Iran J Econ Stud, 2025, 14(1), 287-310

Shiraz University

Iranian Journal of Economic Studies

Journal homepage: ijes.shirazu.ac.ir

Modeling the Economic Complexity of Iran and Other MENA Countries

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Highlights

- **The ECI is the latest multipurpose index for outlining the current and future economic outlook of countries.**
- **The HCI is a powerful engine for advancing all future economic and social indicators of a nation.**
- **Effective governance is a foundation for sustainable economic growth and development.**

Article History

Received: 17 August 2025
Revised:10 October 2025
Accepted: 18 October 2025
Published: 24 November 2025

JEL Classification
O32
O38
O53
C32

Keyword
Economic Complexity Index
Governance Quality
High-Tech Goods
Human Capital
MENA Countries

Abstract

The Middle East and North Africa (MENA) region has been reliant on advanced nations for economic growth and development, despite the fact that they possess rich and valuable resources that could serve as primary drivers. This is due to deficiencies in technology, infrastructure, and other capabilities, which have resulted in an ever-widening gap between the two. The emigration of a highly skilled workforce to developed countries, in conjunction with the sale of raw, inexpensive natural resources, has effectively rendered these nations informal dependencies on more advanced economies, thereby maintaining them at a minimal subsistence level. Economists have devised a novel metric, the Economic Complexity Index (ECI), to account for the development disparities between countries. A sound and principled comprehension of the ECI is essential for the enhancement of the resilience of national economies and the attainment of sustainable development in an era characterized by technology and innovation. This study employs the ECI to evaluate the status of MENA countries from 2007 to 2023 and to identify the most significant factors that influence it. The results suggest that the index is positively and significantly influenced by key variables such as human capital, high-technology products, governance quality. Conversely, the trade balance, and migration has a negative impact.

1. Introduction

One of the fundamental challenges that countries in the Middle East and North Africa (MENA) region have consistently faced is the pervasive reliance on

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DOI: 10.22099/IJES.2025.53975.2055

natural resource exports, particularly oil. This structural dependency frequently results in the neglect of other productive sectors and the phenomenon of Dutch disease, rendering these economies highly susceptible to fluctuations in global prices. These nations are compelled to import both essential and advanced products from developed countries on a large scale due to the absence of technological infrastructure and indigenous production capabilities. This practice significantly exacerbates their economic dependency and developmental gap. This dynamic, which is referred to as "center-periphery dynamics" in the political economy literature, ensnares peripheral economies in a cycle of dependency and underdevelopment.

Despite an abundance of natural resources, MENA countries have faced a multitude of challenges over the past two decades, including economic development, inequality, and sociopolitical instability. In turn, these issues have impeded economic development and facilitated the widespread migration of skilled labor to developed countries. The development costs of industrialized countries are financed by this brain drain, which, in conjunction with the increasing purchase of high-technology products, also erodes the domestic capabilities of MENA nations, thereby impeding their progress toward self-sufficiency and sustainability. The urgency of identifying fundamental strategies to escape this predicament is underscored by this pernicious cycle, which is also referred to as the poverty trap.

Hausmann & Hidalgo developed the Economic Complexity Index (ECI) in response to these obstacles in order to offer a more precise explanation of the profound developmental disparity between nations (Hidalgo, 2021). The capacity of a nation to produce a diverse range of technologically sophisticated products is reflected in this index, which is directly correlated with the amount of knowledge and technology embedded in a country's production and export of commodities (Hidalgo, 2021). An increase in this index is indicative of a higher quality of life, sustainable economic growth, and increased productivity (Mostoulizadeh & Salimi, 2020). As a result, it is crucial to understand and analyze the economic complexity of MENA countries, particularly Iran, which shares significant economic, geographical, and cultural similarities with its neighbors. The present study investigates the present state of these nations and contributes to a strategic analysis by aligning with Iran's 2026 Strategic Vision, which is to attain the highest position in the region.

The importance of this research is illustrated by its emphasis on five primary objectives: first, to mitigate the adverse consequences of reliance on raw material exports; second, to strengthen infrastructure to mitigate vulnerability to threats; third, to resolve the stagflation dilemma that arises from a supply and demand imbalance; fourth, to transition from a single-product economy and improve export diversification; and fifth, to surmount the innovation and technology deficiencies that impede sustainable development. By disregarding these concerns, a cycle of dependence and stagnation is perpetuated. Therefore, the examination and analysis of the ECI not only contribute to the creation of a precise

representation of the economic status of these regions, but also offer practical strategies for overcoming crises and attaining comprehensive development.

The remainder of this paper is structured as follows. Section 2 discusses the theoretical foundations of the Economic Complexity Index. In Section 3, a literature review is provided, and in Section 4, the model is introduced and the results are analyzed. Finally, Section 5 closes the paper with concluding remarks, and gives some policy recommendations.

2. Theoretical Foundations

Economists have consistently prioritized economic expansion and development. Modern economic approaches prioritize the role of human capital and knowledge-based economies as the primary drivers of growth, in contrast to classical theories that emphasize traditional factors such as labor and physical capital (Pazham & Salimifar, 2016). In 2006, researchers at Harvard and MIT introduced a new metric known as the Economic Complexity Index (ECI) to more accurately measure and explain the performance of countries. This index has demonstrated superior predictive capabilities for a country's future growth and development in comparison to other widely recognized metrics, including the Human Development Index and the Global Competitiveness Index (Mohammadi et al., 2023). It assesses the extent of knowledge that is integrated into the production of products.

The ECI symbolizes the collective knowledge and social interactions of a society. In addition to indicating growth, economic complexity also reflects broader changes in macroeconomic, social, and political dimensions, capturing both the quantity and character of societies, as per Hausmann & Hidalgo (2009) and Hausmann et al. (2014). The index is composed of two primary dimensions:

- Diversity: Is the term used to describe the variety of products that a country exports, which necessitates the acquisition of the requisite knowledge and skills to manufacture a diverse array of goods.
- Ubiquity: Indicates the number of countries that are capable of producing a specific product. Many nations produce basic and common goods, while only a handful of countries manufacture sophisticated and rare products (Hidalgo, 2021).

