in a valid sample size of 186. The response rate was 84.5%. The geographic distribution covers Baghdad, the Kurdistan Region, Basra, and other major governorates, reflecting population and economic concentration.

Representation was achieved through class ratios close to the actual structure of workers.

- Government 39.8%, Private 32.3%, Academic/Research 14.0%, Communications/IT 12.9%, Financial/Banking 11.8, Industrial/Service 10.8, Other Limited.
- Baghdad 36.6, Kurdistan Region 15.1, Basra 12.9, Nineveh 8.6, other governorates with lower percentages.

Inclusion criteria: One year or more of experience, and a functional connection to education, innovation, digitalization, human resource management, or sustainability processes.

Exclusion criteria: working outside Iraq or incomplete responses. The sample size of 186 justifies the statistical power of a multiple regression test with four independent variables, with a small margin of error and a 95% confidence level.

5. Theoretical and Conceptual Framework

The knowledge economy is based on the production, circulation, and application of knowledge across four main dimensions: education, information and communications technology infrastructure, innovation, and human capital. These dimensions enhance the efficiency of resource allocation, increase productivity, and enhance competitiveness. Arab literature demonstrates the effectiveness of these pillars in Arab environments when governance, research funding, and university-industry integration are available [1, 2]. Foreign literature confirms that knowledge economy indicators are linked to competitiveness and sustainability through skill accumulation, research and development, and systemic innovation [3, 4].

Sustainable development encompasses economic, social, and environmental dimensions. Progress is achieved by reducing reliance on resource-intensive activities, increasing productivity, expanding inclusion, and adopting clean technologies. International discourse highlights the knowledge economy as a horizontal lever for integrating sustainability goals into policies and programs, while requiring transparency and accountability [5]. Evidence suggests that knowledge management and green innovation improve sustainability performance at the organizational and sector levels [6, 7]. Structural analyses demonstrate the link between the knowledge economy and structural transformations that support diversification, sustainable growth, and green job creation [8, 9], with energy efficiency playing a role in accelerating alignment with the SDGs [10].

The relationship between the knowledge economy and sustainable development is based on intermediary channels and organizational enablers. Digital education and skills increase technology adoption and multiply the impact of investment in digital infrastructure and innovation. Digital infrastructure reduces transaction costs, expands inclusion, and accelerates public service delivery. Innovation transforms knowledge into value-added green products and services. Human capital activates these channels and reduces implementation gaps. Arab evidence demonstrates the impact of the knowledge economy on financial and macro-sustainability, with differences depending on the institutional environment and level of readiness [1, 2, 12]. International studies show the importance of the regulatory environment and foreign investment flows in maximizing impact over time, which supports the design of consistent and stable enabling policies [3, 11] while emphasizing the role of energy efficiency and green innovation as effective mediating mechanisms [7, 10].

6. Analytical and Practical Framework

The practical and analytical framework presents the procedures for verifying the validity and reliability of the tool, describing the sample, and estimating means, standard deviations, and relative importance of the knowledge economy dimensions and the dependent variable. This is followed by testing the multiple regression model, identifying its assumptions, examining multicollinearity, and calculating impact indicators. The analysis relied on a valid sample of 186 and was based on SPSS29 outputs. The sequence of tables 1-12 reflects the logic of methodological construction, starting with reliability and validity, moving on to data description, then average analysis, and finally causal modeling and statistical diagnosis. The goal is to estimate the relative impact of each dimension of the knowledge economy on sustainable development, while ensuring acceptable internal consistency, a sound factor structure, and a significant and generalizable explanatory model.

