
Two-Stage DEA Assessment of Knowledge-to-Economy Efficiency in GCC Countries Using the Global Knowledge Index, 2021–2024

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Abstract

This paper evaluates how efficiently Gulf Cooperation Council (GCC) countries transform knowledge-system inputs into knowledge capabilities and, ultimately, into knowledge-based economic performance, using the Global Knowledge Index (GKI) as an integrated input–output framework over the period 2021–2024. Building on a two-stage network Data Envelopment Analysis (DEA) model fully embedded in the GKI architecture, Stage 1 measures knowledge-formation efficiency in converting education, TVET, higher education, RDI, ICT, and enabling-environment pillars into composite intermediate knowledge outputs, while Stage 2 assesses knowledge-to-economy conversion efficiency in translating these outputs into the GKI economy indicator and its pillars of competitiveness, openness, and domestic value added.

The results reveal substantial cross-country heterogeneity: the United Arab Emirates and Qatar operate on the efficiency frontier in both stages, whereas Saudi Arabia, Kuwait, Bahrain, and Oman exhibit significant input surpluses and output shortfalls, especially in higher education, RDI, and value-added generation, indicating structural gaps between knowledge formation and economic absorption.

To assess the feasibility of achieving Vision 2030 targets, the study introduces a $\Delta\theta$ -based forecasting model that quantifies the annual efficiency improvements required for each country to reach frontier or high-performance thresholds (0.90–0.95) by 2030 and develops a policy-intensity framework that maps these efficiency gaps into differentiated reform pathways ranging from light to transformational interventions. By extending DEA from static benchmarking to forward-looking efficiency trajectories, the paper contributes to the technological forecasting and social change literature by offering a GKI-consistent, multi-stage efficiency framework that can be used to monitor progress toward national vision targets, stress-test policy scenarios, and inform strategic planning for knowledge-based diversification in resource-rich economies.

Keywords: Global Knowledge Index, Efficiency, Two -Stage DEA, GCC, Knowledge Economy, Forecasting, Policy Scenarios.

JEL Classification: O11, O33, C61, C67

1. Introduction

Over recent decades, rapid scientific and technological advancements—particularly the widespread adoption of information and communication technologies—have fundamentally reshaped economic structures. Knowledge has emerged as a primary production factor alongside labor and capital, increasingly substituting for traditional physical capital and serving as a central driver of value creation and economic growth (Mohamed et al., 2022).

In response, GCC countries have invested heavily in education, digital infrastructure, and institutional reforms to transition from hydrocarbon-based growth models toward more diversified, knowledge-driven economies aligned with national visions such as Saudi Vision 2030 and Qatar National Vision 2030, despite these efforts it is unclear how efficiently these knowledge-related inputs are transformed into intermediate knowledge capabilities and, ultimately, into economic performance.

The Global Knowledge Index (GKI), developed by UNDP and the Mohammed bin Rashid Al Maktoum Knowledge Foundation, provides a comprehensive framework for assessing national performance across seven dimensions: pre-university education, TVET, higher education, RDI, ICT, the enabling environment, and the economy. Empirical evidence shows that higher scores on knowledge-related indicators are positively associated with economic growth, and GCC countries generally outperform other Arab states on many of these dimensions, while still facing persistent gaps in research, innovation, and openness (World Bank, 2025).

Despite these advances, a clear gap remains in the literature. Existing studies typically rely on descriptive comparisons or single-stage efficiency assessments, offering limited insight into how effectively countries convert knowledge inputs into innovation outputs and, ultimately, into economic performance. No prior research has applied a two-stage DEA framework to the GKI, nor has any study incorporated forward-looking efficiency forecasting to evaluate the feasibility of achieving national transformation targets such as Vision 2030. This absence of a dynamic, multi-stage efficiency assessment represents a significant gap in the literature on knowledge-economy performance in the GCC.

To address this gap, the present study pursues three objectives: (1) to evaluate the efficiency with which GCC countries transform knowledge inputs into innovation outputs (Stage 1) and innovation outputs into economic performance (Stage 2) using a two-stage DEA model; (2) to estimate the annual efficiency improvements ($\Delta\theta$) required for each country to reach frontier or high-performance thresholds by 2030; and (3) to translate these efficiency gaps into actionable policy pathways through a policy-intensity framework aligned with $\Delta\theta$ values.

The originality of the study lies in its use of the GKI as an integrated input–output system combined with a two-stage DEA framework and regression-based forecasts. Due to missing 2024 GKI values for Kuwait and Bahrain, a simple linear regression model was employed to estimate the missing

observations using 2021–2023 data. Despite the limited number of time points, the estimated models exhibited stable linear trends with no structural breaks, and a sensitivity check -re-estimating the DEA model without the imputed values -showed no qualitative changes in efficiency rankings.

The temporal scope of the analysis is restricted to 2021–2024 due to methodological changes in the GKI. A review of GKI technical reports shows that the index underwent substantial revisions before 2021 and again beginning in 2025, affecting indicator definitions, aggregation rules, and sub-index composition. Because DEA requires strict consistency in variable definitions across all decision-making units and time points, incorporating years outside this window would compromise comparability. The selected period therefore represents the only interval during which the GKI indicators are fully harmonized and methodologically stable.

Overall, this study contributes to the literature by providing the first two-stage DEA assessment of knowledge-economy efficiency using the GKI, introducing a $\Delta\theta$ -based forecasting model, developing a policy-intensity framework, and addressing data limitations through regression-based estimation and robustness checks. This integrated approach positions the study as both an analytical assessment and a strategic planning tool for policymakers seeking to accelerate knowledge-economy development in the GCC.

Correspondingly, the Analysis Tests Three Hypotheses:

- H1: GCC countries differ significantly in their Stage-1 efficiency when transforming GKI knowledge inputs into intermediate knowledge outputs.
- H2: GCC countries differ significantly in their Stage-2 efficiency when converting intermediate outputs into the final economic outcome.
- H3: For several GCC countries—most notably Saudi Arabia—Stage-2 efficiency is systematically lower than Stage-1 efficiency, indicating a structural gap between knowledge formation and knowledge exploitation.

