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RESEARCH ARTICLE

Efficiency and productivity analysis of innovation, human capital, environmental, and economic sustainability nexus: case of MENA countries

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Abstract
Innovation, human capital, economic, and environmental nexus is essential in sustainable development. The Middle East and North Africa (MENA) is an emerging market with the potential to transcend the dilemma of attaining economic and environmental sustainability. Data envelopment analysis through the Malmquist-Luenberger productivity index is utilized to estimate MENA country's innovation, human capital, economic, and economic sustainability efficiency and productivity. Results indicate an upward trend in efficiency, with a 26% increase in average efficiency between 2017 and 2019 compared to 2011 and 2016. However, there is variation in efficiency between countries. The decomposition of the productivity index into technical change and technological change indicates that the efficiency growth in 2017–2019 could be attributed to technical improvement than technological increase. However, there is a shift to more technological progress than technical increase. Study shows that developing human capital and capacity is as integral to sustainable development as innovation advancement. Strategies to simultaneously augment human capital and innovation towards sustainable development are presented.

Keywords Innovation · Human capital · Data envelopment analysis · Malmquist-Luenberger · Sustainable development

Introduction

Human capital is integral to economic growth and sustainability. Several studies have linked increased economic activities to the growing environmental degradation. Today, innovation has been shown to enhance sustainable growth. This has led many countries and regions to become intentional about eco-innovation as a method of reducing emissions. Energy-rich countries and regions such as the Middle East and North Africa (MENA) have outlined strategies and policies to support eco-innovation. However, the literature on empirical findings on these policies is profoundly sparse, coupled with the absence of the human capital factor. Many fail to look at the nexus between human capital and innovation as environmental and economic sustainability factors. Hence, there needs to be a healthy balance between human capital and innovation processes to attain sustainable environmental and economic development. The emerging nature of the MENA region makes it a perfect case study to explore the nexus between innovation, human capital, environmental, and economic sustainability.

Sustainability is the capacity to generate resources that will compensate for factors of production, replace used resources, invest, and continue competing (Barbieri et al., 2010). Innovation is essential for realizing sustainability (Adams et al. 2016). Studies show that technological innovation is vital for sustainable development (Barbieri et al. 2010; Hallenga-Brink and Brezet 2005; Nill and Kemp 2009). Betz (2003) opined that innovation aims at bringing out new or enhanced processes, services, or products. Afuah (2020) suggested that innovation uses new methods to offer improved services. Moreover, innovation and sustainability drive environmental, economic, and social development (Michelino et al. 2019).

Fagerberg (2004) stated that in a broad sense, innovation includes the entire process from the moment new ideas are

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created to their execution and onward transmission into the economic and social system. This is notable in sustainability transitions, where changes in practice, i.e., implementation and diffusion, are essential (Mowery et al. 2010). Edquist (2011), on the other hand, identified innovation policy (and policy instruments) with policies that significantly influence innovation since what counts as tangible impact based on the transition to sustainability is the effect of a policy, not its label. Innovations would generate positive economic, social, and environmental results (Seclen-Luna et al. 2021a). Therefore, sensible sectoral innovation policies and sustainability transitions become relevant. There has been a growing literature drawing insights from innovation studies and to some extent other scientific fields, examining how innovation policy can make a difference through various concepts such as eco-innovation policy (Kemp 2011), transformative innovation policy (Steward 2012), or mission-oriented innovation policy (Mazzucato 2017). This growing innovation trend has affected human capital development, which has played a significant role in economic development. Given this trend, this study seeks to investigate the impact of pure innovation pursuit on environmental and economic sustainability. In this context, Fig. 1 illustrates the conceptual framework of the study. Innovation and human capital are considered inputs to economic and environmental sustainability to analyze the efficiency and productivity of MENA country's sustainable development strategies and policies.

Several studies have analyzed the nexus between innovation and environmental policies adopted by countries and regions. National and regional analyses are essential because developmental and environmental spillover is inevitable (Costantini et al. 2013). However, these studies lack the simultaneous consideration of human capital as an input component of economic and environmental sustainability. Studies that have analyzed the efficiency of innovation, environmental sustainability, and economic sustainability have used the data envelopment analysis (DEA) method due to the complexities of the interconnection. For example, Chen et al. (2011) compared the relative efficiency of research and development (R&D) as an indicator of innovation for twenty-four countries, including sixteen European, four Asian, and four American countries. Wang and Huang (2007) estimated the efficiency of R&D activities for thirty countries. Guan and Chen (2012) evaluated the national innovation system efficiency for twenty-two countries of the Organisation for Economic Co-operation and Development (OECD). Guan and Chen (2010) analyzed thirty selected Chinese provinces' knowledge production and commercialization processes. Lafarga and Balderrama (2015) measured the relative technical efficiency of thirty-two Mexican regions with R&D expenditure as a critical factor for innovation. Noticeably, the above-mentioned studies are void of the human capital component in either innovation efficiency attainment or economic and environmental sustainability. This research extends previous studies such as Bresciani et al. (2021) and Khan et al. (2022) by analyzing the role of human capacity in utilizing innovation towards efficient economic and environmental sustainability. Methodologically, a robust DEA model that accounts for the undesirable environmental consequences of human activities and innovation is utilized. Furthermore, the Malmquist-Luemberger productivity analysis is conducted to analyze and decompose productivity for further inference. Strategies and policies are proposed based on the findings.