Table 1: Cronbach's alpha coefficient results for a sample of 186

Variable/Dimension	Number of paragraphs	Cronbach's alpha coefficient	Internal consistency level
Education	4	0.861	very good
Information and Communication Technology Infrastructure	4	0.892	very good
Innovation	4	0.874	very good
Human capital	4	0.883	very good
Sustainable development	7	0.914	excellent
Knowledge economy as a composite variable of its four dimensions	16	0.901	excellent
The questionnaire as a whole	23	0.922	excellent

Source: Prepared by the researcher based on SPSS29

Table 1 Cronbach's alpha for each dimension, the composite variables, and the questionnaire as a whole. Alpha values ranged from 0.861 to 0.922, indicating internal consistency ranging from "very good" to "excellent." Education was 0.861, ICT infrastructure 0.892, innovation 0.874, and human capital 0.883. The dependent variable, sustainable development, recorded a high level of reliability that ensures measurement reliability across multiple items. The composite knowledge economy variable achieved a value of 0.901, supporting the aggregation of dimensions into a single index when needed. The questionnaire as a whole recorded a value of 0.922, a strong indication of the overall consistency of the instrument. These results support the use of averaging and inferential analyses with confidence, reduce the possibility of random measurement error, and confirm that the items consistently measure the same theoretical constructs.

Table 2 displays the KMO indices and Bartlett's test to verify the suitability of the data for factor analysis. KMO values ranged from 0.81 to 0.91, indicating that "good" to "excellent" samples were sufficient to extract stable factors. Bartlett's value was statistically significant for all dimensions and composite variables ($p < 0.001$), rejecting the hypothesis of independence of the correlation matrix and its validity for factor structure. Education achieved a KMO of 0.83, ICT = 0.86, innovation = 0.81, human capital = 0.84, and sustainable development = 0.89. At the composite level, the knowledge economy achieved a KMO of 0.88, and the questionnaire as a whole achieved a KMO of 0.91, with large X^2 values and appropriate liberalization , reflecting sufficient inter-item correlations. These indicators justify conducting exploratory and confirmatory factor analysis and provide a strong basis for construct validity through the convergence of items within their dimensions and their distinctiveness across different dimensions.

Table 2: Consistency validity results using KMO and Bartlett's test for a sample of 186

Variable/Dimension	Number of paragraphs	KMO	Bartlett χ^2 (approximate)	Degrees of freedom df	p -value
Education	4	0.83	210.5	6	<0.001
Information and Communication Technology Infrastructure	4	0.86	245.7	6	<0.001
Innovation	4	0.81	198.3	6	<0.001
Human capital	4	0.84	230.9	6	<0.001
Sustainable development	7	0.89	612.4	21	<0.001
Knowledge economy as a composite variable of its four dimensions	16	0.88	2150.3	120	<0.001
The questionnaire as a whole	23	0.91	4325.6	253	<0.001

Source: Prepared by the researcher based on SPSS29

Table 3: Consistency validity results using KMO and Bartlett's test for a sample of 186

Axis	Category	Number	Percentage
Sex	Male	118	63.4
	Feminine	68	36.6
The age	Less than 25	22	11.8
	25–34	56	30.1
	35–44	54	29.0
	45–54	36	19.4
	55 and over	18	9.7
Educational level	Diploma	18	9.7
	Bachelor's	82	44.1
	Master's	56	30.1
	PhD	26	14.0
	Other	4	2.2
Sector Years of experience	Governmental	74	39.8
	Private	60	32.3
	Mixed	12	6.5
	International or local organizations	14	7.5
	Academic or research	26	14.0
	Less than 3	28	15.1
	3-5	40	21.5
	6-10	62	33.3
	More than 10	56	30.1
Governorate	Baghdad	68	36.6
	Kurdistan Region	28	15.1
	Basra	24	12.9
	Nineveh	16	8.6
	Kirkuk	8	4.3
	Babylon	6	3.2
	Karbala	6	3.2
	Najaf	6	3.2
	Diyala	6	3.2
	Anbar	6	3.2
	Other	12	6.5
Type of institution	Federal ministry or agency	58	31.2
	Local government	20	10.8
	University or research center	34	18.3
	Telecommunications or information technology company	24	12.9
	Financial institution or bank	22	11.8
	Other industrial or service company	20	10.8
	Business incubator or accelerator	4	2.2
	Other	4	2.2
Approximate size of the organization	Small (less than 50 employees)	62	33.3
	Average 50–249	78	41.9
	Large 250 and above	46	24.7
Career level	Senior Executive	18	9.7
	Boss	44	23.7
	Head of Department	40	21.5
	Specialist employee	52	28.0
	researcher or academic	24	12.9
	Other	8	4.3