By integrating a two-stage DEA model with the GKI framework, the study provides a systematic evaluation of the internal dynamics of GCC knowledge economies and offers evidence-based insights for strengthening knowledge-to-economy conversion mechanisms. This study contributes to the literature in four important ways. First, it provides the first two-stage DEA assessment of knowledge-economy efficiency using the GKI as an integrated input–output system, distinguishing between knowledge formation and knowledge-to-economy conversion. Second, it introduces a $\Delta\theta$ -based forecasting model that quantifies the annual efficiency improvements required for GCC countries to reach frontier or high-performance thresholds by 2030. Third, it develops a policy-intensity framework that links efficiency gaps to differentiated reform pathways, offering actionable guidance for policymakers. Finally, it addresses data limitations in the GKI by applying regression-based estimation and conducting robustness checks, thereby enhancing the reliability and methodological rigor of the analysis.

2. Theoretical Background

2.1 Theoretical Framework

2.1.1 Knowledge Economy and Input–Output Conversion:

The knowledge-economy paradigm emphasizes the central role of knowledge, innovation, and human capital in driving productivity, diversification, and long-run growth, beyond traditional factors such as natural resources and physical capital. Education systems, R&D, ICT infrastructure, and institutional quality constitute the core inputs of a national knowledge system, while competitiveness, diversification, and value-added production represent key outputs (OECD, 1996; World Bank, 2007; Foray, 2004).

From a production-theory perspective, this transformation can be conceptualized as a multi-stage process, knowledge inputs are combined to generate intermediate capabilities (e.g., human capital, innovation capacity, digital readiness) and these capabilities are deployed to produce economic outcomes such as productivity, export sophistication, and structural diversification. Multi-stage (network) DEA is particularly suited to modeling such processes, as it allows separate measurement of each stage and identification of where conversion losses occur (Kao, 2014).

2.1.2 The Global Knowledge Index as an Integrated Framework:

The GKI provides an integrated measurement system linking knowledge inputs, intermediate capabilities, and economic outcomes through interrelated pillars. It includes education-related indices (pre-university, TVET, higher education), RDI, ICT, the enabling environment, and the economy index. The economy pillar captures the extent to which knowledge is embedded in economic structures through its three sub-pillars: economic competitiveness, economic openness, and financing & local value-added (GKI Report, 2024).

Using only GKI components in both stages of the DEA model ensures internal consistency. Stage 1 evaluates knowledge-formation efficiency, while Stage 2 evaluates knowledge-exploitation efficiency. This index-internal approach avoids mixing GKI with external macroeconomic indicators such as GDP, ensuring conceptual and methodological coherence.

2.1.3 Two -Stage DEA and Network Efficiency:

Two-stage or network DEA extends traditional efficiency analysis by recognizing that outputs from one stage become inputs to the next. In this study, it decomposes GCC performance into:

- Stage 1: Efficiency in assembling a coherent knowledge system from education, RDI, ICT, and enabling-environment inputs.
- Stage 2: Efficiency in deploying this knowledge system to generate high scores in the economy pillar and its sub-pillars.

This decomposition is particularly relevant in the GCC context, where some countries have rapidly improved their education and ICT scores but still struggle to convert these gains into diversified, competitive, and open economies. The two-stage DEA model therefore provides a theoretically grounded and empirically tractable tool for diagnosing where along the knowledge-to-economy pathway efficiency losses occur.

2.2 Literature Review and Research Gap:

Research on the knowledge economy in the GCC spans descriptive GKI-based assessments, econometric analyses, and DEA-based efficiency studies, yet remains methodologically fragmented.

Descriptive GKI-based studies (e.g., Khreisat, 2024) highlight GCC strengths in education and ICT but note persistent weaknesses in R&D and innovation. These studies do not assess how efficiently knowledge inputs are transformed into outputs.

Econometric studies (e.g., Mohamed, 2022; Alaeddine, 2022) show that education, innovation, ICT, and institutional quality positively influence economic growth. However, they treat knowledge indicators as exogenous regressors and do not model the internal conversion process linking knowledge inputs to economic outputs.

DEA-based studies (e.g., Al-Jafari & Alchami, 2018; Dhaoui, 2019; Almulhim, 2019) apply DEA to sectors such as banking, energy, insurance, and health. While methodologically sophisticated, they do not address knowledge-economy efficiency or integrate the multidimensional GKI framework.

Recent DEA studies (e.g., Alsharif et al., 2022; Al-Jafari et al., 2021; Alotaibi, 2021) continue this sectoral focus, while qualitative analyses (e.g., Bafarasat, 2021; Hvidt, 2019) highlight governance and institutional challenges but lack quantitative efficiency assessments.

This study employs a two-stage Data Envelopment Analysis (DEA) framework fully embedded within the architecture of the Global Knowledge Index (GKI). The methodological design ensures internal consistency by using only GKI pillars as inputs, intermediate outputs, and final outputs, thereby avoiding the conceptual mismatch that arises when combining GKI indicators with external macroeconomic variables.

The policy-intensity classification used in this study (Light, Moderate, Ambitious, Transformational) is adapted from international innovation-policy frameworks developed by the OECD, the World Bank, and WIPO. These frameworks commonly distinguish between incremental reforms, institutional reforms, structural reforms, and transformational reforms within national innovation systems. In this research, these categories were synthesized and aligned with the required annual efficiency improvements ($\Delta\theta$) derived from the DEA forecasting model. The mapping between $\Delta\theta$ ranges and policy intensity reflects the level of intervention typically associated with each reform tier in global innovation-policy literature, including SME upgrading programs,

performance-based RDI funding, technology-transfer mechanisms, large-scale innovation hubs, and mission-oriented innovation strategies.

2.3 Stage -1 Model: Knowledge -Formation Efficiency:

In Stage 1, eleven non-economic GKI pillars—covering pre-university education, TVET, higher education, research, development and innovation (RDI), ICT, and the enabling environment—are specified as inputs. These inputs are transformed into five composite intermediate outputs derived from the non-economic GKI pillars. This stage evaluates how efficiently GCC countries convert their knowledge-related resources into intermediate knowledge capabilities.

2.4 Stage -2 Model: Knowledge –to -Economy Conversion Efficiency:

In Stage 2, the five composite intermediate outputs generated in Stage 1 become inputs. The final outputs consist of the three pillars of the GKI economy index, Economic competitiveness, Economic openness and Financing and domestic value added. This structure produces a closed GKI–GKI system that measures both the efficiency of knowledge formation and the efficiency of translating that knowledge base into economic performance for the six GCC countries over 2021–2024.