The remainder of the paper is organized as follows: "Literature review" section presents the literature review. The "Analysis framework" section discusses the analysis framework and data description. The methodologies are then discussed in the "Methodology" section with results and discussions in the "Results and discussion" section. The "Conclusion and policy implications" section concludes the paper.

Literature review

Many studies highlight the importance of innovation for sustainable development (Nill and Kemp 2009). Given the conclusion from these studies, we can infer that innovation is a primary driver of industrial growth. Over the last couple of decades, there have been studies on regional innovation systems (Berman et al. 2020; Doloreux and Porto 2017; Gomez 2017), providing evidence of why it should be used as an instrument to assess performance (Janger et al. 2017; Yu 2020). Comparative measures on innovation such as Bloomberg Innovation Index, Global Innovation Index, and European Innovation Scoreboard are introduced to allow comparative assessment at the national level. However, these indexes have flaws that hinder their use. For example, a significant correlation between some index components means they cannot adequately capture all aspects of innovation linked to each region (Schibany and Streicher 2008; Hauser et al. 2018). Nonetheless, they highlight the innovation performance to a certain degree.

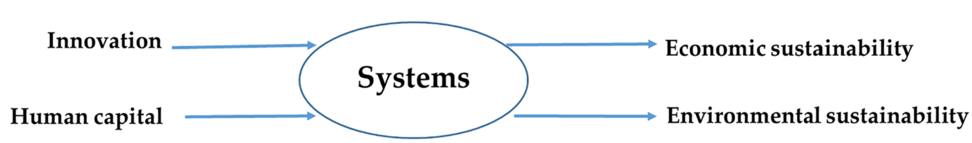

Fig. 1 Conceptual framework for innovation-economic-environmental assessment

Investigating the effects of human capital on economic growth has gained much interest from scientists and policymakers and has been extensively analyzed by researchers over the last few decades. The earliest theory regarding this relationship dates back to the works of Mincer (1958), Schultz (1961), and Becker (1975), who theorized that human capital is like physical capital, which can be advanced through education, health, and training, and can, in turn, increase output and boost economic growth. Hence, human capital can significantly contribute to economic growth (Romer, 1992; Barro, 1999). In conjunction with other factors such as investment in technology, human capital is essential to economic development (Huang et al. 2021). Human capital contributes to increased technical progress since education makes the innovation, transmission, and adoption of new technologies faster and easier. Recent studies have emphasized the need for human capital to attain sustainable development. Given the emergence of innovation-focused strategies for economic and environmental sustainability, the role of human capital is minimized. The MENA region, as an emerging economy, aims to attain a sustainable economic and environmental ecosystem by pursuing aggressive innovation practices. However, how sustainable is this approach in the long term?

Chen et al. (2011) analyzed innovation efficiency using R&D expenditure. Their result shows intellectual property rights protection and human capital accumulation to have a significant positive effect on innovation efficiency. Their study shows that human capital is also a component of innovation. Wang and Huang (2007) estimated the efficiency of R&D activities for 30 countries. Studies such as Carayannis et al. (2016) and Bresciani et al. (2021) build on Chen et al. (2011) and Wang and Huang (2007) using R&D activities as an input for innovation.

In evaluating knowledge processes, Guan and Chen (2010) evaluated national innovation system efficiency for 22 countries of the Organisation for Economic Co-operation and Development (OECD). In their study, a relational network DEA model was utilized. Furthermore, the effect of a policy-based institutional environment is investigated. Guan and Chen (2010) analyzed the knowledge production and commercialization processes for 30 selected Chinese provinces. By decomposing the Malmquist index, they provide a piece of multi-dimensional information to benchmark R&D efficiency. Lafarga and Balderrama (2015) measured the relative technical efficiency of 32 Mexican regions with R&D expenditure as a critical factor for innovation.

Innovation and environmental sustainability are essential elements of sustainable development. Economic development contributes significantly to the overall sustainability of countries and is essential to continuous competitiveness and market globalization. Innovation alone cannot be analyzed exclusively from a technological and market-oriented perspective Bresciani et al. (2021). The human capital component must be considered as part of the sustainable development element. Given the interconnection between innovation, economic development, and environmental sustainability, human capital is perhaps the pivotal factor that cannot be ignored. For optimal organizational structure and performance, Fonseca et al. (2019) point to human capital as a crucial dimension of the innovation process. Similarly, Diebolt and Hippe (2022) analyzed the long-run impact of human capital on innovation and economic growth in the European region. To buttress the conceptual framework of this study, the inference is drawn from industry activities such as the manufacturing industry. The manufacturing industry contributes to the economic sustainability of countries in the MENA region. The environment is also a recipient of the manufacturing industry from the CO2 emission. The findings of Seclen-Luna et al. (2021b) on the manufacturing firm performance show that human capital composition has a direct effect on manufacturing firm productivity. Moreover, in developing countries, human resources, innovation, and size play a significant role in the performance of manufacturing firms. Therefore, assessing the interconnection between the four factors human capital, innovation, economic development, and environmental sustainability is imperative to the sustainable development of countries and regions.