The concept of relatedness is also linked to economic complexity (Hausmann & Hidalgo, 2009). It implies that the capacity of a country to incorporate new knowledge and develop innovative products is contingent upon its collected knowledge base. In other words, the cognitive and technological proximity between existing and emergent activities is a significant factor in the decision to engage in new economic activities, in addition to geographic or cultural proximity.

Raw materials, agricultural goods, and textiles are typically the primary exports of countries with minimal levels of economic complexity (Felipe et al., 2012). Conversely, economies that are more developed are inclined to generate technology-intensive goods, including software, electronics, and pharmaceuticals.

Accumulated knowledge, sophisticated skills, and social interactions are necessary for the production of these products (Shahabadi et al., 2021). The production of a diverse array of sophisticated products is facilitated by the unique expertise and technologies that these economies possess. Knowledge is a critical factor in the enhancement of value-added, the establishment of competitive advantages, and the reinforcement of the competitiveness of industrial and modern economies in the present day (Karimi et al., 2021). Therefore, the production of commodities that are in accordance with a country's comparative advantage, in addition to the utilization of global trade opportunities to transfer technology, attract investment, and upgrade skills, can have a multiplier effect on economic growth and development (Talebi et al., 2022).

3. Literature Review

Hausmann, Hwang, Hidalgo, & Rodrik conducted the initial research on the ECI in 2006. Countries are ranked according to the implicit productivity of their exports in this index. The initial Atlas of Economic Complexity was published in 2011 as a result of their efforts (Shahmoradi & Sadeghi-Siahkali, 2017). The ECI rapidly established itself as an indispensable instrument for the examination of economic structures and the comprehension of disparities in growth trajectory.

Diverse economic complexity dimensions have been investigated in numerous studies. In a comparison between Malaysia and Pakistan, Hausmann & Hidalgo (2009) demonstrated that countries with greater capabilities are capable of producing more sophisticated products. Additionally, they discovered that developed countries have a propensity to specialize in a broader array of products with a lower level of ubiquity. The significance of domestic capabilities in the production of high-value products is underscored by these findings. In the same vein, Hausmann & Hidalgo (2011) investigated the diversity and ubiquity of production across countries and determined that specific nations are capable of producing distinctive products that are only produced by a small number of countries due to their substantial production capacities.

Certain studies have investigated the relationship between economic complexity and macroeconomic variables. Erkan & Yildirimci (2015) discovered a positive correlation between economic complexity and competitiveness in Turkey. They demonstrated that improvements in the ECI result in increases in GDP, exports, revenues, and human development, which in turn further reinforce economic complexity. Ivanova et al. (2017) calculated three indices—economic complexity, innovation complexity, and a composite index—for OECD, BRICS, and certain emerging economies. Their findings indicated a correlation among the three indices, although no correlation was found with GDP per capita.

Additionally, Iran has implemented numerous investigations. Shahmoradi & Sadeghi-Siahkali (2017) conducted an analysis of Iran’s regional status and revealed that it was rated 17th out of 19 regional countries in terms of ECI. The territories that ranked higher were Occupied Palestinian Territory and Turkey

leading the way. These results emphasize the pressing necessity for Iran to improve its economic sophistication.

Elahi et al. (2018) conducted a study on the influence of institutional structures on economic complexity in developed, emerging, and developing countries. Their findings indicated that the most significant effect coefficient was observed in developed nations, underscoring the critical role of efficient institutions in the advancement of economic complexity. Shahabadi & Chayani (2019) investigated the correlation between economic complexity and technology spillovers and determined that entrepreneurship has a substantial and advantageous impact on the index. In a study on Iran, Tabrizi & Motameni (2022) demonstrated that investment in higher education is essential for enhancing the country's economic complexity.

Moreover, Mehrgan et al. (2021) identified a variety of factors, including productivity, higher education, labor and goods market efficiency, financial market development, and technology, as being influential on economic complexity. The reciprocal effects of natural resource abundance, governance, and brain drain on economic complexity in oil-producing countries were examined by Shahabadi & Sadeghi Motamed (2021). Their findings indicated that the index is negatively affected by elite emigration, whereas effective governance and the abundance of natural resources have a positive and substantial impact. In addition, Ghasemkhani et al. (2022) demonstrated that less-developed countries are unable to produce complex products as a result of the increasing inefficiencies. They also demonstrated that the quality of governance institutions and the advancement of technology are essential for increasing complexity. In their assessment, Dadgar et al. (2024) verified the beneficial influence of business environment and economic freedom indicators and the detrimental impact of inflation and the exchange rate on Iran's economic complexity.

Mehrgan et al. (2021) underscored the critical role of productivity, higher education, labor and commodities market efficiency, financial sector development, and technological progress in the formation of economic complexity. Shahabadi & Sadeghi Motamed (2021) contended that the complexity of oil-based economies is reciprocally influenced by the quality of governance, the abundance of natural resources, and the brain drain. They found that the index is significantly positively influenced by resource abundance and efficient governance, while elite migration has a negative impact. Similarly, Ghasemkhani et al., (2022) demonstrated that inefficiencies frequently result in the failure of less-developed countries to produce complex products, underscoring the significance of institutional quality and technological advancement. In the same vein, Dadgar et al. (2024) verified that Iran's economic complexity is positively influenced by business environment and economic freedom indicators, while exchange rate volatility and inflation have negative effects.

3.1. Research and Innovation Gaps of the Present Study

This research aims to address numerous gaps that are identified in a comprehensive literature review. The exploitation of specific variables is a critical issue. For instance, the "trade openness" indicator, which is calculated as (Exports + Imports) / GDP, has been implemented in certain studies. The technological knowledge or value-added content of exports are not captured by this measure, which solely reflects the volume of trade. Instead, the "trade balance" indicator, which is defined as (Exports - Imports) / GDP, is employed in this study. This indicator is more closely aligned with the concept of economic complexity and enables a more precise evaluation of the trade structure.