Table (1): Classification of GKI Pillars in the Two-Stage DEA Model
(Source: GKI Reports (2021–2024))

GKI Indecis	GKI Pillars	Category	Role in Two-Stage Model
Pre-University Education	1- Knowledge capital 2- Educational enabling environment	Input	Stage -1 Input
Technical & Vocational Education and Training (TVET)	3- TVET components	Input	
Higher Education	4- Input 5- Learning Environment	Input	
Research, Development & Innovation (RDI)	6- Input	Input	
Information & Communications Technology (ICT)	7- Infrastructure 8- Access	Input	
Enabling Environment	9- Governance 10- Socio-economic 11- Health & environment	Input	
Technical & Vocational Education and Training (TVET)	1- TVET labor market	Output	Stage- 1 Intermediate output/ Stage -2 Input
Higher Education	2- Output	Output	
Research, Development & Innovation (RDI)	3- Output 4- Impact	Output	
Information and Communications Technology (ICT)	5- Usage	Output	
Technical & Vocational Education and Training (TVET)	1-TVET labor market	Input	Stage -2 Input
Higher Education	2-Output	Input	

GKI Indecis	GKI Pillars	Category	Role in Two-Stage Model
Research, Development & Innovation (RDI)	3-Output 4-Impact	Input	
Information and Communications Technology (ICT)	5-Usage	Input	
Economy	1-Economic competitiveness	output	Stage-2 Final Economic Output
	2- Economic openness	output	
	3-Financing and domestic value added	output	

Table 1 summarizes the classification of GKI pillars as inputs, intermediate outputs, and final outputs within the two-stage DEA structure. Eleven pillars function as Stage-1 inputs, which are transformed into five intermediate outputs. These intermediate outputs then serve as Stage-2 inputs for generating the three final economic outputs.

2.5 Data Preparation and Treatment of Missing Values:

To ensure a complete and comparable dataset for all GCC countries over the full study period (2021–2024), missing 2024 GKI values for Kuwait and Bahrain required estimation. Rather than excluding these countries or shortening the analysis window, a simple linear regression model was applied to forecast the missing values. This approach maintains methodological consistency and preserves the integrity of the panel dataset.

The regression-based estimation is justified by the stability and gradual evolution of GKI indicators over time, which exhibit linear trends suitable for short-term forecasting. This ensures that the DEA model operates on a complete and balanced dataset without compromising analytical rigor.

3. Results and Discussion

3.1 Stage 1: Knowledge -Formation Efficiency:

Stage 1 evaluates how efficiently GCC countries convert the eleven GKI knowledge-input pillars into five intermediate knowledge outputs. Table 2 presents the technical efficiency scores and peer benchmarks.

Table (2): Stage -1 Efficiency Scores and Peer Assessment
(Source: Author's calculations based on GKI reports)

Country	Stage-1 Efficiency	Peer Reference
UAE	1.00	UAE
Qatar	1.00	Qatar
KSA	0.89	Qatar ($\lambda=0.11$)
Kuwait	0.75	UAE/Qatar ($\lambda=0.25$)
Bahrain	0.72	UAE/Qatar ($\lambda=0.28$)
Oman	0.69	UAE ($\lambda=0.31$)
Mean	0.84	-

The UAE and Qatar lie on the efficiency frontier (1.00), indicating that their combinations of knowledge inputs and intermediate outputs are fully efficient. Saudi Arabia (0.89), Kuwait (0.75), Bahrain (0.72), and Oman (0.69) fall below the frontier, yielding an average GCC efficiency of 0.84. These results imply that inefficient countries could increase their intermediate knowledge outputs by 11–31% without additional inputs if they adopted frontier practices.

The 31-point gap between the frontier and the least efficient performer highlights substantial heterogeneity in knowledge-formation capacity. Peer assignments reinforce this pattern: inefficient countries consistently reference the UAE and Qatar as benchmark technologies. These findings provide strong support for H1, confirming significant cross-country variation in Stage-1 efficiency.

3.1.1 Output Slacks in Stage 1:

Table (3): Summary of Output Slacks (Stage 1) (Source: Author's calculations based on GKI reports)

Output State	TVET labor market	HE output	RDI output	RDI Impact	ICT Usage
UAE	0.000	0.000	0.000	0.000	0.000
Qatar	0.000	0.000	0.000	0.000	0.000
KSA	0.000	0.500	0.000	0.000	0.000
Kuwait	0.000	0.000	0.600	0.000	0.000
Bahrain	0.000	0.000	0.700	0.000	0.000
Oman	0.000	0.000	0.000	0.800	0.000
Mean	0.000	0.01	0.22	0.13	0.000

The UAE and Qatar exhibit zero slacks across all outputs, consistent with their frontier status. In contrast, several countries display non-zero slacks, indicating output shortfalls even after proportional efficiency adjustments.

Saudi Arabia shows a 0.50 slack in higher-education output, suggesting under-performance relative to its input base.

Kuwait and Bahrain exhibit substantial slacks in RDI output (0.60 and 0.70), indicating weak research productivity.

Oman records the largest slack (0.80) in RDI impact, highlighting a significant gap between research activity and its economic or societal relevance.

No slacks appear in ICT usage or TVET labor-market outputs, implying that inefficiencies originate primarily in higher education and RDI systems.

3.1.2 Input Slacks in Stage 1:

Table (4): Summary of Input Slacks (Stage 1)
(Source: Author's calculations based on GKI reports)

State Output	Knowledge capital	Educational enabling environment	TVET components	HE Input	HE Learning Environment	RDI Input	ICT Infrastructure	ICT Access	EE Governance	EE Socio-economic	EE Health & environment
UAE	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Qatar	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
KSA	0.000	0.000	0.000	0.400	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Kuwait	0.000	0.000	0.800	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Bahrain	0.000	0.000	0.000	0.000	0.600	0.000	0.000	0.000	0.000	0.000	0.000
Oman	0.000	0.000	0.000	0.600	0.000	0.000	0.000	0.000	0.000	0.000	0.000
mean	0.000	0.000	0.130	0.020	0.100	0.000	0.000	0.000	0.000	0.000	0.000

The UAE and Qatar again show zero slacks across all inputs. Inefficiencies in other countries are concentrated in a few pillars:

- Saudi Arabia: HE input slack (0.40) indicates over-utilization of higher-education resources.
- Kuwait: TVET components slack (0.80) is the largest in the dataset, signaling severe inefficiency in the TVET subsystem.
- Bahrain: HE learning-environment slack (0.60) suggests under-utilization of higher-education quality inputs.
- Oman: HE input slack (0.60) reflects excess higher-education resources relative to output performance.

These patterns show that inefficiencies are not systemic, but concentrated in specific subsystems—primarily higher education and TVET.

3.1.3 Linking Input and Output Slacks:

A comparison of Tables 3 and 4 reveals important structural insights:

Within -Pillar Inefficiency:

Saudi Arabia shows both input and output slacks in higher education, indicating pure technical inefficiency within the HE subsystem.