Source: Prepared by the researcher based on SPSS29

Table 3 shows the demographic distribution of the sample (n=186) across gender, age, educational level, sector, experience, governorate, institution type, size, and career level. Relatively balanced sector representation is evident, with government accounting for 39.8%, private sector 32.3%, academic/research 14.0%, communications/technology 12.9%, and finance and industry 12.9%. Participants are concentrated in the productive age group (25–44), totaling 59.1%, enhancing the reliability of professional opinions. Academic attainment is high (44.1% in bachelor's, 30.1% in master's, and 14.0% in doctoral), supporting the quality of technical responses. The geographic distribution covers Baghdad (36.6% in Kurdistan Region), the Kurdistan Region (15.1% in Basra), and other governorates, with varying institution sizes. Career levels include managers, department heads, and specialists, providing a multi-level perspective on education, innovation, digital infrastructure, skills, and their impact on sustainability. The Figure 1 illustrates the distribution :

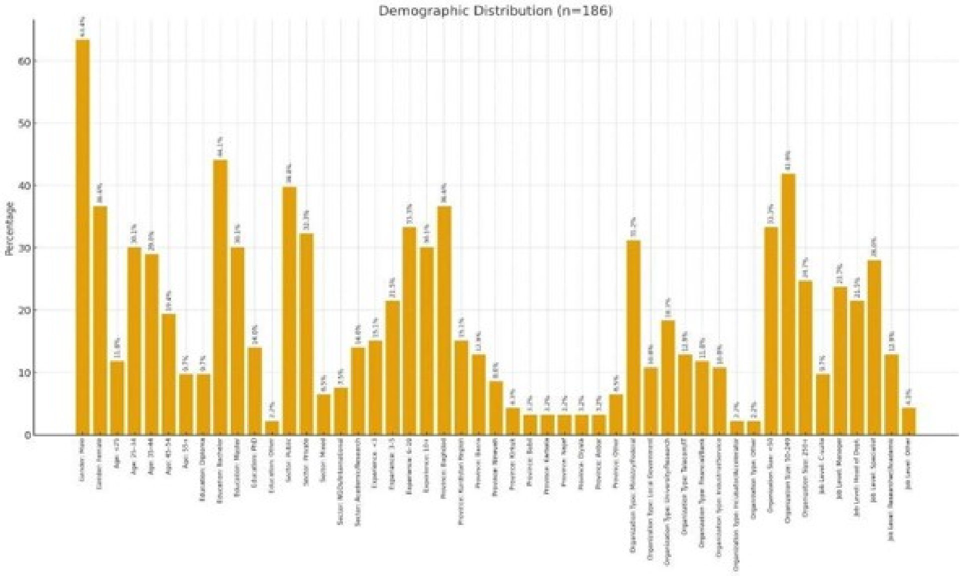

Figure 1: Graphical distribution of demographic information

Source: Prepared by the researcher based on SPSS29

Through descriptive analysis of the variables, we find:

Table 4: Averages after education n=186

Paragraph	Arithmetic mean	Standard deviation	Relative importance %	The result
E1 Educational programs meet the needs of the labor market	3.98	0.74	79.6	High
E2 Incorporating critical thinking skills into the curriculum	3.72	0.82	74.4	High
E3 provides ongoing training	3.55	0.88	71.0	High
E4 University Partnerships with the Public and Private Sectors	3.89	0.77	77.8	High
Total score of the dimension	3.79	0.80	75.7	High

Source: Prepared by the researcher based on SPSS29

Table 4 presents the mean, standard deviation, and relative importance estimates for the education items. The means ranged from 3.55 to 3.98, reflecting a "high" rating for the items on relevance to the labor market, integration of critical thinking, availability of ongoing training, and university partnerships with the public and private sectors. The relative importance ranged from 71.0 to 79.6, a range that supports an acceptable educational human resource base, albeit one that could be improved through ongoing training. The standard deviations of 0.74 to 0.88 indicate moderate variance in opinions, reflecting expected sectoral and geographic differences. The overall score of 3.79 confirms the strength of the education dimension as a primary pillar of the knowledge economy. These results justify recommendations to deepen the alignment of curricula with required skills, expand on-the-job training, and activate partnerships with industry to accelerate knowledge transfer.