An additional discrepancy pertains to the variable "government size." This measure is insufficient to elucidate economic complexity on its own, as its influence is contingent upon the allocation of resources. Investing in education and research, for example, promotes complexity, whereas spending on unproductive sectors does not.

Furthermore, certain researchers have substituted the "Human Capital Index (HCI)" with the "Human Development Index (HDI)." Although HDI is a significant indicator, it is not a suitable substitute for HCI, which directly reflects the quality and skills of the workforce. This indicator is based on life expectancy, educational years, and income per capita. HCI is implemented in this investigation due to its emphasis on education and health as indispensable prerequisites for innovation and production.

Lastly, prior studies have predominantly concentrated on individuals with a high level of education in relation to "brain drain." The hidden potential of migrants with lower educational levels, who may possess latent talents capable of transforming them into future elites, is overlooked by this narrow perspective. Ignoring this group leads to an incomplete analysis and obstructs a genuine comprehension of the influence of migration on a nation's human capital.

3.2. Results

The ECI for countries in the MENA region was analyzed from 2007 to 2023 in this study. This region is responsible for the production of approximately 40.7% of the world's crude oil and gas, and it contains 57% of the world's oil reserves, according to the most recent statistics (Farbod et al., 2021). The analysis encompassed countries for which data and statistics were available.

4. Methodology

4.1. Research Data Analysis

4.1.1 Dependent Variable (ECI)

-3 to +3 is the range of the ECI. Values below zero indicate an unfavorable status, while values above zero and approaching three indicate a favorable status for the index in a given country.

Table 1 presents the ECI of the prominent countries. The table demonstrates that these nations consistently have the maximum economic complexity score.

Table 1. ECI of leading countries

Country	ECI (2020)	ECI (2021)	ECI (2022)	ECI (2023)
Japan	2.15	2.12	2.1	2.08
Switzerland	2.05	2.03	2.01	2
Germany	1.98	1.97	1.96	1.95
South Korea	1.87	1.89	1.9	1.91
Czech Republic	1.85	1.84	1.83	1.82

***Source**: https://atlas.cid.harvard.edu/*

The top ECI rankings are consistently maintained by countries such as Japan and Switzerland, as evidenced by this table.

4.1.1.1 Analysis of Leading Countries' ECI

Table 1 illustrates the ECI for five Economies (Japan, Switzerland, Germany ,South korea, and Singapore) from 2020 to 2023. The ECI is a metric that assesses the knowledge that is ingrained in a country's exports and its productive capabilities, which is indicative of the complexity and diversification of its economic structure. In general, the sophisticated economic characteristics of all four countries are emphasized by their consistently high ECI values, which are typically above table 2.

These countries are characterized by a general trend of sustained and increasing economic complexity, which further solidifies their status as highly competitive and knowledge-driven economies on a global scale. This data substantiates their status as leaders in economic complexity, as a result of their ability to manufacture a wide variety of sophisticated products.

4.1.1.2 Analysis of MENA Countries' ECI

The statistics for the ECI of MENA countries are presented and analyzed in this subsection, which commences with the data in Table 2.

Table 2. ECI Ranking of MENA Countries in 2023

Country	Morocco	Qatar	Iran	Oman	Egypt	Jordan	Lebanon	Tunisia	Bahrain	Saudi Arabia	Occupied Palestine
ECI	-0.5	-0.35	-0.29	-0.15	-0.24	0.44	0.09	0.25	0.34	0.07	1.36
Global rank (out of 145 countries)	91	83	78	66	71	45	57	51	49	60	20
Rank change (2007 to 2023)	+1	-4	-40	-20	-11	+10	+6	-14	-14	-18	2
Ranking among 11	11	10	9	7	8	2	5	4	3	6	1

MENA countries by ECI in 2023

Source: *https://atlas.cid.harvard.edu*

Note**:** A country's rank has improved (moved up the ranking) in the "Rank Change" column, as indicated by a positive sign. This signal indicates a more favorable economic situation and an increase in economic complexity. In contrast, a negative sign suggests that the rank has deteriorated, resulting in a decrease in the ranking.

This study examined 11 MENA countries using the available ECI statistical information from the Atlas of Economic Complexity website. The Occupied Palestinian Territory had the highest ECI among these 11 countries, while Morocco had the lowest. In terms of global ranking, Morocco is rated 91st, the Occupied Palestinian Territory is 20th, and Iran is ranked 83rd out of 145 countries.

Figure 1 illustrates the positive and negative values of the ECI for specific countries. The ECI values of the Occupied Palestinian Territory, Saudi Arabia, Bahrain, Jordan, Tunisia, and Lebanon are positive, whereas those of the other countries are negative. In general, countries with a positive ECI demonstrate fundamental distinctions in their economic structures, technological development levels, and the diversity and depth of their financial activities. In comparison to the other nations, the Occupied Palestinian Territory exhibits a comparatively favorable position with an ECI of 1.36 and a rank of 20. Nevertheless, it has experienced a two-position decline in its ranking over the past 17 years and continues to maintain a substantial distance from the top-ranked countries.

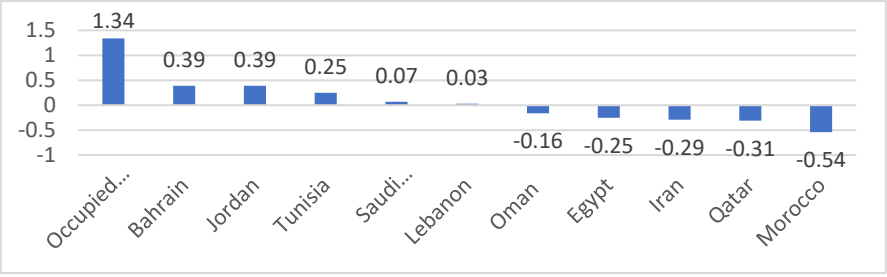

Figure 1 .ECI of MENA Countries in 2023
Source: *Research findings*

The economic complexity indices of the developing countries in the region (Egypt, Iran, Oman, Qatar, and Morocco) have increased from 2007 to 2023. This suggests a propensity for technological advancements and diversification. Nevertheless, they are still undergoing a relative decline, which may be attributed to structural limitations, lack of progress in modern technology, economic sanctions, or the consequences of the Dutch Disease. The technological and

structural development processes of these countries necessitate fundamental reforms. Overall, the MENA region is undergoing substantial transformations in its economic complexity and diversification indices; however, these transformations necessitate ongoing innovative policies and structural reforms.