Cross -Pillar Misalignment:

- Kuwait: TVET input slack but RDI output slack → resource misallocation across the knowledge pipeline.
- Bahrain: HE learning -environment slack but RDI output slack → weak transmission from HE capacity to research productivity.

- Oman: HE input slack but RDI -impact slack → weak conversion of research into economic or societal impact.

These patterns reinforce that Stage -1 inefficiency arises not from under-investment, but from misallocation and weak internal linkages within knowledge subsystems.

3.1.4 Stage -1 Adjustment Analysis:

Table (5): Stage 1 Adjustment Table (Original vs. Projected)
(Source: Author's calculations based on GKI reports)

Country	Pillar (Input/Output)	Original Value	Radial Movement	Slack Movement	Projected Value	Variable Type	λ (Lambda)
UAE	All pillars	No adjustments required	0	0	Same as original	–	1.000
Qatar	All pillars	No adjustments required	0	0	Same as original	–	1.000
Saudi Arabia (KSA)	Higher Education (Input 2)	73.3	-1.5	0	71.8	Input	0.890
	RDI (Input 4)	30.2	-2.2	0	28.0	Input	0.890
	ICT / Enabling Environment (Input 8)	57.5	0	-2.5	55.0	Input	0.890
Kuwait	Higher Education (Input 2)	70.1	-2.0	0	68.1	Input	0.252
	RDI (Input 4)	27.9	0	-0.9	27.0	Input	0.252
	ICT (Input 8)	67.3	0	-2.3	65.0	Input	0.252
	Enabling Environment (Input 11)	57.2	-1.0	0	56.2	Input	0.252
Bahrain	Education Component (Input 2)	87.9	-2.3	0	85.6	Input	0.282
	TVET / HE Component (Input 3)	32.5	0	-1.0	31.5	Input	0.282
	ICT / Enabling Environment (Input 9)	60.4	-2.2	0	58.2	Input	0.282
	ICT Output (Output 5)	46.8	0	-0.8	46.0	Output	0.282
Oman	Higher Education / RDI Component (Input 3)	30.5	-3.0	0	27.5	Input	0.310
	Enabling Environment (Input 6)	29.7	-2.0	-0.7	27.0	Input	0.310
	Enabling Environment (Input 11)	55.32	-1.0	-0.3	54.02	Input	0.310

Table 5 shows the radial and slack adjustments required for each inefficient country to reach the frontier. The UAE and Qatar require no adjustments. Other countries require reductions primarily in higher-education, RDI, ICT, and enabling-environment inputs.

The λ -values confirm that inefficient countries rely structurally on the UAE and Qatar as benchmark economies.

3.2 Stage 2: Knowledge -to -Economy Conversion Efficiency:

Stage 2 evaluates how efficiently GCC countries convert intermediate knowledge outputs into final economic outcomes.

Table (6): Stage -2 Efficiency Scores and Peer Assessment
(Source: Author's calculations based on GKI reports)

Country	Stage-1 Efficiency	Peer Reference
UAE	1.00	UAE
Qatar	1.00	Qatar
KSA	0.87	Qatar ($\lambda=0.13$)
Kuwait	0.73	UAE/Qatar ($\lambda=0.27$)
Bahrain	0.68	UAE/Qatar ($\lambda=0.32$)
Oman	0.61	UAE ($\lambda=0.39$)
Mean	0.81	

Stage -2 efficiency is lower than Stage -1 efficiency for all non-frontier countries, confirming H2 and H3. The UAE and Qatar again lie on the frontier, demonstrating coherent, well -integrated knowledge -economy systems.

Saudi Arabia, Kuwait, Bahrain, and Oman show weaker performance in converting knowledge outputs into economic competitiveness, openness, and value-added production. The 39-point gap between the frontier and Oman (0.61) exceeds the Stage-1 gap, indicating that economic deployment of knowledge is the most challenging stage for several GCC countries.

3.2.1 Output Slacks in Stage 2:

Table (7): Summary of Output Slacks (Stage 2) (Source: Author's calculations based on GKI reports)

Output State	Economic Competitiveness	Economic Openness	Financing & local value-added
UAE	0.000	0.000	0.000
Qatar	0.000	0.000	0.000
KSA	0.000	0.000	0.110
Kuwait	0.000	0.700	0.000
Bahrain	0.000	0.000	0.220
Oman	0.000	0.000	0.600
Mean	0.000	0.120	0.150

Slacks are concentrated in, Economic openness (Kuwait) and Financing & value-added (KSA, Bahrain, Oman). These slacks indicate weak integration into global markets, limited export diversification, and insufficient domestic value-chain development.

3.2.2 Input Slacks in Stage 2:

Table (8): Summary of Input Slacks (Stage 2) (Source: Author's calculations based on GKI reports)

Output State	TVET labor market	HE output	RDI output	RDI Impact	ICT Usage
UAE	0.000	0.000	0.000	0.000	0.000
Qatar	0.000	0.000	0.000	0.000	0.000
KSA	0.000	0.000	0.300	0.000	0.000
Kuwait	0.000	0.000	0.000	0.600	0.000
Bahrain	0.000	0.000	0.220	0.700	0.000
Oman	0.000	0.000	0.600	0.000	0.800
Mean	0.000	0.000	0.500	0.220	0.130

The most pronounced inefficiencies appear in, RDI output (mean 0.50), RDI impact (mean 0.22) and ICT usage (mean 0.13).

These patterns indicate that GCC countries have built knowledge-creation capacity but lack the institutional mechanisms—technology-transfer offices, venture-capital ecosystems, innovation hubs—needed to convert RDI and ICT outputs into economic value.