Analysis framework

Technical efficiency has predominantly been analyzed using two approaches: DEA and stochastic frontier analysis (SFA). While the latter is a parametric method, the former is a nonparametric approach and each has particular strengths and weaknesses and potentially measures different efficiency (Theodoridis and Anwar 2011). However, they have established robustness in estimating the efficiency of systems with multiple inputs and outputs. For example, Silva et al. (2017) show that DEA and SFA provide reliable information on the efficiency of the banking system. Zeng et al. (2021) used DEA and SFA to review 165 articles from academic journals concerning innovation efficiency. It is important to note that when dealing with scenarios involving multiple inputs and outputs in the context of nonlinearity, DEA has shown to be superior (Guan and Chen 2010; Chen et al. 2021; Hoff 2007).

DEA is a nonparametric linear programming approach that enables the relative efficiency assessment of homogeneous systems known as decision-making units (DMUs) (Saati et al. 2012). Each DMU's efficiency is estimated with respect to multiple inputs utilized and multiple outputs produced (Charnes et al. 1978). DEA has been widely applied to the problem of measuring sustainability performance (Ibrahim and Alola 2020; Ibrahim et al. 2021; Sun et al. 2020). The first DEA model was developed by Charnes et al. 1978) with its origin from Farrell (1957). The Charnes et al. (1978) model is referred to as the Charnes, Cooper, and Rhodes (CCR) model. It calculates the relative efficiency of DMUs under the assumption that constant returns to scale prevail. Banker et al. (1984) proposed an alternative model under variable returns to scale, which is referred to as the Banker, Charnes, and Cooper (BCC) model. The DEA methodology has advanced extensively to models such as direction distance function (Chambers et al. 1998; Färe and Grosskopf 2000) and target setting models (Ibrahim et al. 2020). DEA offers the flexibility that allows multiple facets of innovation to be integrated with the need to establish the production function that defines the process (Bresciani et al. 2021). It is well suited to handle analysis with factors that are interconnected. DEA can describe the dynamic change of systems and offers comprehensive discriminatory power.

The integration of innovation to the system process can be quantified for making impactful policies that promote environmental and economic sustainability. Best practices can be identified, and holistic performance trends can be analyzed. To account for the integration of innovation and human capacity towards environmental and economic sustainability, indicators representing each factor presented in the conceptual framework (Fig. 1) are imperative. Furthermore, the socio-economic dynamics need to be considered. Table 1 describes the inputs and outputs indicators of the conceptual framework.

As an input, innovation plays a key role in socio-economic transformation. The number of patents is a reliable indicator of innovation (Yafeng et al. 2018). Lee and Park (2005) used patents as an indicator to measure the international comparison of research and development efficiency. Similarly, Wang et al. (2021) used patents as an input variable to estimate innovation efficiency.

Human capital is a component of innovation development and deployment (Kalapouti et al. 2020). The diffusion of technical and operational knowledge requires human capital. Studies have shown that human capital has a statistically significant effect on environmental performance (Kim and Go 2020). The number of employed persons is utilized to incorporate human capital in the innovation and environmental socio-economical nexus. Numerous studies in different sectors have used the number of employed persons as an indicator of human capital. To assess the efficiency of renewable energy policies, Mohd Chachuli et al. (2021) used the number of employees as one of the input variables in the DEA analysis. Cavaignac et al. (2021) utilized the number of employees in an innovative two-stage DEA analysis of logistics efficiency. Given the macro scale of the analysis and innovation context, the number of employed persons in a country as a proxy variable measures the country's human capital.

Table 1 Data description

Dimension	Role	Indicator	Data source
Innovation	Input	Patents	(Eurostat 2021)
Human capital	Input	Number of employed persons	(WDI 2022c)
Economic	Output	Gross domestic product	(WDI 2011)
Environmental	Output	CO2 emissions	(WDI 2022a)

WDI, world development indicators

Economic and environmental sustainability are fundamental aspects of sustainable development and the primary output of innovation and human capital conjunction. Hence, the innovation-human capital-economic-environmental sustainability nexus. The gross domestic product GDP is selected to account for economic development. GDP is a primary indicator of a country's economic performance (WDI 2022b). GDP is a prevalent indicator used to assess economic sustainability (Wang et al. 2022). To assess resource and environmental efficiency in China, Bian and Yang (2010) used GDP to account for economic sustainability. GDP has also been linked to human capital (Matos et al. 2021), and environmental sustainability (Ibrahim and Alola 2020). Sheikhzeinoddin et al. (2022) used GDP to explore new evidence between economic development and environmental sustainability in MENA. To assess economic sustainability pre and post-COVID-19 pandemic, Lozano-Ramírez et al. (2022) utilized GDP as an output in their DEA analysis.