It is important to acknowledge that a change of a few units and minor fluctuations in the economic complexity rank over the long term are not particularly significant and cannot have a substantive impact on a country's economic growth and development processes. This is particularly valid in a time when the global economy is significantly influenced by new technologies and rapid communication. It is imperative for developing countries to leverage the golden opportunities of the age of innovation by maintaining a pace with technology- and innovation-driven advancements.

4.1.1.3 Analysis of Average ECI in MENA Countries

The 17-year average ECI for selected MENA countries is depicted in figure 2. Iran, Egypt, Morocco, Oman, and Qatar all had an average ECI that was less than zero. The averages of the remaining countries in the sample are also below 0.6, with the exception of the Occupied Palestine, which had an average of 1.57. The country has not experienced significant growth since 2007, despite the fact that this figure is not regarded as excessive.

The MENA region's average ECI is 0.05, as illustrated in both figures, suggesting a significant disparity in ECI between the prominent countries. The primary reason for this is that all MENA countries have consistently exported raw or unprocessed natural resources due to a lack of advanced technology and qualified human capital. This has impeded their ability to establish a robust ECI.

The countries that exhibit the most substantial improvement in ranking and have positive values for the ECI are those that have implemented effective policies to improve their technological indicators and economic diversity, as indicated by figure 2.

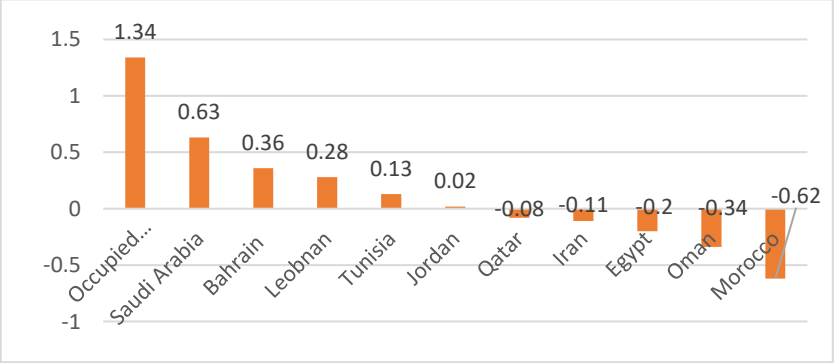

Figure 2. Average ECI of MENA countries during 2007-2023
***Source**: Research findings*

Iran's index value remains low, despite its remarkable progress of 40 ranks in the ECI over the past 17 years, which suggests a trend toward higher positions. In order to attain a higher ranking, this circumstance necessitates more efficient planning and policymaking. Iran has consistently encountered hostile threats and sanctions, rendering this advancement all the more remarkable.

4.1.1.4. Analysis of Iran's ECI and Trade Performance

From 2007 to 2023, the ECI of Iran exhibited a highly volatile and predominantly negative trend, as illustrated in figure 3. This demonstrates the significant influence of exogenous shocks, particularly international sanctions, on a country's productive structure. The sanctions' intensification is associated with the ECI's steep decline from -0.24 in 2007 to -1.05 in 2012. Diplomatic engagement and the implementation of the Joint Comprehensive Plan of Action (JCPOA) led to a transient improvement in 2013, during which the ECI reached -0.21. Nevertheless, the ECI resumed its decline in 2018 following the US withdrawal from the JCPOA and the reimposition of "maximum pressure" sanctions. The ECI's brief peak of -0.04 in 2020 is likely due to short-term adaptive strategies or efforts at domestic production substitution. Nevertheless, this upward trend was transient, and the ECI declined to -0.29 by 2023. This trajectory suggests that the development and stability of a diverse, knowledge-based economic structure have been disrupted by geopolitical isolation and severe sanctions regimes, which have incentivized the economy to engage in less complex and resource-dependent activities.

Iran's exports amounted to $11.4 billion in 2023. Nevertheless, the economy has faced a substantial obstacle in the form of a 34.7% annual decline in total exports over the past five years. The annual decline in non-oil exports has also been 28.1%. In the same year, imports totaled $29.9 billion, resulting in a substantial trade deficit. The country's severe economic vulnerability is primarily due to the non-diversification of export destinations (China 32.25%, Turkey 18.35%, and Pakistan 7.9%) and the types of commodities exported (primarily chemical and mineral products). Khosravi & Soltanpanah (2021) have identified 921 export chemical products, of which only 78 have an RCA greater than one. These products also have a product complexity of approximately 5.85, which suggests that Iran's export products have a low level of (PCA).

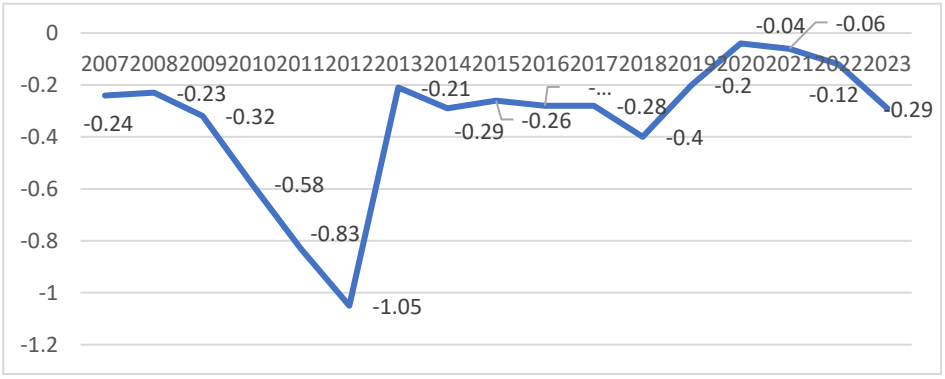

Figure3. Iran's ECI during 2007-2023
Source: *Research findings*

The traditional process of structural transformation, which entails the transition of economic activities from low-productivity industries (such as agriculture) to high-productivity sectors (such as textiles, electronics, and automation), has not yet been initiated in Iran. Iran's electronic and machinery sectors have yet to flourish, despite the fact that its proportion of the global textile export market has remained stagnant over the past decade. Iran is expected to experience an annual growth rate of 2.6% over the next decade, according to the Harvard Growth Lab's projections. However, this would still rank Iran in the bottom half of all countries (Hausmann et al., 2014).