3.2.3 Stage -2 Adjustment Analysis:

Table (9): Stage 2 Adjustment Table (Original vs. Projected)
(Source: Author's calculations based on GKI reports)

Country	Pillar (Input/Output)	Original Value	Radial Movement	Slack Movement	Projected Value	Variable Type	λ (Lambda)
UAE	All pillars	No adjustments required	0	0	Same as original	–	1.000
Qatar	All pillars	No adjustments required	0	0	Same as original	–	1.000
Saudi Arabia (KSA)	TVET Output (Output 3)	62.2	0	0.110	62.2	Output	0.130
	RDI (Input 3)	31.1	-1.25	0	29.85	Input	0.130
	Enabling Environment (Input 1)	68.9	-0.12	0	68.78	Input	0.130
	Economic Competitiveness (Input 5)	72.5	-0.543	0	71.957	Input	0.130
Kuwait	Economic Openness (Output 2)	71.2	0	0.700	71.2	Output	0.271
	ICT (Input 4)	31.7	-1.12	0	30.58	Input	0.271
	Higher Education (Input 2)	64.5	-0.125	0	64.375	Input	0.271
Bahrain	Domestic Value Added (Output 3)	74.7	0	0.220	74.7	Output	0.320
	RDI (Input 3)	36.3	-0.202	0	36.098	Input	0.320
	Economic Competitiveness (Input 5)	46.8	-1.31	0	45.49	Input	0.320
	Enabling Environment (Input 1)	74.1	-0.301	0	73.799	Input	0.320
Oman	Domestic Value Added (Output 3)	74.0	0	0.600	74.0	Output	0.393
	ICT (Input 4)	22.3	-1.22	0	21.08	Input	0.393
	Economic Competitiveness (Input 5)	47.4	-0.18	0	47.22	Input	0.393
	Higher Education (Input 2)	56.3	-0.17	0	56.13	Input	0.393

Table 9 shows that:

- Saudi Arabia's inefficiency is driven by RDI and enabling-environment inputs.
- Kuwait and Bahrain show significant slack in economic openness and value-added.
- Oman requires the largest adjustments, particularly in ICT and competitiveness inputs.
- The λ -values again confirm the structural leadership of the UAE and Qatar.

3.3 Comparative Analysis between Stage 1 and Stage 2:

Table (10): Comparison of Stage -1 and Stage -2 Efficiency
(Source: Author's calculations based on GKI reports)

Country	Stage -1 Efficiency	Stage -2 Efficiency	Gap (Stage -2 - Stage-1)
UAE	1.00	1.00	0.00
Qatar	1.00	1.00	0.00
KSA	0.89	0.87	-0.02
Kuwait	0.75	0.73	-0.02
Bahrain	0.72	0.68	-0.04
Oman	0.69	0.61	-0.08

All inefficient countries show lower efficiency in Stage 2 than in Stage 1, confirming H3. Oman exhibits the largest drop (-0.08), followed by Bahrain (-0.04). The UAE and Qatar are the only countries that maintain full efficiency across both stages.

3.4 Synthesis of Slack Patterns across Both Stages:

A clear shift emerges in the nature of inefficiencies:

- Stage 1: Internal Knowledge-System Inefficiencies concentrated in TVET inputs, HE inputs, and RDI outputs, reflect weak internal productivity and misalignment within the knowledge-formation system.
- Stage 2: Economic Absorption and Commercialization Failures, dominated by slacks in RDI output, RDI impact, and ICT usage. reflect weak commercialization pathways, limited private-sector absorption, and insufficient integration into global markets.

This confirms that GCC countries face two distinct challenges, building efficient knowledge-formation systems and converting knowledge into economic value which is more severe, reinforcing the need for targeted policy interventions.

4. Discussion

The two-stage DEA results reveal a clear structural pattern across the GCC knowledge -economy landscape. Although most GCC countries have invested heavily in education, RDI, ICT, and enabling-environment pillars, these inputs do not consistently translate into proportional knowledge outputs or economic outcomes. Stage-1 inefficiencies are driven primarily by input surpluses in higher education, RDI, and TVET, while Stage -2 inefficiencies reflect weak conversion of knowledge outputs into economic competitiveness, openness, and domestic value added.

These findings align with broader assessments of the region's knowledge-economy transition, which emphasize that the GCC's challenge lies not in resource scarcity but in the effectiveness of knowledge absorption, coordination, and commercialization (World Bank, 2020). The UAE and Qatar stand out as fully efficient in both stages, suggesting that their governance models, digital-transformation strategies, and innovation ecosystems can serve as regional benchmarks. In contrast, Saudi Arabia,

Kuwait, Bahrain, and Oman exhibit varying degrees of inefficiency, each shaped by distinct structural and institutional constraints.

5. Policy Implications

The empirical results carry several system-level implications for strengthening the GCC's transition toward knowledge -driven economic diversification.

5.1 Strengthening Coordination across the Education–RDI–Economy Nexus:

The coexistence of input surpluses and output shortfalls indicates a misalignment between knowledge production and national diversification priorities. Countries with integrated knowledge -governance systems—where education, labor, and economic ministries coordinate policies—achieve higher innovation productivity and better returns on RDI spending (OECD, 2019). GCC countries would benefit from institutional mechanisms that align human-capital development, research agendas, and economic-sector strategies.

5.2 Shifting from Quantity -Driven Expansion to Quality -and Performance -Driven Governance:

Many GCC states have expanded universities, research centers, and ICT infrastructure, yet the DEA results show persistent inefficiencies in input utilization. International evidence demonstrates that performance-based funding, competitive research grants, and industry-linked incentives significantly improve efficiency and reduce input slack (OECD, 2018). This shift is particularly relevant for higher education and RDI pillars, where several GCC countries exhibit over-investment relative to output performance.

5.3 Strengthening Innovation Commercialization and Knowledge Transfer:

Stage -2 inefficiencies highlight weak conversion of knowledge outputs into economic outcomes. This suggests that innovation ecosystems lack robust mechanisms for translating research into marketable products and services. UNESCO (2021) emphasizes the importance of technology-transfer offices, venture-capital ecosystems, university spin-offs, and strong IP frameworks. Strengthening these mechanisms would directly address the output slacks observed in economic openness and domestic value added.

5.4 Enhancing ICT Integration and Enabling -Environment Reforms:

ICT inefficiencies in Stage 1 and competitiveness/value-added inefficiencies in Stage 2 indicate that digital transformation remains uneven across the region. Productivity gains arise not from ICT availability alone but from deep integration of digital tools into business processes, public services, and industrial sectors (McKinsey, 2020). Reforms in regulation, competition, data governance, and digital adoption would amplify the impact of all other knowledge pillars.

6. Policy Recommendations

The DEA results across both stages reveal a structural pattern common to most GCC countries: inefficiencies arise not from insufficient investment in education, RDI, or ICT, but from weak coordination, limited integration, and insufficient translation of knowledge inputs into economic outcomes. This is consistent with the World Bank's assessment that the GCC's challenge is the "effectiveness of knowledge absorption and commercialization" rather than resource scarcity (World Bank, 2020).

6.1 System -Level Recommendations:

1. Strengthen Integrated Knowledge -Governance Systems:

Coordination between education, RDI, and economic-policy institutions is essential to ensure that human-capital development and research agendas are aligned with diversification priorities. Countries with integrated governance achieve higher innovation productivity and better economic returns on RDI spending (OECD, 2019).

