Print ISSN: 2008-448X
Online ISSN: 2538-3310
International Journal of Business and Development Studies
University of Sistan and Baluchestan
Homepage: https://ijbds.usb.ac.ir

The Effects of Sustainable Development Index on Economic Complexity in Oil-Exporting Countries

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ARTICLE INFO

Article type:
Research

Article history
Received: 2025.02.28
Revised: 2025.07.24
Accepted: 2025.08.19
Published: 2025.10.01

Keywords:
Sustainable Development, Economic Complexity, Oil-exporting Countries, Panel Data.

JEL Classification:
C23, O50, R11, Q01

Abstract:
Since Adam Smith, the wealth of nations has been attributed to the division of labor and knowledge. Economists have treated national and global economies as complex systems, but empirical studies on economic complexity have developed over the last decade with the growth of data and new models. Among the many factors affecting economic complexity, sustainable development plays a key role. Economic complexity reflects a country's production structure. This study introduces sustainable development by integrating economic, social, and environmental dimensions. Focusing on oil-exporting countries, where sustainability is challenged by economic development pressures, the research aims to assess the influence of the combined Sustainable Development Index (SDI) on Economic Complexity Index (ECI). Using panel data for 20 oil-exporting countries from 1997 to 2023, the study employs unit root tests (IPS), F-Limer test, Hausman test, fixed effects estimation, and Dumitrescu-Hurlin Granger causality tests. The findings show that SDI has a positive and significant effect on ECI. Specifically, as the SDI increases, the ECI rises in the selected countries. Furthermore, a unidirectional Granger causality relationship is found from SDI to ECI, but not in the reverse direction. Descriptive statistics also reveal significant differences in SDI across oil-exporting countries. These results suggest that improving sustainable development can enhance economic complexity, and policy recommendations include strengthening the rule of law, trade openness, economic freedom, and human capital investment.

1. Introduction

The globally interconnected financial system has begun to grow in today's world, and it has been noted that the sustainable development indices have both direct

Cite this article: M. Rahimdel, E. Ghaed and H. Heidari (….). The Effects of Sustainable Development Index on Economic Complexity in Oil-Exporting Countries. *International Journal of Business and Development Studies*. DOI: 10.22111/ijbds.2026.54501.2320.

and indirect effects on many economic factors, among which the concept of economic complexity is the most noticeable. Economic complexity is one of the factors that account for disparities among nations. It is a measure of the technological and productive capabilities of the society and implies the production and export of goods that are supported by the acquired and specialized knowledge and skills. It is not the case that modern societies are characterized by each individual possessing more productive knowledge than the people in the past, but that the society has a huge store of knowledge which is shared and accessed through networks, allowing specialization and thus the enlarging of the very store shared (Yaprakli & Özden, 2021). Two fundamental concepts in the discourse of economic complexity are diversification and inclusiveness. Product diversification characterizes a country that produces a wide range of products. Hence, a nation that manufactures a lot of different goods and is only traded with a few other nations is deemed to have a high level of economic complexity (Kaios & Huarng, 2020). Hausmann et al. (2014) posit that economic complexity provides the highest predictive power for economic growth when compared to the traditional factors, which are, among others, human capital, governance, institutional quality, and natural resources.

Thus, a nation that creates a broad spectrum of products and has a connection to goods from only a few countries is classified as having a great economic complexity level (Kaios & Huarng, 2020). Hausmann et al. (2014) believes that economic complexity has the highest power of prediction for economic growth over all other factors like human capital, governance, institutional quality, and natural resources. The research indicates that countries able to combine product diversity with more complex goods are generally more developed economically and expect to have faster growth in the near future. Economic complexity is associated with the structure of a country’s production and export goods, which represents their ability to keep and mix knowledge and skills. It is obvious that societies lacking parts of this capability set, will fail in the production of such complex goods. Consequently, economic complexity turns out to be a measure of the required capabilities for the production of a given economy's goods (Findler et al., 2017) indirectly. Hence, the study intends to contribute to the discussion surrounding the impact of the economy on the environment and the challenges of sustainable development in the context of economic complexity, through examining the relationship between the sustainable development index and economic complexity in oil-exporting countries by posing the research question: "Is there a positive impact of the sustainable development index on economic complexity?" Along with this, the hypotheses are to be tested in this study:

1. The combined sustainable development index has a significant positive effect on economic complexity in oil-exporting countries.
2. There is a unidirectional Granger causality relationship from the sustainable development index to economic complexity.

3. The combined sustainable development index differs significantly among oil-exporting countries.

In this research, the main objective is to utilize econometric modeling of panel data for the first time to explore the direction of causality between sustainable development and economic complexity in a selected group of oil-exporting countries covering 1997 to 2023. Consequently, the outline of this paper is as follows: after the opening, theoretical foundations are discussed in Section 2 and then the next Section reviews some related literature both from domestic and international perspectives, followed by the methodology in Section 4, while the last section concludes and offers recommendations.