The positions of both Iran and Egypt have declined, as evidenced by a comparative analysis of Iran's ECI classification with countries such as South Korea, Turkey, Malaysia, Pakistan, and Egypt over the past five decades. Pakistan and Egypt, which have encountered substantial political and economic obstacles, have consistently ranked higher than Iran (Cheshmi et al., 2015). The ECI position of Iran deteriorated further between 2021 and 2023, and its exports exhibited moderate to low levels of complexity in 2020 (Dadgar et al., 2024).

In general, the improvement of a nation's global standing and ECI classification facilitates greater integration into international economic networks. This development enhances resilience to global risks and vulnerabilities, while simultaneously facilitating the transition to sustainable economic development and growth. Iran is subject to the same argument.

4.1.2 Independent Variable

4.1.2.1 Human Capital Index (HCI)

This variable was evaluated using a variety of proxies. Nevertheless, the measure implemented was the proportion of individuals enrolled in higher education in relation to the total population, as a result of the restricted availability of pertinent statistical data across countries and study years.

4.1.2.2 Governance Quality (GOV)

This indicator consists of six sub-dimensions:

1) Government accountability;
2) Political stability;
3) Government effectiveness;
4) Rule of law;
5) Regulatory quality;
6) Control of corruption.

The standardization of the average of these six governance components results in a value range of -2.5 to +2.5 for this index.

4.1.2.3 High-Technology Exports (HITec)

The World Bank was the source of the data used to calculate this measure. It was defined as the proportion of high-technology exports to total exports.

4.1.2.4 Migration (MIG)

Additionally, this variable was acquired from the World Bank. It was quantified as the difference between the number of individuals entering and exiting a country, in accordance with the Bank's definition. The net migration figure was adjusted in relation to the total population of each country for the purposes of this analysis.

4.1.2.5 Trade Balance (TRADE)

The trade balance variable was obtained from the World Bank and is defined as the trade index in relation to a nation's GDP.

4.2. Model Estimation and Results Analysis

The model of this study is based on previous research on human capital (Zobeiri & Motameni, 2020; Shahabadi et al., 2017), institutional and governance factors (Elahi et al., 2018), migration (Shahabadi et al., 2019), and trade balance (Sepehrdoost et al., 2020).

The Panel Data Method, which integrates cross-sectional and time-series data, was employed to estimate the economic complexity model for Iran and other MENA countries from 2007 to 2023. The model is nonlinear and is defined as:

$$ECI_{it} = B0 + B1\ \ln(HCI_{it}) + B2(GOVN_{it}) + B3(TRADE_{it}) + B4(HTEC_{it}) + B5(MIG_{it}) + U_{it} \quad (1)$$

ECI_{it} : Economic complexity index of country *i* at time *t*;
HCI_{it} : Human capital index of country *i* at time *t*;
$GOVN_{it}$: Governance quality index of country *i* at time *t*;
$TRADE_{it}$: Trade balance for country *i* at time *t*;
$HTECN_{it}$: High-technology exports of country *i* at time *t*;
MIG_{it} : Net migration for country *i* at time *t*;
U_{it} : Error term.

The necessary data for this analysis were acquired through a library-based approach, which involved the extraction of statistics from international time-series datasets, such as:

-TheWorldBank

- The Harvard Growth Lab's Atlas of Economic Complexity

4.2.1. Model Diagnostic Tests

In order to validate the regression model and prevent the production of spurious regression results, a stationarity test was implemented. The stationarity of all model variables was assessed using the Levin, Lin, and Chu unit root tests. Table 3 summarizes the results.

Table 3. Results of the stationarity test for research variables

Symbol	Variable	Test statistic	P-value	Result
ECI	Economic complexity index	-1.70	0.0443	Stationary at level
HCI	Human capital index	-3.24	0.019	Stationary at level
Hi-Tec	High-technology export	-4.63	0.0000	Stationary at level
MIG	Migration	-2.43	0.0075	Stationary at level
TRADE	Trade balance	-2.75	0.0030	Stationary at level
GOV	Governance quality	1.66	0.9525	Stationary after first differencing

Source: *Research findings*

The Levin, Lin, and Chu unit root test, a fundamental diagnostic procedure in panel data analysis, is the source of the findings in Table 3. Its purpose is to verify variable stationarity and prevent spurious regressions. The results indicate that all variables in the model are stationary, although in certain instances, stationarity is only attained after the initial differencing.

In particular, ECI, MIG, Hi-Tec, HCI, and TRADE are determined to be stationary at their respective levels, suggesting that their statistical characteristics—such as mean and variance—remain constant over time. The stability of these variables is confirmed by the consistently low p-values (all below 0.05), which enable the rejection of the null hypothesis of a unit root.

In contrast, GOV demonstrate stationarity only after the initial differencing process, suggesting that these variables initially exhibit non-stationary behavior at their respective levels. Nevertheless, they achieve stationarity once they have been differentiated (i.e., the change that occurs between successive periods). The differenced series' low p-values serve as compelling evidence of stability, rendering them suitable for integration into regression models.

In summary, the diagnostic assessment confirms that the dataset for all variables meets the criteria for panel data regression analysis. The regression results are guaranteed to be robust and distortions caused by non-stationary data are minimized by adhering to the stationarity condition.