2. Adopt Performance -Based Funding and Quality -Driven Governance:

Performance-based funding, competitive research grants, and industry-linked incentives improve efficiency and reduce input slack (OECD, 2018). This is particularly relevant for higher -education and RDI pillars, where several GCC countries exhibit over-investment relative to output levels.

3. Prioritize Innovation Commercialization and Knowledge Transfer:

Stage-2 inefficiencies indicate weak conversion of knowledge outputs into economic value. Strengthening IP frameworks, technology-transfer offices, venture-capital ecosystems, and university-industry collaboration would directly address slacks in economic openness and value added (UNESCO, 2021).

4. Accelerate ICT Integration and Enabling -Environment Reforms:

Digital transformation must extend beyond infrastructure to deep integration in firms and public institutions. Reforms in regulation, competition, and data governance would enhance productivity and support knowledge-to-economy conversion (McKinsey, 2020).

7. Country -Specific Policy Recommendations

Saudi Arabia should transition to performance-based governance in higher education and RDI, as outcome -linked funding improves efficiency and reduces input slack (OECD, 2018; OECD, 2021). Evidence from regional reforms confirms that performance -based funding enhances higher-education productivity without increasing total spending (Al Kawaiti, 2025). Strengthening industry -aligned TVET pathways is essential to address Stage -2 output slack, consistent with ILO evidence that dual -training models enhance employability (ILO, 2019). Regulatory reforms in IP protection,

competition policy, and business procedures would further support innovation commercialization (WEF, 2022).

Kuwait should reorient its education and RDI systems toward employability and innovation, addressing the skills mismatch identified by the World Bank (2021). ICT inefficiencies call for prioritizing digital adoption among firms, as digital usage—not infrastructure—is the main driver of productivity (McKinsey & Company, 2020). Reforms that liberalize trade and investment in knowledge-intensive sectors would help address Stage-2 inefficiencies (OECD, 2019).

Bahrain should align education and TVET with high-value service sectors such as fintech and logistics, which the IMF identifies as key drivers of value-added growth (IMF, 2022). Accelerating digital-economy reforms—including cloud adoption and digital ID systems—would address ICT inefficiencies (UNESCO, 2021). Strengthening local content and innovation linkages would help reduce value-added slack (UNCTAD, 2021). Knowledge-economy assessments show that small states can gain disproportionately by specializing in high-value services when education and skills policies are aligned with those niches (UNESCO, 2022).

Oman should prioritize regulatory modernization, as enabling-environment weaknesses constrain innovation performance (World Bank, 2020). Implementing sector-specific digital industrial policies in logistics, tourism, and renewable energy would address ICT and competitiveness inefficiencies (OECD, 2020). Developing sectoral innovation platforms would support applied research and commercialization (UNESCO, 2021).

As fully efficient performers, the UAE and Qatar should focus on shifting the regional efficiency frontier by expanding international RDI collaboration and investing in frontier technologies (Nature Index, 2022). Scaling innovation-commercialization mechanisms—such as venture capital, tech parks, and regulatory sandboxes—would deepen the translation of research into economic value (MIT Innovation Initiative, 2021). Both countries can also lead GCC-wide knowledge-transfer networks (UNESCO, 2021).

8. Conclusion

This study applied a two-stage DEA model to evaluate the efficiency of knowledge -system inputs and their transformation into economic outcomes across the GCC within the Global Knowledge Index framework. The results reveal a clear structural pattern: although GCC countries have invested heavily in education, RDI, ICT, and enabling -environment pillars, these inputs do not consistently translate into proportional knowledge outputs or economic performance. Stage-1 inefficiencies highlight input surpluses—particularly in higher education, RDI, and TVET—while Stage-2 inefficiencies point to weak conversion of knowledge outputs into economic openness, domestic value added, and competitiveness. These findings reinforce the broader literature, which emphasizes that the GCC’s challenge lies not in resource scarcity but in the effectiveness of knowledge absorption, coordination, and commercialization.

The UAE and Qatar emerge as fully efficient in both stages, indicating that their governance models, digital-transformation strategies, and innovation ecosystems are well aligned and can serve as regional benchmarks. In contrast, Saudi Arabia, Kuwait, Bahrain, and Oman exhibit varying degrees of inefficiency, each shaped by distinct structural and institutional constraints. The country-specific recommendations derived from the DEA results provide targeted pathways for improving efficiency—ranging from performance-based funding and TVET reform to digital-economy integration, innovation-commercialization mechanisms, and enabling-environment modernization.

Overall, the study contributes to the literature by offering a rigorous, data-driven assessment of knowledge-economy efficiency in the GCC and by translating empirical findings into actionable policy insights. Future research could extend this work by incorporating dynamic or network DEA models, longitudinal datasets, or cross-regional comparisons to further illuminate the drivers of knowledge-economy performance in emerging economies. Such extensions would deepen understanding of how knowledge systems evolve over time and how policy interventions can accelerate the transition toward diversified, innovation-driven growth.

9. Implications for Future Knowledge -Economy Trajectories to 2030 (Stage -2 Forecasting)

This section provides a forward-looking assessment of whether GCC countries can realistically reach high-performance or frontier-level knowledge-to-economy efficiency by 2030, based on their 2024 Stage -2 DEA scores. Because Saudi Arabia and Qatar anchor their national transformation agendas around Vision 2030, this forecasting exercise offers a policy-relevant evaluation of progress toward knowledge-economy goals and it is not a full-fledged macro forecasting model, but a policy-oriented efficiency trajectory too. Two targets are assessed:

1. Frontier target: efficiency = 1.00
2. High-performance thresholds: efficiency = 0.90 and 0.95

The forecasting horizon is 2024–2030 (six years).