2. Theoretical Foundations and Literature Review.

Theoretical Foundations Sustainable development has been a matter of great interest in academic circles, industries, and policymakers over the past few years. It was the Brundtland Commission's (1987) report that first brought the term of sustainable development to light. According to the Commission, the term meant “development that satisfies the present needs without jeopardizing the future generations' needs”. This basis put forward four aspects of sustainable development: social, environmental, cultural, and economic. The first three overlap and are so interlinked that there cannot be a clear-cut demarcation (Axelsson et al., 2011). Sustainability is, as per UNESCO, the very basis for envisioning the future in which the environment, society, and economics are given equal weight to enhance the quality of life (Ferraz et al., 2021). Different indices have been developed by various institutions to assess sustainable development, each having its own goals. Le Caous & Huarng (2020) point to a basic divide between the reformist and the transformational approaches towards sustainable development. The former pays attention to indicators that top-down improve the current decision-making systems and the latter claims that the only way out through political actions inside and outside the current systems. Chelsey and Beswick cite Le Caous & Huarng when reporting that the managerial approach still dominates the debate over sustainable development (Ahmed et al., 2022).

Additionally, economic complexity is a concept that signifies the coexistence and interaction of several and different factors which lead to the development of various dependencies and complicated relationships in the economic sphere (Gómez-Zaldívar et al., 2020). The Harvard Economic Complexity Atlas characterizes economic complexity as an indicator of the level of a society's knowledge that is based on the knowledge contained in the products that are manufactured in that country. The economic complexity index, according to this atlas, is the "ranking of countries based on how complex and diverse their export basket is" (Yaprakli & Özden, 2021). A country's export complexity can serve as a good indicator of its income level. Besides, if a nation's economic complexity is greater than what is deemed appropriate for its income level, the country is likely to experience quicker economic growth (Wichaisri & Sopadang, 2018).

2.1 The Relationship between Environmental Indicators and Economic Complexity

Carbon dioxide (CO_2) emissions are now considered a global concern as the Earth's atmosphere has been gradually renewed with CO_2 due to the rapid consumption of carbon-based energy sources across the globe (Can & Gozgor, 2017). The coupling of CO_2 emissions, production, and economic complexity has given rise to the terms of "carbon emissions" and "the least inequalities." The more fossil fuel driven an economy is the greater this increase of CO_2 and other green house gases emissions, and economic complexity is usually the reason behind this pairing. The more developed, thus more complex economies with bigger production and consumption are most likely to have the greatest disparities in CO_2 emissions (Laverde-Rojas & Correa, 2021). In contrast, low-income countries and less developed or complex economies are usually the ones majorly emitting the least CO_2. The disparities could be mainly due to the presence of few industrial activities or better energy management practices. Therefore, economic complexity reduction and sustainable production patterns shift could simultaneously bring about the CO_2 emissions drop and environmental benefits. The relationship thus requires one to always factor in the environmental aspect when talking about economic development and to bring forth energy resources and environmental protection management strategies that are efficient (Niagu & Teodoru, 2019).

2.2 Energy Consumption and Economic Complexity

Energy consumption is a major factor in sustainability of any society that is linked to economics, politics, and overall people's activities. The discussions regarding the "energy paradox" have led to many studies on the correlation between energy consumption and economic complexity. The paradox refers to the phenomenon that, in general, the levels of energy consumed by a country go up with the complexity of the economy and the industrial development. This scenario could be attributed to the types of activities and energy needs in complex economies. Heavy energy inputs are needed in complex economies for all production, transport, and service activities. Still, on the other hand, studies suggest that proper management of demand for energy, together with the effective use of technology, could reduce the adverse impacts of the "energy paradox" on economic sustainability and energy consumption. Therefore, good electricity consumption practices and proper environmental impact assessment could be an efficient way of minimizing economic complexity and simultaneously allowing for coexistence of economic growth with a friendly environment (Niagu & Teodoru, 2019).

2.3 The correlation between Political Stability and Economic Complexity

The correlation between political stability and economic complexity has been a significant issue in the areas of economics and political science. Political stability is understood as a condition in which a nation's political system is robust and secure and the disturbances resulting from changes in governance are kept to a minimum. Studies have indicated that political stability can be a powerful factor in the reduction of economic complexity. The political situation of the day has an effect on how quickly information is passed around, the nature of economic interactions, and the volume of trading and investments taking place. On the other hand, political instability can make the economy more uncertain and business and investment decisions may be affected. Therefore, political stability has been deemed as an essential means to achieve and maintain economic development (Haasman et al., 2014).