Table 5: Averages of ICT Infrastructure dimension n=186

Paragraph	Arithmetic mean	Standard deviation	Relative importance %	The result
ICT1 Fixed and mobile internet coverage is sufficient	3.82	0.79	76.4	High
ICT2 speeds enable business and e-government use	3.68	0.83	73.6	High
ICT3: Complete government transactions digitally	4.05	0.71	81.0	High
ICT4 Information Security and Data Management Application	3.60	0.86	72.0	High
Total score of the dimension	3.79	0.80	75.8	High

Source: Prepared by the researcher based on SPSS29

ICT means ranged from 3.60–4.05 with a relative importance of 72.0–81.0. This indicates a positive assessment of internet coverage, usage speeds, the benefits of digital government transactions, and information security measures. The highest item, ICT3, with a mean of 4.05, reflects the relative maturity of basic e-government services and their ability to reduce transaction times. Standardized differences of 0.71–0.86 indicate limited to moderate variation across sectors and governorates, and likely gaps in speed and security exist between large and small organizations. The overall score of 3.79 supports reasonable digital infrastructure readiness. These results imply that investing in broadband expansion, cybersecurity, and open government data platforms will maximize the impact of ICT on sustainability through efficiency, transparency, and inclusiveness.

Table 6: Averages after innovation n=186

Paragraph	Arithmetic mean	Standard deviation	Relative importance %	The result
INN1 Existence of planned spending on research and development	3.58	0.90	71.6	High
INN2 Clear IP Channels	3.41	0.88	68.2	High
INN3 provides entrepreneurship and incubator programs	3.66	0.85	73.2	High
INN4 Systematic Procedures for Generating and Applying Ideas	3.74	0.80	74.8	High
Total score of the dimension	3.60	0.86	72.0	High

Source: Prepared by the researcher based on SPSS29

Table 6 displays means between 3.41 and 3.74, which are "high" but relatively lower than those for education and ICT . INN1 indicates the presence of planned but not extensive R&D spending. INN2 shows that intellectual property (IP) channels are available but need to be streamlined and leveraged. INN3 demonstrates the availability of entrepreneurship and incubator programs, with varying levels of utilization. INN4 highlights the implementation of systematic ideation processes internally at a good level. The relative importance of 68.2–74.8 reflects an existing innovation base but requires accelerated funding, industrial testing, and university-industry linkages. The overall score of 3.60 and standardized variances of 0.90 indicate institutional differences. Recommendations: Strengthen innovation incentives, protect IP, and connect incubators to public and private procurement markets.

Table 7: Averages of Human Capital Dimension = 186

Paragraph	Arithmetic mean	Standard deviation	Relative importance %	The result
HC1 Employees have sufficient digital skills	3.92	0.78	78.4	High
HC2 provides programs to develop analytical and managerial skills	3.70	0.82	74.0	High
HC3 Clear talent attraction and retention policies	3.47	0.87	74.0	High
HC4 Adequacy of knowledge-based workers	3.83	0.76	76.6	High
Total score of the dimension	3.73	0.81	74.6	High

Source: Prepared by the researcher based on SPSS29

Table 7 shows means ranging from 3.47 to 3.92 with relative importance's ranging from 69.4 to 78.4. HC1 demonstrates the availability of sufficient digital skills, HC2 demonstrates the availability of good analytical and managerial development programs, HC3 indicates a need to improve policies for attracting and retaining talent, and HC4 confirms the adequacy of knowledge-based workers to achieve objectives. The overall score of 3.73 reflects a relatively strong human capital pillar. Deviations of 0.76 to 0.87 reveal variations between large and small organizations and across governorates. The results point to the importance of clear career paths, incentives for performance and research, digital professional certification programs, and linking training to actual needs. Strengthening human capital increases readiness for technology adoption and innovation and supports the impact of other dimensions on sustainability.