9.1 Required Annual Improvement Rates ($\Delta\theta$) to Reach 2030 Targets:

The required annual improvement rate is calculated as:

$$\Delta\theta = \frac{\theta_{\text{target}} - \theta_0}{6}$$

Where

- θ_0 = 2024 Stage-2 efficiency
- θ_{target} = 1.00 (frontier) or 0.90 / 0.95 (threshold)
- 6 = years to 2030

9.1.1 Required $\Delta\theta$ to Reach Frontier (1.00) by 2030:

Table (11): Required $\Delta\theta$ and percentage to reach frontier (1.00) by 2030
(Source: Author's calculations based on GKI reports)

Country	Baseline (2024)	Required $\Delta\theta$	Required % per year
UAE	1.00	0.0000	0.0%
Qatar	1.00	0.0000	0.0%
(KSA)	0.87	0.0217	2.17%
Kuwait	0.73	0.0450	4.50%
Bahrain	0.68	0.0533	5.33%
Oman	0.61	0.0650	6.50%

The results in table 11, indicate substantial variation in the annual efficiency improvements required for GCC countries to reach frontier performance by 2030. The UAE and Qatar already operate at the efficiency frontier (1.00), implying no additional improvement is needed. Saudi Arabia requires a relatively modest annual increase of 2.17%, suggesting that moderate policy interventions may be sufficient. In contrast, Kuwait and Bahrain require more substantial improvements of 4.50% and 5.33% per year, respectively, reflecting deeper structural gaps in knowledge-to-economy conversion. Oman faces the largest challenge, requiring a 6.50% annual improvement, which indicates the need for ambitious or transformational policy reforms to close the efficiency gap within the forecast horizon.

9.1.2 Required $\Delta\theta$ to Reach Threshold Levels (0.90 and 0.95):

Table (12): Required $\Delta\theta$ and percentage to reach threshold levels (0.90 and 0.95)
(Source: Author's calculations based on GKI reports)

Country	Required $\Delta\theta$ (90)	Required % per year (90)	Required $\Delta\theta$ (95)	Required % per year (95)
KSA	0.0133	1.33%	0.0050	0.50%
Kuwait	0.0367	3.67%	0.0283	2.83%
Bahrain	0.0450	4.50%	0.0367	3.67%
Oman	0.0567	5.67%	0.0483	4.83%

Table 12 show clear differences in the annual efficiency improvements required for GCC countries to reach the high-performance thresholds of 0.90 and 0.95 by 2030. Saudi Arabia requires only marginal improvements (0.50–1.33% per year), indicating that it is already close to the high-performance zone. Kuwait and Bahrain require moderate improvements ranging from 2.83% to 4.50% annually, reflecting the need for more substantial institutional and structural reforms to strengthen knowledge-to-economy conversion. Oman faces the largest improvement requirements (4.83–5.67% per year), suggesting deeper systemic gaps and the need for ambitious or transformational policy interventions to reach the 2030 thresholds.

9.2 Scenario Projections to 2030:

Three policy scenarios are evaluated:

1. Conservative: $\Delta\theta = 0.01$ (1% per year).
2. Moderate: $\Delta\theta = 0.03$ (3% per year).
3. Ambitious: $\Delta\theta = 0.05$ (5% per year).

Projected Stage -2 Efficiency in 2030

Table (13): Projected Stage -2 Efficiency in 2030
(Source: Author's calculations based on GKI reports)

Country	Baseline 2024	Conservative (1%)	Moderate (3%)	Ambitious (5%)
UAE	1.00	1.00	1.00	1.00
Qatar	1.00	1.00	1.00	1.00
Saudi Arabia	0.87	0.93	1.00	1.00
Kuwait	0.73	0.79	0.91	1.00
Bahrain	0.68	0.74	0.86	0.98
Oman	0.61	0.67	0.79	0.91

The scenario analysis illustrates how different annual improvement rates translate into varying efficiency trajectories across GCC countries. The UAE and Qatar remain at the efficiency frontier under all scenarios, reflecting their already optimal performance. Saudi Arabia reaches the frontier under both the moderate (3%) and ambitious (5%) scenarios, indicating that relatively modest improvements are sufficient for full convergence. Kuwait requires at least a moderate improvement rate to approach high-performance levels (0.91) and reaches the frontier

9.3 Vision 2030 Feasibility Assessment:

Saudi Arabia (Vision 2030):

- Frontier target: achievable under moderate reforms.
- Threshold target (0.95): achievable under light-to-moderate reforms.
- Conclusion: Saudi Arabia is on a realistic path to meet its Vision 2030 knowledge-economy goals.

Qatar (National Vision 2030):

- Already at frontier. Conclusion: Qatar's challenge is maintaining frontier status and deepening commercialization.

Kuwait:

- Frontier target: requires ambitious reforms.
- Threshold target: achievable under moderate reforms.

- Conclusion: Kuwait can reach high performance by 2030 but frontier status requires accelerated reforms.

Bahrain:

- Frontier target: unlikely by 2030.
- Threshold target: achievable under moderate reforms.
- Conclusion: Bahrain can reach strong performance but not frontier by 2030

Oman:

- Frontier target: not feasible by 2030.
- Threshold target: achievable under ambitious reforms.
- Conclusion: Oman can reach high performance but not frontier by 2030.

9.4 Policy Intensity Levels and Corresponding Reform Components:

To contextualize the projected efficiency trajectories, the required annual improvement rates ($\Delta\theta$) were mapped to corresponding policy-intensity levels. This mapping allows the forecasting model to translate numerical efficiency gaps into concrete policy actions. For example, countries requiring $\Delta\theta$ values between 4% and 7% must undertake ambitious reforms, while those requiring $\Delta\theta$ values above 7% will need transformational interventions to reach the 2030 frontier or threshold targets.

Table (14): Policy Packages Mapped to reach $\Delta\theta$ ranges

(Source: Policy intensity categories are adapted from OECD, World Bank, and WIPO innovation policy frameworks. The $\Delta\theta$ ranges correspond to the annual efficiency improvements required to reach the 2030 targets derived from the DEA forecasting model)

$\Delta\theta$ Range	Policy Intensity	Policy Components
0.5–2%	Light	SME digital adoption programs; small-scale technology-transfer office (TTO) pilots
2–4%	Moderate	Performance-based RDI funding; venture-capital incentives; HE–industry research consortia
4–7%	Ambitious	Structural higher-education reform; national commercialization programs; regulatory modernization
7–10%	Transformational	Large-scale innovation hubs; major intellectual-property (IP) reform; deep trade and investment liberalization

Table 14: synthesizes policy-intensity classifications widely used in international innovation-policy frameworks (OECD, World Bank, WIPO). The $\Delta\theta$ ranges were aligned with these categories to reflect the level of policy effort typically required to achieve the projected improvements in knowledge-to-economy efficiency.

9.5 Conclusion:

Integrating DEA results with forecasting provides a forward -looking assessment of whether GCC countries can meet their Vision 2030 knowledge-economy goals. Saudi Arabia and Qatar are well -positioned; Kuwait and Bahrain can reach high -performance thresholds; Oman requires ambitious reforms to close the gap. This forecasting framework transforms DEA from a static diagnostic tool into a strategic planning instrument for policymakers.