The Relationship between Rule of Law and Economic Complexity The rule of law, as a major aspect of social and economic structures, is one of the primary factors that determine economic complexity. The rule of law embodies the enforcement of existing laws and regulations in such a way as to ensure order, justice, and legal certainty throughout society. It has been found that in countries with a strong and stable rule of law, they are free from the burden of legal infractions and conflicts, which subsequently leads to lower economic complexity. A strong rule of law can make the business environment more predictable and stable, thereby increasing public trust in economic activities. Conversely, in countries where the rule of law is weak or unstable, there will be a greater incidence of legal violations and conflicts, resulting in more uncertainty and complexity in the economy. Hence, the creation and maintenance of a strong and stable rule of law not only facilitate the development of a modern legal system but also, at the same time, reduce the complexity and improve the economic situation (Elahi et al., 2018).

2.4 The Dual Role of Economic Freedom: Catalyst or Hindrance to Economic Complexity

In a nutshell, freedom represents the lack of restraint and coercion, which in turn enhances the development of societies. The Heritage Foundation characterizes economic freedom as an individual's ability to partake in the whole process of making goods and services as well as their distribution and consumption. According to the creators of the Economic Freedom Index of the Heritage Foundation, since freedom implies no compulsion, pressure, or limitations in the choices made, it is beneficial for both economy and society. Economic freedom in the developed competitive world is like a catalyst that quickens the process of economic integration, and consequently, with the pooling of foreign investment and exchange of technology, economic complexity heightens. This can be explained by the fact that foreign companies are attracted to the free trade environments in such countries and thus, they invest there (Doğan et al., 2020). On the contrary, it demands large-scale investment to train the specialized workforce and to financially support the research projects, which are the basis for producing complicated products. Completely depending on domestic investment to suffice these needs is not practical, and the right foreign investment conditions can play a crucial role in improving the management practices, raising the productivity level, and developing the human resource, which in turn leads to the encouragement of the domestic investment and thus the rise in the economic complexity (Ali Esmaili et al., 2019). Nevertheless, the economic freedom route, which has lessened international barriers, has set up rivalry in both the local and the foreign markets, and if the local manufactures are not able to go through the competition, it will bring about a negative consequence for the local economy. Being that the countries' aim is to broaden their economic-based through diversifying their palates of goods, then the amount of liberty in trade should be such that it invigorates the inventive activities. Economic freedom can turn into a plus for the nations if it is customized as per the country's internal system and then utilized to stretch out to the inventive activities that bring about economic complexity. If not, economic freedom might not only be counterproductive but also cause more innovative activity to die down (Mangala & Liu, 2020).

2.5 Trade Freedom as a Driver of Technology Transfer and Product Sophistication

The economic complexity issue is decisively determined by the trade opulence composite index that measures aharif and nontariff restrictions on both exports and imports. These limitations affect the movement of high-tech products in and out of the country, since the trade freedom, through the increase of competition of domestic versus foreign companies, exerts a pressure on the less efficient local firms to get rid of the unproductive ways of using the resources and achieve the scales of production that would make them more economically viable, thus increasing the overall productivity of the local firms. In case the country has improved the factors' production and is near to acquiring new knowledge, it is the complex goods production, high-tech products and the increased competitiveness of countries that will be the output (Sahperdost et al., 2020). Moreover, the removal of trade restrictions will not only make the country to be able to absorb new technologies rapidly but also by importing upon transfer of knowledge, it would be able to producing an even wider and sophisticated range of products (Liu & Gao, 2022; Lee et al., 2023). Thus, trade freedom is understood as a system where exchanged items between nations are free from government restrictions, and such practice entails numerous economic advantages. Besides, the trading gives way to the purchase of capital goods that are equipped with advanced production technology which can then be the cause of the uplift in the national output if followed through an export-oriented strategy that would be enhancing the comparative advantage of the country.

2.6 Previous Studies

The topic's novelty has resulted in limited local investigations, which will be understood from the discussion below. Moreover, international studies section will point out early research as well as recent papers on economic complexity. Using panel data for the period 1975 to 2003, Gnangnon and Moser (2014) analyzed the association between the protection of intellectual property rights, export diversification, and economic complexity in both developing and developed countries. They have concluded that the protection of intellectual property, freedom of trade, innovation, and GDP growth, along with human capital, were the preconditions for the production of a wider range of export products that subsequently led to economic complexity. The study of Hartmann et al. (2017) was concentrated on the interrelationship between economic complexity, institutions, and income inequality. The findings indicated that negative social factors like income inequality, low human capital, and lack of good institutions were the ones hindering economic complexity. This research has shown that lack of sustainable development has negative consequences on a country's competitiveness and on the level of its economic complexity.