Furthermore, the cointegration test is crucial for preventing spurious regression outcomes by assessing the existence of a long-term equilibrium relationship among the variables. Table 4 demonstrates that the variables are cointegrated, indicating a long-term convergence within the model's framework, as the null hypothesis is rejected (p-value < 0.01). This serves to bolster the model's dependability in empirical analysis. Thus, a long-term relationship between them is confirmed and spurious regression is ruled out.

Table 4. Results of Kao Cointegration Test

Test statistic	P-value	Test result
-3.69	0.0000	Null hypothesis rejected (no long-term relationship between model variables)

Source: *Research findings*

A correlation matrix was employed to further investigate dual collinearity among the independent variables, and it failed to demonstrate any evidence of dual collinearity.

Furthermore, the Variance Inflation Factor (VIF) criterion was implemented to identify multicollinearity. Table 5 displays the results of the VIF test.

Table 5. Results of Variance Inflation Factor Test (VIF)

Variable	TRADE	MIG	GOV	HCI	HITec	C
Centered VIF	1.82	1.35	2.23	1.182	1.74	NA

Source: *Research findings*

The VIF test results indicate that there is no evidence of multicollinearity among the independent variables, as all variables have VIF values that are below the threshold of 5. This finding implies that the regression estimates are reliable due to the fact that the explanatory variables are sufficiently independent.

In summary, the correlation matrix for dual collinearity and the VIF criterion, both diagnostic methods, verify that multicollinearity is not a concern in the model. Thus, the model can be regarded as resilient in this respect.

The White test was implemented to identify heteroskedasticity. The null hypothesis of variance homogeneity is denied due to the statistical significance of the F-statistic (p-value < 0.05). Furthermore, the presence of serial autocorrelation in the model is confirmed by the low value of the Durbin–Watson statistic.

A histogram was employed to confirm the normality of the model residuals. The residuals do not adhere to a normal distribution, as evidenced by the Jarque–Bera statistic (13.36) with a p-value of 0.0012. The null hypothesis of accurate model specification is accepted based on a p-value of 0.7, as the Ramsey RESET test was conducted to ensure the accuracy of the model specification.

The majority of the classical assumptions are ultimately disproven due to the presence of heteroskedasticity, serial autocorrelation, and non-normal residuals.

Therefore, in these situations, the use of a robust estimator in panel data modeling results in increased efficiency and consistency. Due to this, a robust estimation methodology was implemented.

4.2.2. Panel Data Model

The research data, which are panel data, necessitate an assessment of sample homogeneity or heterogeneity following the completion of classical assumption tests and other essential checks for stationarity, reliability, and cointegration of the model variables. This ascertains whether the intercepts in the sample are homogeneous or heterogeneous, and whether the slopes are consistent across all cross-sections.

- The model is a fixed-effects model if there are substantial differences between the cross-sections, and each cross-section has a unique, constant intercept.
- If the heterogeneity of the cross-sections is not correlated with the independent variables and cannot be distinctly segregated for each one, but instead results from random factors, the model is a Random Effects model (Souri, 2021).
- The appropriateness of an aggregated or panel data model was assessed using the F-Limer test. In contrast to the alternative hypothesis, which indicates that the model should be estimated as a panel data model, the null hypothesis of this test is that the model can be estimated as a pooled model.

The null hypothesis of the absence of Random Effects is not supported, as determined by the results presented in Table 6, in order to ascertain which estimation method (Fixed Effects or Random Effects) is more appropriate for the model. As a result, the final research model is defined with Fixed Effects across cross-sectional units (MENA countries).

Table 6. Results of F-Limer and Hausman Tests for MENA Countries (2007-2023)

Test	Chi-square statistic	P-value	Result
F-Limer test	189.222	0.0000	Null hypothesis rejected (pooled model rejected)
Hausman test	34.339	0.00000	Null hypothesis of random effects rejected

Source: *Research findings*

4.2.3. The Estimation Model Analysis

$$ECI_{it} = -0.97 + 0.24 \ln(HCI)_{it} + 0.62(Govn)_{it} - 0.017(Trad) + 0.03(HITec)_{it} - 0.022(Mig)_{it} \quad (2)$$

I. The negative intercept reflects the baseline level of the dependent variable (ECI) when all explanatory variables in the model are set to zero. In the

absence of institutional, human, and technological variables, a negative coefficient indicates that the ECI for MENA countries inherently falls within a negative range under such hypothetical conditions. This outcome suggests that the economies of the region are characterized by a structural negative bias. In other words, the baseline economic complexity would remain below zero even if governance, human capital, high-technology exports, and trade were wholly absent. The underlying causes of this condition are as follows: an export structure that is dependent on primary resources rather than intricate products, a historical deficiency in the diversification of industrial and technological sectors, and inadequate institutional and educational infrastructure to attain self-sufficiency in complex production.

II. Table 7 displays the estimated coefficients of the model. The Human Capital Index (HCI) coefficient of 0.24 suggests a positive and stable relationship between the two variables, with diminishing returns. Specifically, a theoretically justifiable 0.24% increase in the ECI is the result of a one-unit improvement in the Human Capital Index. In this field, a study has demonstrated that the development of human capital is more influential than information technology infrastructure in the drive of economic complexity. The necessity of targeted policy-making to strengthen institutions, human capital, and innovation systems, as well as the substantial disparity between Iran and innovative economies, is of the utmost importance (Yadollah et al., 2019).

III. The dependent variable is positively and statistically significantly influenced by the Governance Quality Index (GOV). This indicates that a country's economic complexity is enhanced by 0.62 units for every unit increase in governance quality. This result is entirely consistent with the hypothesis of this study and the underlying theoretical framework, emphasizing the critical and pivotal role of government in a nation's economic advancement.

IV. The growth of diversification and economic complexity in MENA countries has been constrained and negatively impacted by the increase in trade, which is mainly due to a dependence on complex manufactured goods from other countries and an export structure that is reliant on natural resources and raw materials, rather than enhancing economic complexity. The small negative coefficient of this index (–0.017) in relation to the ECI underscores a critical point: the exports of these countries have a negligible yet detrimental effect on the dependent variable of the model. This effect is entirely consistent with theoretical expectations and corroborates the resource curse hypothesis that has been cited in previous studies.