A sustainable environment is paramount for attaining sustainable development goals (SDGs). Baloch et al. (2022) analyzed the role of innovation in attaining the SDGs in which environmental sustainability plays a vital role in interconnecting many of the goals. To account for environmental sustainability, CO_2 emission is selected in the study. CO_2 emission is a viable indicator of environmental sustainability. The less CO_2 emitted, the more environmentally sustainable the country. Rahman et al. (2022) discussed the connection between innovation and CO_2 emissions to abate climate crises. In the same lane, Bekun et al. (2019) highlighted the role of CO_2 in attaining a sustainable environment. Sueyoshi and Goto (2013) used CO_2 emissions as an output in DEA environmental assessment. Anser et al. (2020) also utilized CO_2 emissions as an output variable in establishing the role of energy innovation in emission reduction.

Methodology

The efficiency of innovation, environmental, and economic sustainability nexus analyzed in this study measures the utilization of innovation and human capital towards economic sustainability while taking into consideration the environmental impact of the development. Since the introduction of data DEA by Charnes et al. (1978). DEA has grown to be a robust technique for evaluating the relative efficiency of systems known as decision-making units (DMUs) with multiple inputs and outputs. A prominent DEA model is the directional distance function (DDF) model (Chambers et al. 1996), especially in the eco-efficiency context. Conventional DEA models take the form of input minimization (input–orientation) or output maximization (output–orientation) for efficiency estimation while assuming all outputs are desirable products. This is inappropriate when desirable and undesirable outputs are jointly produced (Färe et al. 1994). Chung et al. (1997) used DDF to measure eco-efficiency by simultaneously increasing desirable outputs and decreasing undesirable outputs. This study applies a robust novel undesirable outputs DDF model of (Álvarez et al. 2020) to estimate efficiency and productivity.

The DDF model measures the efficiency of units by projecting input–outputs of DMU (x_o, y_o); inputs $x_0 = (x_{10}, x_{20,} \dots, x_{m0})$ and outputs $y_0 = (y_{10}, y_{20,} \dots, y_{s0})$ onto a pre-assigned direction $g = \left(-g_x^-, g_y^+\right) \neq 0_{m+s}, g_x^- \in \mathfrak{R}^m \text{and} g_y^+ \in \mathfrak{R}^s$, in a direction β with a production possibility set $P = \{(x, y) | x \geq X\lambda, y \leq Y\lambda, \lambda \geq 0\}$.

Model (1) illustrates the linear program associated with the estimation.

$$
\begin{aligned}
&\underset{\beta,\lambda}{Max}\beta \\
&\text{Subject to} \\
&X\lambda \leq x_0 - \beta g_x^- \\
&Y\lambda \geq y_0 + \beta g_x^+ \\
&\textstyle\sum_{j=1}^{n} \lambda_j = 1 \\
&\lambda \geq 0
\end{aligned}
\tag{1}
$$

Given the undesirable environmental output resulting from economic activities (CO_2 emissions), an estimation that does not adequately account for these outputs will yield erroneous results. To accommodate for desirable and undesirable outputs, reference is made to the DDF function that accounts for the asymmetry between both outputs. The production possibility set is then redefined as follows: $P = \left\{ \left(x, y^d, y^u\right) | x \geq X\lambda, y^d \leq Y\lambda, y^u = Y\lambda, \lambda \geq 0 \right\}$ where the outputs are separated into desirable and undesirable, i.e., $y = \left(y^d, y^u\right)$ with $y^d \in R_{++}^q$ and $y^u \in R_{++}^r$ respectively. Therefore, the directional efficiency measure of a DMU $\left(x_0, y_0^d, y_0^u\right)$ is projected along a pre-assigned directional outputs vector $g_y = \left(y^d, y^u\right) \neq 0_{m+s}$. The corresponding solution to the linear program model (2) illustrates the efficiency score. If the optimal solution $\beta^* = 0$ with $\lambda_0 = 1, \lambda_j = 0 (j \neq 0)$, then the unit is directional efficient. Otherwise $\beta^* > 0$ implies the unit is inefficient.

$$
\begin{aligned}
&\underset{\beta,\lambda}{Max}\beta \\
&\text{Subject to} \\
&X\lambda \leq x_0 \\
&Y^d\lambda \geq y_0^d + \beta y_0^d \\
&Y^u\lambda \leq y_0^u + \beta y_0^u \\
&max\left\{y_i^u\right\} \geq y_0^u + \beta y_0^d \\
&\lambda \geq 0
\end{aligned}
\tag{2}
$$