In their study, González et al. (2019) focused on the shifting economic complexity in developing nations and chose Paraguay as a prime example for their analysis. The authors strategically employed the Analytical Hierarchy Process (AHP) technique to determine both the sectors and the products that would lead to a transition toward a more complex economy. By their results the approaches used were a good guide for policymakers in pinpointing the sectors which could be economically developed through complexity and capacity building. Mealy & Taitilboim (2020) in their research explored the relationship between economic complexity and green economics. Data from the study revealed that the higher the country's rank, the more likely that it would have a higher environmental patent registration rate and lower CO_2 emissions. Laverde-Rojas together with Correa (2021) looked into the issue of economic complexity, economic growth and CO_2 emissions in 86 countries during the period 1971-2014. The outcome of their study was that an increase in the economic complexity index is accompanied by a decrease in pollution levels only in the case of developed countries.

According to Cakir et al. (2021), the countries that slowly got to economic complexity, also, had inside activities that made them more resistant to external shocks. They hinted that the economic complexity index could be the mirror of the "resilience" aspect of complex economies. Yaprakli and Özden (2021) analyzed the interaction of sustainable development and economic complexity in OECD countries through the panel data that spanned from 1996 to 2017. They pointed out that economic complexity was greatly affected by sustainable development indicators such as GDP, foreign direct investments, R&D

expenditures, social development indicators, CO_2 emissions from the production side, and renewable energy and greenhouse gas consumption. They also indicated the role of technological progress and knowledge-based production methods in strengthening economic complexity and at the same time ensuring sustainable development. Shahabadi and Sadeghi Mo'tamed (2019) looked into the reciprocal relationship between the abundance of natural resources via governance and elite migration and the level of economic complexity in a group of oil-producing countries from 2007 to 2016. The authors of the article concluded that the connection between resource wealth and governance was both positive and significant, whereas elite migration had a negative and significant impact on economic complexity. Sahperdost et al. (2020) used a panel data from 2002 to 2017 to study how the implementation of trade liberalization policies had an impact on the economic complexity of developing countries. They managed to discover that positive trade liberalization shocks resulted in an increase in economic complexity during the short run, but the import of capital and intermediary goods was a factor that at first raised and then lowered the effect in the long run. Hasanvand et al. (2021) used simultaneous equation modeling for the period of 1995-2018 in their study to investigate the interplay between economic complexity and income inequality in Iran. The results of their research indicated that the intensification of income inequality was a factor of increasing economic complexity, whereas economic complexity played the role of a compensating factor for the specific disadvantage of income inequality. Also, industrialization, human capital, and GDP growth were cited as positive contributors to higher economic complexity. Shahabadi et al. (2021) adopted the Generalized Method of Moments (GMM) approach to assess the innovation and economic freedom in the selected science-producing countries' economic complexity for the years 2008-2017. They concluded that the innovative and economic freedom vibe together positively impacted economic complexity, and moreover, factors like entrepreneurship, financial development, and market size were also good influences on economic complexity. The review and analysis of the theoretical and empirical literature up to now shows that most of the studies conducted have examined the effect of individual variables on sustainable development or economic complexity separately. Nonetheless, a comprehensive study has not yet been done which would analyze the relationship between the variables simultaneously.

On the one hand, the study shows that there is no such thing as a universal pattern between the sustainable development indicators and the countries' economic complexity if the latter are viewed as a group of oil-exporting nations. As a result, the present research, which concentrates on this association in oil-revenue-dependent countries, brings both theoretical and practical benefits. The existing literature on this subject has been limited, thus it stresses the need for the present study and may help to understand better how the interplay between sustainability and economic change in the oil-reliant countries is structured.

3. Research Methodology

The panel data method has been employed as the estimation method in this research, which is a technique that combines both cross-sectional and time-series data. In the merge of cross-sectional and time-series data, a number of estimation models are suggested. The main advantage of having integrated data is that one could then measure and evaluate the effect of either time or cross-sectional data on the fixed parameter (intercept) or the slope parameters of regression. Two possible model types are:

- **Pooling Model:** All the coefficients are assumed to be constant, and the only factor differentiating the cross-sectional units and time periods is the random error. This is what is termed the Pooling model.

$$Y_{it} = \sum \alpha_i + X_{it}\beta + \epsilon_t \quad (1)$$

- **Fixed Intercept Model:** The coefficients of the variables (the slopes) are held constant, while the intercept is different for each cross-sectional unit.