V. Consistent with theoretical predictions, the High-Technology Exports Index (Hi-Tec) demonstrates a positive and statistically significant coefficient. The results suggest that a 0.031 improvement in the ECI of MENA countries is the consequence of a one-unit increase in high-tech exports. The positive and significant effect of this coefficient, despite its relatively small magnitude, suggests a potentially critical role in the advancement of the economies of the

MENA region. Nevertheless, the influence of this variable is restricted by the current low level of technological capacity in these countries.

VI. According to the Migration Index (Mig), a one-unit increase in migration results in a –0.02 reduction in the economic complexity of MENA countries, a negative and persistent influence on the ECI. The domestic labor force is reduced, and a brain drain occurs, which is the emigration of skilled, talented, and efficient professionals. These economies are adversely affected by migration in two main ways. Both mechanisms diminish production diversity and reduce economic complexity. This finding is consistent with the theoretical foundations, corroborates the research hypothesis, and is in accordance with previous empirical investigations.

The independent variables in the model account for approximately 53% of the variation in the dependent variable, as indicated by the robust R^2 of approximately 0.53. The weighted R^2w value of 0.81 indicates that the independent variables account for 81% of the variation in the ECI when evaluating the stable portion of the data. The R^2w is regarded as a more significant indicator than the conventional R^2, as it indicates that the model performs exceptionally well on the core and stable subset of the data, whereas the standard R^2 value has been reduced by the presence of outliers. The aggregate statistical significance of the model is also confirmed by the Rn-squared test statistic (469.05) with a p-value < 0.0000.

Table 7. Results of panel data regression estimation for the ECI in selected MENA countries, 2007–2023

Symbol	Variable	Coefficient	Z-statistic	Economic interpretation
C	Intercept	-0.97	-4.56 0.000	The ECI for MENA countries inherently falls within a negative range in the absence of institutional, human, and technological drivers.
Ln(HCI)	Human capital	0.24	4.23 0.000	The extraordinary, almost transformative, significance of this indicator in enhancing economic complexity is reflected in the positive and statistically significant elasticity of human capital with regard to economic complexity.
GOV	Governance quality	0.62	9.88 0.000	The critical significance of institutional frameworks and policy effectiveness is underscored by the substantial positive impact of governance quality on the ECI—approximately 0.625 units.
TRADE	Trade balance	-0.017	-9.03 0.000	The ECI's negative correlation with trade balance suggests that these economies are dependent on sophisticated products from other countries and have an export structure

HITec	High-tech exports	0.03	6.42 0.000	that is reliant on natural resources; therefore, these economies experience a decrease in economic complexity as a result of increased trade volumes. Despite its diminutive size, the coefficient is positive and statistically significant; an increase in the proportion of high-technology exports directly enhances economic complexity. This finding corroborates the theory of "industrial advancement through complex technologies," as a 0.031 increase in the ECI is induced by a one-unit increase in Hi-Tec.
MIG	Migration	-0.022	-2.41 0.015	Migration's detrimental influence on the ECI implies that the capacity to manufacture intricate products is impaired by the exodus of specialized labor or shifts in population composition. Despite the fact that the coefficient is comparatively small, its long-term impact is statistically significant. In particular, a 0.02 point decrease in the ECI is correlated with a one-unit increase in the migration variable.
R^2			0.53	
R^2w-squared			0.81	
Rn-Squared	469.05		0.000	

Source: *Research findings*

Subsequently, based on Table 8 we investigate the individual impact of the independent variables on the ECI for selected countries, as the average influence of slope coefficients is estimated uniformly in panel models and is consistent across all countries.

For 11 selected MENA countries from 2007 to 2023, Table 8 provides a country-by-country breakdown of the impact of each independent variable—trade balance, net migration, high-tech commodities, governance, and human capital—on the ECI. The statistical significance of each coefficient is denoted by the p-values (alpha) in parentheses.

Table 8. Impact of Independent Variables on ECI in MENA Countries (2007-2023)

Countries	Bahrain	Egypt	Iran	Occupied Palestine	Jordan	Lebanon	Morocco	Oman	Qatar	Saudi Arabia	Tunisia

Variables											
Human capital	0.303 (0.00)	0.26 (0.00)	0.26 (0.00)	0.18 (0.00)	0.30 (0.00)	0.28 (0.00)	0.32 (0.00)	0.38 (0.00)	0.33 (0.00)	0.20 (0.00)	0.28 (0.00)
Governanc	-0.22 (0.00)	-0.085 (0.3)	0.23 (0.00)	1.01 (0.00)	-0.20 (0.00)	0.22 (0.00)	-1.23 (0.00)	-1.03 (0.00)	-0.40 (0.00)	1.38 (0.00)	-0.11 (0.02)
High-tech exports	0.094 (0.00)	-0.04 (0.00)	-0.035 (0.00)	-0.72 (0.00)	0.06 (0.00)	0.01 (0.36)	0.22 (0.000)	0.29 (0.00)	0.08 (0.00)	-0.16 (0.00)	0.06 0.002)
Net migration	-0.007 (0.00)	0.055 (0.00)	0.05 (0.00)	0.17 (0.00)	0.01 (0.000)	0.019 (0.00)	-0.04 (0.00)	-0.05 (0.00)	-0.002 (0.3)	0.13 (0.00)	0.024 (0.00)
Trade balance	-0.006 (0.00)	-0.003 (0.00)	-0.004 (0.00)	0.002 (0.00)	-0.006 (0.000)	-0.005 (0.00)	-0.012 (0.00)	-0.013 (0.00)	-0.009 (0.00)	.00 25 (0.00)	-0.006 (0.00)

Source: *Research findings*

4.2.4. Key Findings from Table 8

Human Capital: This variable is statistically significant in all countries and has a positive and significant impact on economic complexity, as indicated by the p-value. The ECI is influenced by human capital to a degree of +0.20 to +0.30 from 2007 to 2023, which emphasizes the significance and function of this variable in various countries. The coefficient of this variable for Iran is 0.24, which indicates that a one-percent increase in human capital will result in a 24 percent increase in the ECI in Iran.