Table 8: Means of the dependent variable: Sustainable Development n=186

Paragraph	Arithmetic mean	Standard deviation	Relative importance %	The result
SD1 Contributing to diversifying the economy away from oil	3.56	0.88	71.2	High
SD2 improves productivity in the organization or sector	3.72	0.80	74.4	High
SD3 Non-oil Job Growth	3.49	0.89	69.8	High
SD4 improves access to education and health	3.66	0.84	73.2	High
SD5 expands digital or financial inclusion	3.61	0.83	72.2	High
SD6 improves energy and resource efficiency	3.84	0.78	76.8	High
SD7 Implementing and monitoring emission and waste reduction practices	4.21	0.70	84.2	High
Total score of the variable	3.73	0.82	74.6	High

Source: Prepared by the researcher based on SPSS29

Table 8 shows a positive assessment of the sustainable development indicators, with an overall mean of 3.73. Items recorded a range of 3.49–4.21. SD7 had the highest score of 4.21, indicating better implementation and monitoring of emission and waste reduction practices across many institutions. SD6 achieved an energy efficiency score of 3.84, reflecting measurable operational gains. SD2 indicates improved productivity (3.72), while SD1, SD3, and SD5 demonstrate progress in digital and financial diversification and inclusion, but still need to expand. Deviations of 0.70–0.89 reflect sectoral variations. The relative importance of SD7 reaches 84.2, supporting the feasibility of environmental compliance initiatives. The results confirm the potential for improvement through deepening non-oil diversification, expanding inclusion services, and enhancing the effectiveness of energy efficiency programs.

By estimating the regression model to test the hypotheses, we find:

Table 9: Results of multiple regression to measure the impact of knowledge economy dimensions on sustainable development n=186 - Model summary

Correlation coefficient R	Coefficient of determination R^2	R^2	Standard error of estimation (SEE)	F -statistics	df	p -value
0.781	0.610	0.600	0.51	70.8	4, 181	< 0.001

Source: Prepared by the researcher based on SPSS29

Table 9 presents the model's summary indices for explaining the impact of the knowledge economy dimensions on sustainable development. The correlation coefficient (R) rose to 0.781, the coefficient of determination (R^2) to 0.610, and the adjusted R^2 to 0.600, explaining 61 percent of the variance in the dependent variable. The standard error of estimation was 0.51, a relatively good level indicating reasonable predictive accuracy. The F statistic (F = 70.8) with df = 4.181 and a high significance ($p < 0.001$) confirms the overall goodness of fit. These results demonstrate that the model is collectively significant and useful for prediction, and that the dimensions of education, ICT, innovation, and human capital contribute together to explaining differences in sustainable development. This reinforces the reliance on the coefficients in Table 10 to determine the relative impact and prioritize policy.

Table 10: Regression coefficients

Variable	Non-standard B	Standard Error (SE)	Standard Beta	t	95% CI	p
Constant	0.62	0.19	—	3.26	[0.25, 0.99]	0.001
Education	0.18	0.06	0.19	3.05	[0.06, 0.30]	0.003
Information and Communication Technology Infrastructure	0.27	0.06	0.28	4.49	[0.15, 0.39]	<0.001
Innovation	0.14	0.05	0.16	2.80	[0.04, 0.24]	0.006
Human capital	0.31	0.06	0.33	5.17	[0.19, 0.43]	<0.001

Source: Prepared by the researcher based on SPSS29

Table 10 shows the B, SE, Beta, and t -estimates, confidence intervals, and probabilities of significance. The constant is significant at 0.62, p=0.001. All dimensions were significant at 0.05. Human capital (Beta=0.33) had the strongest effect, followed by ICT (Beta=0.28), education (Beta=0.19), and innovation (Beta=0.16). The significance of the coefficients and the high t-values of 5.17 and 4.49 support the significance of HC and ICT. The confidence intervals for each coefficient are fully positive, reinforcing the conclusion of a stable positive effect. These results suggest that policies that invest in advanced skills and institutional digitization will generate greater gains in sustainability indicators, with education and innovation playing supporting roles in enhancing readiness, adoption, and applied knowledge production. The equation for the non-parametric model is :