Malmquist-Luenberger index productivity analysis

Chung et al. (1997) introduce the undesirable Malmquist-Luemberger (ML) productivity index to measure the productivity change of a system with undesirable outputs by referencing the relative efficiency across different time periods. The combined period efficiency $\left(x_0^t, y_0^{t,d}, y_0^{t,u}\right)$ is calculated for periods $t = 1, 2$. Both scores are denoted by $\beta^{1,1}$, and$\beta^{2,1}$, the first superscript refers to the observation of the first time period and the second corresponds to the reference technology. Prieto et al. (2020) relied on the work of Aparicio et al. (2013) to prevent inconsistencies in the original model by projecting observations along the pre-assigned direction. While $\beta^{1,1}$ represents the solution to model (2), the intertemporal score $\beta^{2,1}$ is the solution to model (3), which evaluates period 2 observation $\left(x_0^2, y_0^{2,d}, y_0^{2,u}\right)$ with respect to period 1 technology:

$$
\begin{aligned}
&\underset{\beta,\lambda}{Max}\beta \\
&\text{Subject to} \\
&X^1\lambda \leq x_0^2 \\
&Y^{1,d}\lambda \geq y_0^{2,d} + \beta y_0^{2,d} \\
&Y^{1,u}\lambda \leq y_0^{2,u} - \beta y_0^{2,u} \\
&max\left\{y_i^{t,u}\right\} \geq y_0^{2,u} - \beta y_0^{2,u} \\
&\lambda \geq 0
\end{aligned}
\tag{3}
$$

An ML > 1 signifies efficiency growth. Therefore, the system produces more desirable outputs and less undesirable out. A unison score of ML = 1 infers productivity remains unchanged, while ML < 1 signifies a decline in productivity. The ML index can be decomposed into two indices, efficiency changes (MLTEC) and technical change (MLTC). MLTEC refers to the operational components of the system, while MLTC refers to the technological change of the system (Grosskopf 1993).

$$
\begin{aligned}
ML = \text{MLTEC} \times \text{MLTC} = &\left(1 + \beta^{1,1}\right) / \left(1 + \beta^{2,2}\right) \\
&\times \left(\left(1 + \beta^{2,2}\right) / \left(1 + \beta^{2,1}\right) \times \left(1 + \beta^{1,2}\right) / \left(1 + \beta^{1,1}\right)\right)^{(1/2)}
\end{aligned}
\tag{4}
$$

The ML indices are defined as:

$$
ML_1 = \left(1 + \beta^{1,1}\right) / \left(1 + \beta^{2,1}\right) \; and \; ML_2 = \left(1 + \beta^{1,2}\right) / \left(1 + \beta^{2,2}\right)
\tag{5}
$$

The change in MLTEC is defined as:

$$\mathrm{MLTEC} = \left(1 + \beta^{1,1}\right) / \left(1 + \beta^{2,2}\right) \quad (6)$$

And the technical change MLTC:

$$MLTC_1 = \left(1 + \beta^{2,2}\right) / \left(1 + \beta^{2,1}\right) \text{ and } \mathrm{MLTC}_2 = \left(1 + \beta^{1,2}\right) / \left(1 + \beta^{1,1}\right) \quad (7)$$

Results and discussions

The descriptive statistics of the data used for the analysis is presented in Table 2. Across the evaluated period, average innovation represented by no. of patents increased steadily with a slight dip in 2018 and 2019. Similarly, average human capital in MENA increases steadily, including the minimum values. However, the standard deviation for innovation is more significant than human capital. The MENA region shows tremendous economic growth with a 25% increase in GDP in 2019 compared to 2011. The minimum economic growth also shows a 38% improvement. Average CO_2 emissions steadily increased with a slight decline in 2018 and 2019. Maximum CO_2 emission is observed in 2015. 2018 and 2019 indicate an 8% and 4% decline, respectively.

Based on the selected variables, model (1) is used to evaluate eleven MENA countries' innovation, human capital, economic, and environmental efficiency from 2011 to 2019. Figure 2 illustrates the average annual efficiency scores, and Fig. 3 presents the individual efficiency scores for each country. The average annual efficiency ranges between 55 and 67% from 2011–2016. It increased to about 82% from 2017–2019. Post-2016, average innovation, no. of employed persons, and GDP show improvement compared to prior periods. More importantly, the percentage increase in CO_2 emissions is lesser compared to the percentage of GDP increase. About 50% of the countries performed below average. Algeria, Iran, Israel, Kuwait, Malta, and the UAE are among the top-performing countries. At the same time, Jordan and Saudi Arabia are identified as the least-performing countries. There was a 26% increase in average efficiency between 2016–2019. The UAE had a 74% increase in efficiency, 59% for Tunisia, and 48% for Egypt. Currently, the UAE has the highest efficiency growth among the evaluated countries. The boost in efficiency comes as a result of its aggressive digitalization strategy. Furthermore, the UAE has embarked on major renewable energy transition projects to cut its CO_2 emissions. The UAE's sustainable development strategy put environmental sustainability and clean energy as the cornerstone of its strategy (UAE 2017).