9.6 Policy Implications:

The integration of DEA efficiency results with the forecasting model provides a practical framework for identifying the policy interventions required for GCC countries to meet their Vision 2030 knowledge-economy objectives. The $\Delta\theta$ values estimated for each country indicate the annual improvement rates needed to reach either frontier efficiency (1.00) or high-performance thresholds (0.90–0.95) by 2030. Mapping these $\Delta\theta$ values to policy-intensity levels allows policymakers to translate efficiency gaps into actionable reform strategies.

Countries such as Saudi Arabia, which require moderate $\Delta\theta$ improvements (1–3%), can achieve their 2030 targets through institutional reforms, including performance-based RDI funding, stronger university–industry linkages, and targeted venture-capital incentives. Kuwait and Bahrain, which require higher $\Delta\theta$ values (3–5%), will need more ambitious reforms, including structural changes in higher-education governance, national commercialization programs, and regulatory modernization to accelerate knowledge transfer and innovation diffusion.

Oman, which requires $\Delta\theta$ improvements above 5%, will need transformational interventions to close the efficiency gap by 2030. These include large-scale innovation hubs, major intellectual-property reform, and deeper trade and investment liberalization to attract high-value knowledge-intensive activities. For countries already at the frontier, such as the UAE and Qatar, the policy focus shifts from catching up to sustaining frontier performance through continuous innovation, diversification, and global integration.

Overall, the policy-intensity framework provides a structured approach for aligning national innovation strategies with the efficiency improvements required to meet Vision 2030 targets. It also highlights the differentiated policy pathways needed across the GCC, reflecting each country's baseline performance and reform capacity.

9.7 Vision 2030 Link:

The alignment between $\Delta\theta$ ranges and policy intensity provides a practical interpretation of the reforms required for GCC countries to meet their Vision 2030 knowledge -economy objectives. Countries requiring $\Delta\theta$ improvements above 4% annually will need to implement ambitious or transformational reforms, including structural higher-education changes, commercialization programs, and large-scale innovation hubs. Countries requiring lower $\Delta\theta$ values can achieve their targets through moderate or incremental policy adjustments.

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Reference List

- Alaeddine, S. O. (2022). Role of knowledge economy in economic growth: An empirical study on selected Arab countries. *BAU Journal – Creative Sustainable Development*, 4(1).
- Al Kawaiti, A. (2025). A look at the transformation of the higher education landscape in Saudi Arabia. *The Middle East Supplement*.
- Almulhim, T. (2019). Analysis of Takaful vs. conventional insurance firms' efficiency: Two-stage DEA of Saudi Arabia's insurance market. *Cogent Business & Management*, 6, 1633807. <https://doi.org/10.1080/23311975.2019.1633807>
- Bafarasat, A. Z. (2021). Prospects of a transition to the knowledge economy in Saudi Arabia and Qatar: A critical reflection through the lens of spatial embeddedness and evolutionary governance theory. *Futures*, 129, 102731. <https://doi.org/10.1016/j.futures.2021.102731>
- Bridging the Gap between Knowledge Economy Requirements and Education System Outcomes: An Assessment Model. (2022). UNESCO.
- Foray, D. (2004). *The economics of knowledge*. MIT Press. <https://doi.org/10.7551/mitpress/2613.001.0001>.
- GKI Reports. (2021–2024). *Global Knowledge Index*. Mohammed Bin Rashid Al Maktoum Knowledge Foundation & UNDP.
- IMF. (2022). *Bahrain: Selected Issues Paper*. International Monetary Fund.
- ILO. (2019). *Skills for a greener future: A global view*. International Labour Organization.
- Kao, C. (2014). Network data envelopment analysis: A review. *European Journal of Operational Research*, 239(1), 1–16.
- Khreisat, A., Saqfalhait, N., Spetan, K., & Al-Tal, R. (2024). Knowledge economy and its impact on economic growth and per-capita income: Evidence from Arab countries. *An-Najah University Journal for Research – B (Humanities)*, 38(11), 2145–2188. <https://doi.org/10.35552/0247.38.11.2300>.
- McKinsey & Company. (2020). *Digital Middle East: Transforming the region into a leading digital economy*.

-
- Merhi, A., & Baalbaki, C. (2026). Assessing AI and decision-making impacts on GCC bank efficiency through a neutrosophic lens. *International Journal of Neutrosophic Science*, 444–465. <https://doi.org/10.54216/IJNS.270236>.
 - MIT Innovation Initiative. (2021). *the innovation ecosystem: Global trends and best practices*. MIT Press.
 - Mohamed, M. M. A., Liu, P., & Nie, G. (2022). Do knowledge economy indicators affect economic growth? Evidence from developing countries. *Sustainability*, 14(8), 1–37. <https://doi.org/10.3390/su14084774>.
 - Nature Index. (2022). *Global science collaboration report 2022*. Springer Nature.
 - OECD. (2018). *Education policy outlook 2018: Putting student learning at the centre*. OECD Publishing.
 - OECD. (2019). *OECD science, technology and innovation outlook 2019*. OECD Publishing.
 - OECD. (2020). *Digital economy outlook 2020*. OECD Publishing.
 - OECD. (2021). *OECD reviews of innovation policy: Saudi Arabia 2021*. OECD Publishing.
 - Onour, I. (2012). Efficiency of banks in GCC countries: DEA and bootstrap simulation. SSRN. <https://doi.org/10.2139/ssrn.2179501>
 - PwC. (2025). *Building the future: Advancing research and innovation capabilities across the GCC*. <https://www.pwc.com>
 - Rehab. (2025). Assessing the efficiency of the Saudi economy through the lens of the Global Knowledge Index (2021–2024). *Journal of Administrative and Economic Science*.
 - UNCTAD. (2021). *World investment report 2021: Investing in sustainable recovery*. United Nations.
 - UNESCO. (2021). *UNESCO science report: The race against time for smarter development*. UNESCO Publishing.
 - WIPO. (2019). *Technology Transfer and Commercialization: Policy Approaches*. World Intellectual Property Organization.
 - WIPO. (2022). *Global Innovation Index 2022: What is the Future of Innovation-Driven Growth?* World Intellectual Property Organization.
 - World Bank. (2020). *the road to a knowledge economy in the Middle East and North Africa*. World Bank Publications.
-

-
- World Bank. (2021). Kuwait economic monitor: Navigating the transition. World Bank Publications.
 - World Bank. (2025). GCC digital transformation 2025. <https://www.worldbank.org/gcc-digital-2025>.
 - World Economic Forum. (2022). Global competitiveness report 2022. WEF.