$$Y_{it} = \sum \alpha_i + X_{it}\beta + \epsilon_{it} \quad (2)$$

Whether the coefficients are fixed (non-random) or random depends on the models which are termed as Fixed Effects or Random Effects models (Judge et al., 1988). The F-Limer Test is employed to determine whether to use the Pooling model or the Fixed Effects model. This test compares the restricted residual sum of squares (RRSS) from the OLS estimation of the pooled model with the unrestricted residual sum of squares (URSS) from the within-group regression estimation. The following formula applies:

$$F = \frac{(RRSS - URSS)}{(URSS)} \quad (3)$$

In the F Test, the null hypothesis H0 asserts that the intercepts are equal (Pooling or Combined model), while the alternative hypothesis H1 suggests that the intercepts differ (Panel Data model). Consequently, if the null hypothesis H0 is rejected, the Panel Data model is accepted. The Hausman Test is employed to make a decision between the Fixed Effects and Random Effects models. The Hausman test is set up in the following way (Hausman, 1983):

$$\text{Hausman Test} = (b_{FE} - b_{RE})'[\text{Cov}(b_{FE}) - \text{Cov}(b_{RE})]^{-1}(b_{FE} - b_{RE}) \quad (4)$$

Where W has a Chi-squared distribution with R degrees of freedom. In this case, b_FE is the coefficient vector for the Fixed Effects model and b_RE is the coefficient vector for the Random Effects model. If the coefficients derived from both models are significantly different, it means that the Fixed Effects model is the right one to use. The hypothesis of the Hausman test advocates for the use of the Random Effects model, while the opposing hypothesis advocates for the use of the Fixed Effects model (Baltagi, 1995).

3.1 Model Specification

The methodology of this work was a causal-analytical approach and its aim was applied. The primary technique for gathering data is documentary-library. The twenty-six-year time frame for this research based on the availability of data is from 1997 to 2023. The statistical population is a selection of oil-exporting countries, more specifically 20 oil-exporting countries: Saudi Arabia, Russia, Iran, Iraq, Canada, the United Arab Emirates, Kuwait, the United States, Nigeria, Kazakhstan, Norway, Angola, Libya, Mexico, Azerbaijan, Venezuela, Qatar, Brazil, Oman and Algeria. The Economic Complexity Index (ECI) and the Sustainable Development Index (SDI) are the main variables of this research. The sources of the dependent and independent variables employed in this work are detailed in Table 1.

Table 1: Definition and Source of Research Variables Economic Freedom (EFI) and Trade Openness (Trade)

Variable Name	Definition	Unit	Source
Economic Complexity	Economic Complexity Index (ECI)	Ranking estimate	Our World in Data (OWD)
GDP	Gross Domestic Product at constant US Dollars (2015)	USD	World Bank Data (WBD)
FDI	Foreign Direct Investment	% of GDP	World Bank Data (WBD)
R&D Expenditure	Research and Development Expenditure	% of GDP	World Bank Data (WBD)
Human Development	Human Development Index (HDI)	0 to 1 scale	World Bank Data (WBD)
Income Inequality	Gini Coefficient	Index	World Bank Data (WBD)
CO_2 Emissions	CO_2 Emissions Based on Production	% of total emissions	World Bank Data (WBD)
Renewable Energy Consumption	Renewable Energy Consumption	% of total energy consumption	World Bank Data (WBD)
Political Stability	Political Stability Index (PS)	-2.5 to 2.5 scale	World Bank Data (WBD)
Rule of Law	Rule of Law Index (RL)	-2.5 to 2.5 scale	World Bank Data (WBD)

Source: Research Findings

In the World Bank data, there were some countries and years with missing values. In this research, the missing values were replaced by the average of all years for each country since that was considered the best option. Moreover, the data used in this study came with various units and scales. As an instance, the Gross Domestic Product (GDP) of countries is expressed in billions of dollars while the Human Capital Index (HCI) is simply a number that ranges from 0 to 1. In order to have a common scale for the use and integration of these data, there was a need to remove the units and to align the scales adequately. Normalization was therefore applied to the data. For this purpose, the index data (e.g., GDP) for

each country in each year was first centered by subtracting the mean of that index for the same country over the study period and then scaled by dividing it by the standard deviation of that index for the country during that period.
The formula is as follows:

$$Z_{jk} = \frac{X_{jk} - \bar{X}_j}{SD_{X_j}} \qquad (5)$$

Z_jk is the variable value calculated for the respective country j in the corresponding year k. The process involves taking the actual value for country j in the year k (X_jk) and deducting the mean (((X_j) ¯)) of that index for the country. This result is then divided by the standard deviation (SD_(X_j)) of the variable for the country over the period of the study. By doing this, the units are eliminated, and due to the normalization of the data, the scales are now comparable, allowing for easier comparison of data. The next calculation done is the Sustainable Development Index (SDI) for each country as follows: SDI = \frac{GDP + FDI + R&D + HCI - GINI - CO2 - REE - GHE}{8} In the equation given above, SDI signifies the Sustainable Development Index of all countries for the corresponding years, which is computed through the following elements:

GDP (Gross Domestic Product)
FDI (Foreign Direct Investment)
R&D (and Development Expenditure as a percentage of GDP)
HCI (Human Capital Index)
GINI (Gini Coefficient)
CO2 (CO2 Emissions in Industry and Construction)
REE (Renewable Energy Usage)
GHE (Greenhouse Gas Emissions)

The negative signs before the GINI, CO2, and GHE variables imply that the decrease of these variables is the intention of the sustainable development objective, not the increase. The use of "index" for each of these variables is meant to signal that their specific units have been excluded. The present investigation utilizes Panel Data method to analyze the relationship between Sustainable Development and Economic Complexity in oil-exporting countries. The model that is applied in this study is based on the research works of Zhu and Gao (2019) and Moschovou and Giannopoulos (2021) and can be expressed with the following formulas: The Economic Complexity Index (ECI) in these equations is the dependent variable of this study, and it is represented by actual explanatory variables such as:

SDI: The Sustainable Development Index, which is extracted from the integration of economic, social, and environmental data.
PS: The Political Stability Index
RL: The Rule of Law Index
EFI: The Economic Freedom Index

Trade: The Index of Trade Openness
Besides that, iand are the indicators for country and year, respectively, αis the constant, βis the parameter of the explanatory variables, and ϵis the residual.

4. Model Estimation and Interpretation of Results

It is the primary pursuit of the study to unravel the chain of impact from Sustainable Development to Economic Complexity and vice versa in a group of oil-exporting nations. Consistent with this objective, this study employs Panel Data. However, to secure validation of the findings, a number of preliminary tests are to be conducted prior to the estimation of the econometric model. In this part, first, the descriptive statistics of the variables, which include details of the minimum, maximum, average, variance, etc., will be reviewed before the econometric model is estimated. Then tests for the variables' stationarity, fixed effects, Hausman test, heteroskedasticity, autocorrelation, and Granger causality are conducted.

4.1 Descriptive Statistics

Descriptive statistics summarize the central tendency and dispersion of the data. The measures of dispersion include standard deviation, variance, coefficient of variation, and range. Table (2) presents the descriptive statistics for the oil-exporting countries in this study.

Table 2: Statistical Indices for Oil-Exporting Countries

Variable	Mean	Median	Maximum	Minimum	Standard Deviation	Number of Observations
Trade Openness	74.05	71.50	79.22	-92.22	41.82	240
Economic Freedom Index	6.49	6.59	7.59	-1.053	1.04	240
Rule of Law	-0.239	-0.252	1.308	-2.095	0.622	240
Political Stability	-0.717	-0.772	1.37	-1.323	0.37	240
Economic Complexity Index	0.1109	0.063	3.0	-2.41	0.569	240
Sustainable Development Index	0.63	-0.163	3.37	-2.41	1.0	240

Source: Research Findings

The mean Sustainable Development Index (SDI) for oil-exporting countries is 0.63, but after normalization per country it is close to zero. The negative median (-0.163) indicates that the data distribution leans toward lower values, resulting in a right-tailed distribution. The highest SDI value (3.37) is recorded for Saudi Arabia in 2001, whereas Kazakhstan in 2009 has the lowest value (-2.41). The relatively similar standard deviations imply that variations among countries are not substantial.

The average Economic Complexity Index (ECI) is 0.1109, which is lower than that of industrialized countries, revealing the economic structure's reliance on natural resource exports. The median (0.063) indicates that many countries have low economic complexity, while only a few (e.g., UAE, Saudi Arabia, Norway) show better performance.

Political Stability (PS) and Rule of Law (RL) show negative averages of -0.717 and -0.239, respectively, illustrating weaknesses in institutional stability and governance quality. The mean Economic Freedom Index (EFI) is 6.49, indicating relatively favorable conditions, though many oil-exporting countries still face institutional and regulatory limitations.

The Trade Openness Index has an average of 74.05 and a high standard deviation (41.82), indicating large differences in global economic integration. The UAE, Qatar, and Kuwait have the fewest trade restrictions, while Iran and Venezuela impose more limitations.

Overall, Table (2) reveals that despite abundant natural resources, oil-exporting countries lag behind developed nations in sustainable development, economic complexity, and good governance. This underscores the need for economic structural reforms, export diversification, and institutional improvement.

4.2 Unit Root Test

In model estimation, it is necessary to have stationary data in order to avoid the problem of spurious regression. The stationarity of data is indicated by the condition that the mean and standard deviation of each variable do not change over the period of study. If the data is non-stationary, the coefficients obtained through regression estimations will be invalid, and the influence of the independent variables on the dependent variable will not be represented properly.

In a panel data setup, two kinds of unit root tests are performed depending upon whether the time-series data is superior or inferior to the cross-sectional data. In this case, time-series data is superior to cross-sectional data (24 years for 20 countries), so the Im, Pesaran, and Shin (IPS) unit root test was used. The application of the unit root test in panel data is necessary to guarantee that the results are accurate and valid.