Table 3 shows the ML productivity index for the evaluated periods derived from model (4) through models 2 and 3. An index < 1 signifies decline and lower productivity, while > 1 indicates improvement and productivity gains. A unitary value implies that the reference frontier

Table 2 Descriptive statistics

		2011	2012	2013	2014	2015	2016	2017	2018	2019
Patent	Mean	127.31	132.53	144.81	147.41	159.54	167.86	179.32	171.96	169.67
	Std Dev	376.73	406.88	440.86	448.56	471.61	507.11	491.51	561.43	506.95
	Min	0.25	0.02	0.02	0.33	0.17	0.02	0.02	0.20	0.09
	Max	1369.43	1481.29	1603.49	1631.01	1713.34	1844.97	1771.33	2036.53	1841.54
No.of employed persons (million)	Mean	10.06	10.26	10.57	10.69	10.86	11.12	11.26	11.41	11.64
	Std Dev	11.17	11.32	11.63	11.78	11.83	12.16	12.32	12.47	12.75
	Min	0.20	0.21	0.21	0.22	0.23	0.24	0.25	0.27	0.28
	Max	36.36	37.13	38.09	38.96	38.52	39.46	39.49	39.88	40.63
GDP ($billion)	Mean	17,330.70	19,037.78	20,223.26	20,441.00	21,168.18	23,258.59	23,057.74	22,815.71	23,216.77
	Std Dev	40,965.09	46,184.28	49,558.70	49,744.47	51,893.05	58,589.81	57,647.29	56,901.33	59,036.93
	Min	7.72	8.03	8.47	9.12	10.00	10.41	11.25	11.83	12.49
	Max	142,700.22	162,587.53	174,990.64	175,335.40	183,616.25	208,932.11	205,268.15	202,776.27	211,789.77
CO_2 emissions (kt)	Mean	104.10	111.75	113.47	118.20	122.38	123.66	124.31	123.35	123.77
	Std Dev	123.65	132.25	135.59	144.94	151.35	151.24	147.89	142.82	147.24
	Min	0.48	0.51	0.56	0.46	0.54	0.49	0.47	0.49	0.48
	Max	456.67	488.75	499.38	536.81	561.14	556.74	540.70	514.60	537.35

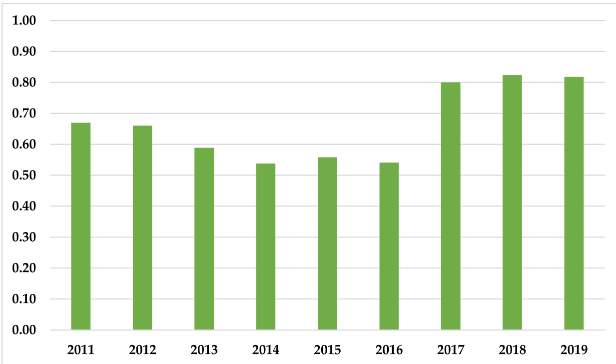

Fig. 2 Average efficiency scores of innovation-economic-environmental sustainability

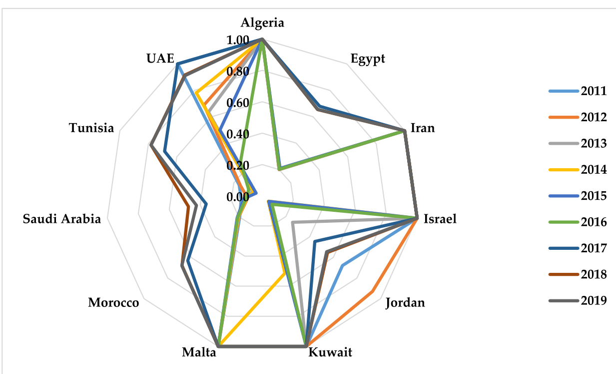

Fig. 3 Efficiency scores for MENA innovation-economic-environmental sustainability

is unchanged. On average, 45% of countries evaluated show productivity gains post-2016 compared to 35% between 2011 to 2016. The average annual ML continued to increase across the evaluated period and leveled slightly in 2017–2018. The increase in ML could be interpreted as an improvement in the innovation, economic, and environmental efficiency of the region. The 2016–2017 period showed the highest number of countries with productivity gains. Egypt, Malta, Saudi Arabia, and Tunisia showed improvement, while Morocco remained the same. Other countries indicate productivity decline. In the 2018–2019 productivity analysis, Malta has the highest score. The Malta government launched the digital Malta program, which introduced innovation in various sectors such as business and management, food technology, and the environment (Malta 2016). The initiative expands its human capital and infrastructure while strengthening its regulation and legislation. This initiative by the Malta government could explain the productivity gains, which have a socio-economic and environmental impact.