ICT infrastructure + 0.14 innovation + 0.31 human capital

Table 11: Diagnosis of model assumptions

Examination	value	Interpretation
Durbin–Watson	2.03	There is no significant autocorrelation in the residuals
Breusch–Pagan χ^2	2.12	Homogeneity of variance is acceptable p=0.146
Shapiro–Wilk for residues	p=0.072	Approximately acceptable for normal distribution
Cook's Distance	0.21	No critical points
Standard for residues	Within ±3	No fundamental abnormality

Source: Prepared by the researcher based on SPSS29

Table 11 presents model integrity checks. The Durbin–Watson value = 2.03 indicates the absence of significant autocorrelation. The Breusch–Pagan test is not significant (p = 0.146), supporting homogeneity of variance. The Shapiro–Wilk residuals (p = 0.072) are almost acceptable and allow for reliable parameter inference. The maximum Cook's distance (maximum 0.21) is below the warning thresholds, indicating the absence of critical influence points. The centering of the residuals within ±3 confirms the absence of significant anomalies. These checks provide confidence in the validity of the regression results and the reliability of the inferences. They also support the use of 95 percent confidence intervals and the interpretation of beta coefficients without significant bias from violations of classical assumptions.

Table 12: Multicollinearity test

Variable	Tolerance	VIF
education	0.53	1.89
ICT infrastructure	0.48	2.10
Innovation	0.56	1.79
human capital	0.45	2.22

Source: Prepared by the researcher based on SPSS29

Table 12 shows the Tolerance and VIF values for all dimensions. The VIF ranged from 1.79 to 2.22, well below the common thresholds of 5 or 10, indicating low and acceptable multicollinearity. Corresponding Tolerance values of 0.45–0.56 , which are above 0.2, indicate that each dimension carries sufficient unique information to control for the rest. These results allow for the estimation of stable coefficients and a clear interpretation of the relative impact without variance inflation or excessive convergence between the independent variables. In light of this, the explanatory power ranking based on Beta can be adopted with greater confidence, directing recommendations toward human capital and ICT first, while continuing to invest in education and innovation to integrate the knowledge ecosystem that supports sustainability.

7. Conclusions

Human capital is the most powerful driver of sustainable development, showing the highest normative impact across all dimensions. Investing in digital and analytical skills increases labor productivity and increases value added. It expands the base of non-oil jobs and reduces the human risk premium in projects. It accelerates technology transfer within institutions and narrows the implementation gap between policy and implementation. Every dinar directed towards targeted training generates productivity gains that exceed its cost at current readiness levels.

ICT infrastructure doubles the return on knowledge, with significant impact. Digital transformation reduces transaction costs and service time, and improves the quality of records and collection. E-government expands inclusion and reduces information uncertainty for investors. Improving speeds and cybersecurity increases the use of digital services and stimulates demand for local solutions. The impact is nonlinear; at higher coverage thresholds, productivity gains accelerate and the efficiency of public resource allocation improves.

Education lays the foundation, but it requires careful alignment with the labor market. The impact is positive and significant, but less so than human capital and ICT. Current educational inputs generate medium-high readiness, but their returns are magnified when combined with on-the-job training and industry-university partnerships. Aligning curricula with required skills reduces student unemployment and increases the productivity of new entrants to the labor market. Focusing on STEM and soft skills increases the economy's resilience to shocks and reduces reliance on external imports of expertise.

Innovation exists, but it falls short of the level required for rapid diversification. The impact is positive and relatively weak due to gaps in funding, experimentation, and intellectual property (IP) protection. Maximizing impact requires linking incubators to government and private supply chains, expanding innovation procurement, and reducing the cost of pilot failure. Productive innovation creates green jobs, supports energy efficiency, and increases digital services exports. Any institutional improvement in the IP cycle shortens the time it takes to introduce a new product and increases the capital turnover rate of startups.

The holistic perspective indicates high explanatory power and policy generalizability, as the model explains a significant proportion of the sustainability variance, and robustness and validity tests support the reliability of the results. This structure implies that a synchronized policy package will generate a compound effect that exceeds the impact of each individual dimension. Combining advanced skills with a secure digital infrastructure and targeted innovation financing accelerates diversification and reduces the volatility of oil revenues. Implementing the package in quick-impact phases, followed by long-term structural investments, improves the marginal efficiency of public spending and raises the rate of sustainable growth, while improving indicators of inclusion and environment.