Table (3): Results of Im, Pesaran, and Shin (IPS) Unit Root Test

Variable	t-statistic	Probability	Result
ECI	-5.925	0.000	Stationary
SDI	-3.255	0.000	Stationary
PS	-1.890	0.0359	Stationary
RL	-1.932	0.022	Stationary
EFI	-2.374	0.003	Stationary
Trade	-4.893	0.000	Stationary

Source: Research Findings

The results of the IPS unit root test indicate that all variables are stationary at the 5% significance level, as the probability values are less than 0.05 for all variables. Therefore, the null hypothesis of the existence of a unit root (non-stationarity) is rejected.

4.3 F-Limer Test (Chow Test)

To determine whether pooled OLS or panel data methods (fixed/random effects) are appropriate, the F-Limer test was conducted. The null hypothesis assumes homogeneity of intercepts across countries (pooled data). The results are presented in Table (4).

Table (4): Results of F-Limer Test
Redundant Fixed Effects Tests

Effects Tests	Statistic	d.f.	Probability
Cross-section F	411.04	(19, 455)	0.0000

Source: Research Findings

The results of the F-Limer Test documented in Table (4) indicate that the p-value is less than 0.05. Hence, the null hypothesis of pooled data is rejected. It can, therefore, be inferred that the country intercepts are not homogeneous, and our data are panel data that deserve either fixed or random effects estimation methods.

4.4 Hausman Test

The Hausman test is used to determine whether the fixed effects or random effects model is more appropriate for panel data analysis. The test statistic follows a chi-square distribution with k-1 degrees of freedom, where k is the number of independent variables. The null hypothesis assumes that the random effects model is consistent and efficient.

Table (5): Results of Hausman Test
Correlated Random Effects - Hausman Test

Test Summary	Chi-sq Statistic	Chi-sq d.f.	Probability
Cross-section random	31.96	4	0.0000

Source: Research Findings

The results of Table (5) show that the chi-square statistic is 31.96 with 4 degrees of freedom, and the probability value is 0.0000, which is less than 0.05. Therefore, the null hypothesis of random effects is rejected, and the fixed effects model is selected for this study.

4.5 Fixed Effects Model

In order to test the hypotheses of the current study, which posit that the Sustainable Development Index strongly influences Economic Complexity, the regression results derived from the fixed effects model are presented in Table (6).

Table (6): Results of Fixed Effects Estimation

Variable	Coefficient	t-statistic	Probability
SDI	0.0037	2.17	0.037
PS	0.0325	1.05	0.296
RL	0.516	7.78	0.000
Trade	0.0033	4.86	0.000
EFI	0.1009	3.53	0.000
Constant	0.589	2.76	0.006
R-squared	0.6897	F-statistic	19.73
Corr(u_i, Xb)	-0.2237	Prob F-statistic	0.000

Source: Research Findings

The results derived from the regression analysis shown in Table (6) for oil-exporting countries indicate that the Sustainable Development Index significantly and positively affects Economic Complexity. On the contrary, the connection of Political Stability with Economic Complexity in these nations turns out to be positive but not statistically relevant. The effects of Rule of Law, Trade Openness, and Economic Freedom Index on Economic Complexity are all positive and significant as well. In addition, the R-squared value that shows the explanatory power of the explanatory variables is 0.6897. The F-statistic value of 19.73 indicates that the overall regression is statistically significant. It is true that in this test, the null hypothesis states that the coefficients of all variables are zero. The probability value of the F-statistic being zero, therefore the null hypothesis is rejected and the model is considered significant.

4.6 Tests for Heteroskedasticity and Autocorrelation

The characteristics of panel data often lead to issues such as heteroskedasticity and autocorrelation. Since these problems can significantly affect standard errors and statistical inference, it is essential to test for their presence before estimation. The results of these tests are presented in Table (7).

Table (7): Results of Variance Heteroskedasticity and Autocorrelation Tests

Test	Statistic	p-value	Decision
Heteroskedasticity	0.318216	0.2531	Reject Heteroskedasticity
Serial Autocorrelation	18.421	0.1578	Reject Autocorrelation

Source: Research Findings

The test results in Table (7) indicate that at the 95% confidence level, the null hypothesis of no heteroskedasticity and no serial autocorrelation cannot be rejected. Therefore, the model does not suffer from heteroskedasticity or autocorrelation.

4.7 Granger Causality Test

To investigate the causal relationship between the Sustainable Development Index (SDI) and the Economic Complexity Index (ECI), the Granger causality test proposed by Dumitrescu and Hurlin (2012) was employed. This approach allows for the possibility of unidirectional causality (from SDI to ECI or from ECI to SDI) or bidirectional causality between the two indices. The results are presented in Table (8).