By decomposing the ML productivity index into technical efficiency change in Table 4 and technology change in Table 5, the cause of productivity growth and decline can be identified for individual countries. The results show that MENA has performed outstandingly in TEC and gained ground in TC. The average TEC after 2016 is 1.2, 1.02, and 1.00, while the average TC is 0.82, 0.94, and 1.07, respectively (see Fig. 4). The majority of the countries either maintained or had a slight improvement in TEC. This observation speaks to the operational efficiency of the region in attaining sustainable development. Human capital is considered a technical improvement and an operational dimension of systems (Gangani et al. 2006). Therefore, the ability of most MENA countries to attain productivity gains so far is primarily due to the positive TEC. However, the regional TEC performance viewed from the average TEC score signifies a decline in the region's TEC. This decline needs to be addressed to prevent a technologically dependent system that lacks operational proficiency. Systems that are

Table 3 Malmquist-Luenberger (ML) productivity index

Countries	2011–2012 ML	2012–2013 ML	2013–2014 ML	2014–2015 ML	2015–2016 ML	2016–2017 ML	2017–2018 ML	2018–2019 ML
Algeria	0.94	0.96	1.03	0.98	0.95	0.71	1.00	1.00
Egypt	0.99	0.99	1.00	1.00	0.99	1.02	0.95	0.98
Iran	1.04	1.09	0.93	0.89	0.98	0.75	1.00	1.05
Israel	1.00	1.02	0.99	0.96	0.98	0.89	1.15	0.92
Jordan	1.01	0.63	0.93	1.01	1.01	0.99	1.00	1.00
Kuwait	1.25	0.44	0.67	2.73	0.89	0.96	1.30	0.93
Malta	0.82	1.31	1.29	1.01	0.82	1.24	0.43	1.80
Morocco	1.00	1.00	1.00	1.00	0.99	1.00	1.01	0.98
Saudi Arabia	0.97	1.01	0.99	1.01	0.99	1.03	0.85	1.08
Tunisia	0.98	0.97	1.00	0.99	1.02	1.01	0.99	0.99
UAE	0.61	0.91	1.11	0.79	0.81	0.99	0.85	0.99

Table 4 Malmquist-Luenberger technical efficiency change (MLTEC)

Countries	2011–2012 MLTEC	2012–2013 MLTEC	2013–2014 MLTEC	2014–2015 MLTEC	2015–2016 MLTEC	2016–2017 MLTEC	2017–2018 MLTEC	2018–2019 MLTEC
Algeria	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Egypt	1.00	1.00	1.00	1.00	1.00	1.36	0.98	1.00
Iran	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Israel	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Jordan	1.24	0.61	0.89	1.00	1.02	1.23	1.07	1.00
Kuwait	1.00	1.00	0.67	1.49	1.00	1.00	1.00	1.00
Malta	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Morocco	1.00	1.00	1.00	1.01	1.00	1.31	1.04	1.00
Saudi Arabia	0.98	1.01	0.99	1.01	0.99	1.16	1.08	0.97
Tunisia	0.99	0.96	0.99	0.99	1.03	1.45	1.08	1.00
UAE	0.76	0.96	1.12	0.81	0.86	1.74	0.92	1.00

Table 5 Malmquist-Luenberger technical change (MLTC)

Countries	2011–2012 MLTC	2012–2013 MLTC	2013–2014 MLTC	2014–2015 MLTC	2015–2016 MLTC	2016–2017 MLTC	2017–2018 MLTC	2018–2019 MLTC
Algeria	0.94	0.96	1.03	0.98	0.95	0.71	1.00	1.00
Egypt	0.99	0.99	1.00	1.00	1.00	0.75	0.97	0.98
Iran	1.04	1.09	0.93	0.89	0.98	0.75	1.00	1.05
Israel	1.00	1.02	0.99	0.96	0.98	0.89	1.15	0.92
Jordan	0.82	1.02	1.04	1.01	0.99	0.80	0.93	1.01
Kuwait	1.25	0.44	1.00	1.84	0.89	0.96	1.30	0.93
Malta	0.82	1.31	1.29	1.01	0.82	1.24	0.43	1.80
Morocco	0.99	1.00	1.00	1.00	1.00	0.77	0.97	0.98
Saudi Arabia	0.99	1.00	1.00	1.00	0.99	0.89	0.79	1.11
Tunisia	0.98	1.01	1.00	1.00	0.99	0.69	0.92	0.99
UAE	0.79	0.94	1.00	0.97	0.95	0.57	0.92	0.99