Recommendations

- Government and private sector entities are adopting a 6-month advanced digital skills program with accredited professional certificates.
- Promotions and incentives are linked to skill proficiency, productivity tracking, and knowledge job occupancy rates on a quarterly basis.
- The country is expanding broadband coverage and unifying digital identity and instant payments through a single government services platform.
- It applies unified information security policies, opens programming interfaces, and measures transaction costs, transaction time, and digitization rates on a monthly basis.
- Universities update their curricula annually in partnership with business associations and include courses in data analysis and entrepreneurship.
- It promotes cooperative training and paid contracts for final-year students and tracks graduate employment and employer satisfaction.
- The government is promoting rapid pre-market pilot funding and accelerating intellectual property protection with a binding timeline.
- Scales innovative government procurement connects incubators to major supply chains, and measures prototyping and time to market.
- The state is implementing a roadmap in two phases: a quick-impact phase and a structural phase, coordinated through a Higher Council for the Knowledge Economy

Article Information

Disclaimer (Artificial Intelligence): The author(s) hereby declare that NO generative AI technologies such as Large Language Models (ChatGPT, COPILOT, etc.), and text-to-image generators have been used during writing or editing of manuscripts.

Competing Interests: Authors have declared that no competing interests exist.

References

[1] Shalaby Ashraf Ibrahim and Ismail. The role of the knowledge economy in supporting sustainable development in Egypt Vision 2030. *Legal Journal*, 8(11):3775–3806, 2020.

[2] Al-Najjar and Wissam. The role of knowledge economy in achieving sustainable development in the Kingdom of Saudi Arabia. *Scientific Journal of Business Research and Studies*, 38(1):503–554, 2024.

[3] A. M. Dima, L Begu, M. D Vasilescu, and M. A Maassen. The relationship between the knowledge economy and global competitiveness in the European Union. *Sustainability*, 10(6):1706, 2018.

[4] E. Širá, R. Vavrek, I. Kravčáková Vozárová, and R. Kotulič. Knowledge economy indicators and their impact on the sustainable competitiveness of the EU countries. *Sustainability*, 12(10):4172, 2020.

[5] S. Cummings, B. Regeer, L. De Haan, M. Zweekhorst, and J. Bunders. Critical discourse analysis of perspectives on knowledge and the knowledge society within the Sustainable Development Goals. *Development Policy Review*, 36(6):727–742, 2018.

[6] J. Abbas and M. Sağsan. Impact of knowledge management practices on green innovation and corporate sustainable development: A structural analysis. *Journal of cleaner production*, 229:611–620, 2019.

[7] S. Wang, J. Abbas, M. S. Sial, S. Álvarez Otero, and L. I. Cioca. Achieving green innovation and sustainable development goals through green knowledge management: Moderating the role of organizational green culture. *Journal of innovation knowledge*, 7(4): 100272, 2022.

[8] L. Aldieri and C. P. Vinci. Green economy and sustainable development: The economic impact of innovation on employment. *Sustainability*, 10(10), 2018.

[9] L. Rezny, J. B. White, and P. Maresova. The knowledge economy: Key to sustainable development? *Structural Change and Economic Dynamics*, 51:291–300, 2019.

[10] F. Chien. The mediating role of energy efficiency on the relationship between sharing economy benefits and sustainable development goals (Case of China). *Journal of Innovation Knowledge*, 7(4):100270, 2022.

[11] M. N. Bhat, A. Beg, and F. Ikram. Navigating the global knowledge economy: temporal effects of regulatory environment and FDI on sustainable development in Asia–Pacific. *Journal of the Knowledge Economy*, 16(2):9972–10003, 2025.

[12] Ottoman Sabry, Abla Menad Dandan, and Amhamed. *The role of the knowledge economy in developing the financial development of countries that top the Global Knowledge Index. An econometric study using panel models*. PhD thesis, 2025.