Table (8): Results of Granger Causality Test for the Impact of Sustainable Development Index on Economic Complexity

P-value	HPJ Wald test	Causality Direction
0.0182	0.7693	From SDI to ECI

Source: Research Findings

The null hypothesis of the Granger causality test states that there is no causal relationship from SDI to ECI. The results in Table (8) show that the p-value (0.0182) is less than 0.05, leading to the rejection of the null hypothesis. Therefore, it is concluded that changes in the Sustainable Development Index Granger-cause changes in the Economic Complexity Index.

Table (9): Results of Granger Causality Test for the Impact of Economic Complexity on Sustainable Development Index

P-value	HPJ Wald test	Causality Direction
0.9521	0.0069	From ECI to SDI

Source: Research Findings

The results in Table (9) indicate that the p-value (0.9521) is greater than 0.05. Therefore, the null hypothesis of no causal relationship from ECI to SDI cannot be rejected. Consequently, there is no evidence that changes in the Economic Complexity Index Granger-cause changes in the Sustainable Development Index.

Considering the results of Table (8) ($p = 0.0182$, rejecting the null hypothesis of no causality from SDI to ECI) and Table (9) ($p = 0.9521$, failing to reject the null hypothesis for the reverse direction), it is concluded that there is **unidirectional causality** running from the Sustainable Development Index to the Economic Complexity Index, not bidirectional causality.

5. Conclusion and Recommendations

The research primarily aimed at investigating the effects of the Sustainable Development Index (SDI) on the Economic Complexity Index (ECI) in oil-exporting countries from 1997 to 2023. The econometric method employed was panel data analysis. Following the scientific pathway of the research, the results are reviewed according to the hypotheses posed.

Hypothesis 1:

The composite Sustainable Development Index has a significant effect on the Economic Complexity of oil-exporting countries.

To test this hypothesis, as indicated by the results of the fixed-effects estimation (Table 6), the Sustainable Development Index has a positive and significant effect on Economic Complexity. Thus, in the 20 selected countries over the study period, as the SDI of each country increases, the ECI of that country also increases. Hence, it can be concluded that a focus on sustainable development is reflected in greater economic complexity and the production of more technologically advanced goods.

The Granger causality test (Dumitrescu & Hurlin, 2012) suggested a unidirectional causality from SDI to ECI ($p = 0.0182$), while the reverse causality from ECI to SDI was not statistically significant ($p = 0.9521$). The goodness of fit (R-squared) for the model was 0.6897, meaning that the model explains 68.97% of the variations in economic complexity. In addition, the F-statistic (19.73) confirmed the overall significance of the model.

Hypothesis 2:

The overall Sustainable Development Index has a Granger causality effect on Economic Complexity, and this effect is one-directional.

The testing of this hypothesis was performed based on Granger causality results found in Tables (8) and (9). The results confirmed the first part of the hypothesis (presence of Granger causality from SDI to ECI). Thus, it can be asserted that a rise in SDI corresponds to a rise in economic complexity. However, the second part of the hypothesis (one-way causality) was corroborated, contrary to the earlier mistaken claim of two-way causality. The findings indicate unidirectional causality from SDI to ECI, not mutual causality. Therefore, an increase in SDI leads to an increase in ECI, but the reverse does not hold.

Hypothesis 3:

The composite Sustainable Development Index in oil-exporting countries differs among countries. To test this hypothesis, we rely on the results shown in Tables (3) and (4), obtained through descriptive statistics, which confirm that there is a significant difference in the SDI of oil-exporting countries. Normalization of the data (z-score) resulted in the average SDI being very close to zero. Nevertheless, some oil-rich countries had a much lower median SDI, indicating that most oil-exporting countries are at a lower sustainable development level compared to the median. The average was raised only by a few countries with higher indices. The maximum SDI of the oil-exporting countries was also considerably lower than that of developed countries, indicating the limited potential of these countries to enhance their SDI during the study period. The minimum SDI among the oil-rich countries belongs to Iran, signaling the difficult situations that some of these countries face with regard to sustainable development.

Based on these results, it is advisable that the governments of oil-producing countries direct their attention to increasing investment and improving the quality of the legal system. This is the way to create the necessary conditions for the production of goods with better technology and higher skill levels. By doing so, national income will rise and sustainable development indicators will improve. Indicators such as social equity, reduced pollution, and a better environment are some areas where improvements can be observed.

Moreover, the economic complexity of oil-producing countries can be improved through greater attention to human capital development, R&D investments, and production process optimizations. In addition, raising the levels of exports and imports, granting economic freedom, and improving the rule of law are among the main factors that could benefit both SDI and ECI. Which factor to focus on depends on the resources and policies of each country, but a proper mix of these factors can have a **substantial** (instead of "terrific") influence on the economic advancement and sustainable development of oil-exporting countries.

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