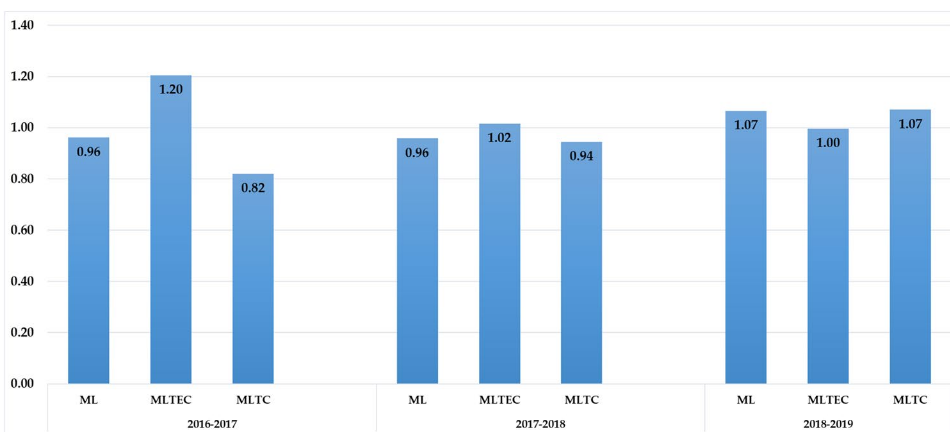

Fig. 4 Average productivity decomposition of MENA's sustainable development. ML: Malmquist-Luenberger productivity index; MLTEC: Malmquist-Luenberger technical efficiency change; MLTC: Malmquist-Luenberger technological change

heavily technologically dependent lose efficiency and productivity over time (Davis 1993). In the 2018–2019 period, Israel showed a productivity decline. In that period, the MLTEC value is unison, meaning there is no change in operational performance; however, a slight fall in MLTC results in productivity regression.

Role of innovation and human capital in economic and environmental sustainability

Decomposing the productivity index into technical change and technological change gives further insight into the analysis. The result shows that the MENA region's technical efficiency has been the primary driver of its sustainable development. The result also indicates a decline in technical efficiency (see Fig. 4) with a shift towards technological-based development. The growth in MLTC speaks to the region's technological advancement. However, there should be complementary technical and technological growth for sustainable socio-economic development. The result indicates that when countries maintain or increase technical or technological efficiency, productivity gains are positive. The reverse is the case; when there is a decline in either technical or technological efficiency, productivity falls.

For economic and environmental sustainability, human capital has a significant role. There is compelling evidence of innovation in the region with the socio-economic upside of digitalizing the economy. However, to attain environmental sustainability, it is essential to implement national green strategies at the industrial level. Green human resource management has been identified as an effective avenue for attaining environmental sustainability (Song et al. 2021). The economic and environmental growth will be sustained by incorporating green human resources management and innovative practices in the region.

Conclusion and policy implications

One of the most crucial strategic decisions of developing countries and regions is to ensure sustainable development. This study analyzes the role of human capital and innovation in attaining economic and environmental sustainability. The research applied DEA-Malmquist-Luenberger productivity for efficiency and productivity analysis. Unlike conventional DEA efficiency estimations, the models utilized adequately accommodate desirable and undesirable outputs of the innovation-human capital-economic-environmental nexus. The decomposition of productivity gives insight into the cause of efficiency change over time. The results of the analysis point to human capital being an integral part of the MENA region's sustainable development. There is an improvement in average efficiency in the region. Further analysis shows a decline in technical efficiency, which is related to the human capital component of the nexus. In the long run, this might affect the economic and environmental sustainability of the region, given the interconnection of the sustainable development components. The study concludes that sustainable human capital and innovation are significant to economic and environmental sustainability—the findings of this study point to three main policy implications. First, the analysis suggests human capital augmentation parallel to the boost in innovation experienced in many parts of the region. This requires the strengthening of human capital and capacity in many aspects of the economy. This could be achieved through a human capital monitoring system—tracking the loss of human capital across the different sectors to enhance the efficiency of replacement and upskilling activities. The second implication suggests the need for human-centered environmental innovation. This requires re-engineering of the human capital to integrate emerging innovation. Re-engineering human capital under sustainable economic and environmental conditions will enhance sustainability (Kruzhkova et al. 2021). This could be achieved through increased R&D spending on eco-innovation projects for different sectors, thereby simultaneously increasing human capital and innovation activities. Lastly, continuous monitoring of the human capital-innovation dynamic is required to prevent the irreversible decline of economic and environmental sustainability gains. This study's contextual result can influence human capital-innovation agendas in emerging economies to boost environmental and economic sustainability.

The study suffers from a set of conventional limitations. First, the time period and the number of countries limit the study to 2019. Secondly, exogenous factors that may drive efficiency are not considered. Recommendation for future research includes expanding the study to a two-stage analysis to include drivers of innovation and human capital growth. The student shows that innovation and human capital are essential for economic and environmental sustainability. Examining factors that support human capital and innovation would address the challenges from the source. Furthermore, an inter-regional comparison could yield an interesting economic and environmentally sustainable development conclusion.

Author contribution Mustapha D. Ibrahim: conceptualization, data curation, formal analysis, methodology, supervision, validation, visualization, writing—original draft, writing—review, and editing.

Data availability The data that support the findings of this study are openly available in (Mendeley data) at https://doi.org/10.17632/yvt8zvbt8c.14

Declarations

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