Governance Quality: The coefficient of this variable is negative in Bahrain, Egypt, Jordan, Morocco, Oman, Qatar, and Tunisia, but it is positive and statistically significant in the remaining countries under study. The results in Iran suggest that a one-unit increase in the Governance Quality Index increases the ECI of Iran by 0.62 units, with a coefficient of 0.62 and a p-value of 0.000.

High-Technology Exports (HITec): The coefficient of this variable is statistically significant in the majority of countries, with the exception of Lebanon. The significance of this variable for the ECI is underscored by its statistical significance. The anticipated effect, as per the research hypothesis, is positive; however, in certain countries, such as Iran, it is negative and substantial.

The negative sign indicates that the technological content of exported goods and products is minimal, while the high proportion of raw-material exports in these countries has decreased their ECI. This illustrates that the variable has a negative impact on the economic complexity of the entity.

Net Migration: The coefficient of this variable is statistically significant in all countries except Qatar. The negative and statistically significant effect of migration on economic complexity in Iran is indicated by a coefficient value of –0.02 and a p-value of 0.015. This implies that the ECI decreases as a result of the emigration of residents.

Trade Balance: The coefficient of this variable is statistically significant at the 100% confidence level for all countries in the study with respect to economic complexity. This variable has a coefficient of –0.017 with 100% confidence in the case of Iran, which suggests a statistically significant negative impact on the ECI. This result is in contrast to the initial research hypothesis. It is logical that the ECI should increase as a result of an improvement in the trade balance, which is indicative of increased exports and a greater diversification of export commodities. The coefficient of this variable is negative for nine countries, as demonstrated in Table 8. This suggests that the majority of MENA economies are exporters of natural resources and basic materials, with products of reduced economic complexity. In contrast, this variable has a statistically significant and positive impact in countries with relatively high ECIs, such as the Occupied Palestinian Territory and Saudi Arabia.

5. Conclusion and Policy Recommendation

One of the most comprehensive and robust metrics for assessing a country's economic, social, and political performance is the ECI. It has the potential to effectively elucidate a nation's growth, development, and productive knowledge capabilities. Countries with a high level of economic complexity and a diverse range of exported products possess a substantial competitive advantage in their productive capacity, knowledge, and technological capabilities. Public infrastructure (e.g., bridges, ports, highways, land, equipment, and machinery), public culture, technical and vocational training, intellectual property rights, democratic institutions, legal stability, an efficient judicial system, trade freedom, government accountability, human capital, innovation, and social security are among these capabilities. These factors contribute to the enhancement of a country's economic ranking and complexity.

A society's capabilities, experience, general knowledge, and commitment to effective governance within complex social interaction networks must be perpetually enhanced in order to increase the ECI. Therefore, the attainment of the highest ECI rankings necessitates the implementation of long-term strategies and targeted planning in all of these domains.

Additionally, the economy is a dynamic and living system that is perpetually in flux due to a variety of internal and external factors in order to attain equilibrium. Consequently, policymakers must exercise a greater degree of

caution and consideration in their decision-making, acknowledging the economy's vulnerability to environmental factors.

The results of this investigation indicate that the ECI in Iran and the MENA region was unfavorable from 2007 to 2023. This is especially true for Iran, where the index has consistently been negative or near zero, as the country's exports primarily consist of products with low-to-moderate complexity.

The findings suggest that the (ECI) is significantly and positively influenced by human capital, government efficiency, and high-technology exports. Conversely, this index is significantly and adversely affected by the trade balance and migration variables. Therefore, the development of human capital and the transition to a knowledge-based economy are among the most effective strategies for enhancing ECI. Sustainable economic growth and development can be achieved through the implementation of smart policymaking and effective governance, as well as the establishment of an enabling environment for production and trade, the promotion of skills training and human capital development, the maintenance of economic stability, and the reformation of mindsets in macroeconomic decision-making.

Educational policies must transition from an exclusively quantitative approach to enhancing the quality of education and skills training that are customized to the requirements of intricate industries, in light of the significant and influential role of human capital. In order to guarantee the development of a competent workforce that is capable of meeting the demands of global markets and advanced technologies, educational institutions and universities should be aligned and coordinated with industrial and manufacturing sectors. In this regard, the adoption of successful countries like South Korea, Japan, and Singapore can significantly contribute to the achievement of development objectives, while also enhancing the welfare of elites and future generations and elevating the economic and social status.

It is crucial to recognize that sustainable economic growth is not achieved solely through scientific and technological advancements. Globalization is essential for obtaining access to global markets and capitalizing on international opportunities. The market share of target countries in global trade can be increased and sustainable economic growth and development can be facilitated by effective governance, the establishment of robust relationships with target countries, particularly in sectors with a comparative advantage, and the utilization of intensive diplomacy.

A long-term strategic plan is essential and highly beneficial for the development of diversified and complex exports with high value-added in the oil and gas value chain (petrochemicals) and other natural resources, given the negative impact of a raw-material-oriented export structure on the trade balance.

Ultimately, the proposed policies and solutions will facilitate a more rapid access to the desirable ECI and its positive results. A more practical and exhaustive comprehension can be attained by expanding the scientific literature, analyzing new variables, and updating previous studies.

Author Contributions

Conceptualization, all authors; methodology all authors; formal analysis, all authors; resources, all authors; writing—original draft preparation, all authors; writing—review and editing, all authors; supervision Abdoli, Q. All authors have read and agreed to the published version of the manuscript.

Funding

This research received no external funding.

Conflicts of Interest

The authors declare no conflict of interest.

Data Availability Statement

The data used in the study were taken from worldbank.org and atlas.cid.harvard.edu .The most recent data from the World Bank (updated to 2025) and the Atlas of Economic Complexity (updated to 2024) have been used.

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