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The Impact of Economic Complexity on Reshaping Trade Performance in Arab Economies: A Distributional Approach Using Unconditional Quantile Regression (RIF-Panel Quantile Regression)

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Economic Complexity; Trade Performance; Export Market Penetration; High-Technology Exports; Trade Complexity; Research Complexity; Unconditional Quantile Regression.

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ABSTRACT

This study aimed to analyze the impact of economic complexity on reshaping the trade performance of four Arab countries—Algeria, Saudi Arabia, Tunisia, and Morocco—during the period 2000–2022. The study employed the Unconditional Quantile Regression for Panel Data (RIF-Panel Quantile Regression) methodology, allowing the measurement of the impact of economic complexity indicators across different levels of trade performance rather than focusing solely on average effects.

The analysis focused on three main dimensions of trade performance: total exports, high-technology exports, and export market penetration. Economic Complexity, Trade Complexity, and Research Complexity indicators were incorporated as key explanatory variables.

The results revealed that the relationship between economic complexity and trade performance in Arab countries is nonlinear and conditional upon both the level of trade performance and the type of complexity indicator considered. The impact of trade complexity remained limited in the lower and middle quantiles of total exports but became more pronounced in the upper quantile. The findings also showed that economic complexity contributed to supporting high-technology exports during the early stages of industrial development, whereas the negative effect of research complexity highlighted a gap between scientific research outputs and the requirements of manufacturing and export activities.

Regarding market penetration, the results indicated that trade complexity was more effective when supported by an enabling institutional and commercial framework. The study recommends adopting selective industrial and trade policies that strengthen the link between scientific research and manufacturing while enhancing product quality and promoting qualitative integration into global value chains.

1. INTRODUCTION

Over the past decades, the global economy has witnessed rapid growth in international trade volumes and a significant increase in trade openness among countries. According to data from the World Bank and the World Trade Organization, the value of global trade in goods and services increased from approximately USD 7 trillion in the early 1990s to more than USD 32 trillion in 2022. Moreover, the ratio of trade to global GDP reached around 63% in recent years, compared with less than 40% at the beginning of the 1990s. These developments reflect the growing economic and commercial interconnectedness among countries and their increasing integration into global value chains.

Such transformations have reshaped the determinants of trade competitiveness. Achieving strong trade performance is no longer solely associated with abundant natural resources or low production costs; rather, it increasingly depends on economies' ability to produce more diversified and sophisticated goods and to develop a knowledge and technological base capable of generating high value-added exports...

In this context, the concept of economic complexity has emerged as a modern indicator for understanding the productive structure of economies and their capacity to utilize accumulated knowledge in producing and exporting more advanced products. Higher levels of economic complexity indicate that an economy possesses more diversified and interconnected productive and knowledge capabilities, which may positively influence its competitiveness and trade performance in international markets. However, this effect is not necessarily uniform across countries or different levels of trade performance. The strength and direction of the relationship may vary depending on structural characteristics, institutional quality, the degree of productive diversification, and the efficiency of the logistical and technological environment.

This issue is particularly important for Arab countries, many of which continue to face significant challenges in diversifying their productive and export structures and transitioning from traditional export patterns largely based on primary resources or low value-added products toward more sophisticated and competitive exports. Despite efforts undertaken by some of these countries to strengthen industrial development, innovation, and trade openness, the outcomes in terms of improved trade performance remain uneven. This raises important questions regarding the extent to which economic complexity can explain these differences and the nature of its impact across Arab economies with diverse economic structures.

Recent literature has examined the relationship between economic complexity and trade performance from multiple perspectives. Abdi et al. (2023) demonstrated that economic complexity enhances bilateral trade flows, particularly in manufacturing sectors and high value-added products, confirming that the development of productive and knowledge capabilities is a key pathway to effective integration into international trade. In the African context, Olasehinde-Williams and Oshodi (2021) found that economic complexity improves export competitiveness, although its effect remains conditional on macroeconomic variables such as GDP, exchange rates, and foreign investment. Similarly, Białowąs and Budzyńska (2022) argued that participation in global value chains strengthens the comparative advantage of developing countries, especially when linked to more sophisticated and value-added products.

From the perspective of export destinations, Lyubimov (2021) emphasized that export destinations are as important as the type of exported products because penetrating high-income markets with stricter standards reflects a deeper level of competitiveness. Furthermore, Shahzad et al. (2022) highlighted that export quality, economic complexity, and institutional quality are critical structural factors supporting long-term growth and advancement within global value chains.

Despite the importance of these studies, most have focused on the impact of economic complexity on trade volume, export competitiveness, comparative advantage, or economic growth. Few have directly examined the role of economic complexity and research complexity in export market penetration as an independent outcome. Additionally, most previous studies have concentrated on average effects, while differences across low, medium, and high levels of trade performance remain underexplored, particularly in the context of Arab economies.

Accordingly, this study contributes to the literature by providing a comparative quantitative analysis of the extent to which economic complexity and research complexity explain trade performance and export market penetration in Algeria, Morocco, Saudi Arabia, and Tunisia during the period 2000–2022. To achieve this objective, the study employs the RIF-Panel Quantile Regression methodology, which enables the examination of heterogeneous effects across different points of the trade performance distribution.

To achieve its objectives and address the research gap concerning the impact of economic complexity on trade performance in Arab countries, the paper is organized into four main sections. The first section reviews the relevant literature, focusing on studies that investigate the relationship between economic complexity and trade performance indicators, while identifying the contribution of the present study. The second section presents the econometric methodology, describes the model employed, and explains the variables and data sources for the selected Arab countries. The third section discusses the empirical findings and analyzes the impact of economic complexity on trade performance, highlighting their economic implications and their effects on the ability of Arab countries to penetrate foreign markets and enhance export competitiveness. Finally, the fourth section summarizes the main findings, presents policy recommendations for improving productive structures and increasing economic complexity, and outlines the limitations of the study and directions for future research.

2. LITERATURE REVIEW

Recent literature in international trade and economic development has shifted its focus from the volume and value of exports toward their qualitative characteristics, knowledge content, and ability to penetrate foreign markets. In this context, the Economic Complexity Index (ECI) has emerged as an important tool for measuring the productive and technological capabilities embedded within an economy. It reflects the accumulated knowledge that enables countries to produce and export more sophisticated goods and services. Consequently, economic complexity has become a key concept for understanding why some countries successfully transition from primary or low-technology activities to more competitive and sustainable production and export structures.

Numerous studies suggest a positive relationship between economic complexity, export diversification, and export upgrading. For instance, Gnangnon (2022) found that higher economic complexity promotes the diversification of service

exports, particularly when accompanied by foreign direct investment (FDI) inflows that facilitate technology and knowledge transfer. Similarly, Canh and Thanh (2020) demonstrated that export diversification helps reduce economic growth volatility and strengthens economies' resilience to external shocks. In the same vein, Bayar (2022) argued that competitiveness is increasingly determined by quality, technological advancement, and product design rather than traditional price-based competition. These findings indicate that the knowledge content of exports contributes to improving product quality and broadening the range of exportable goods and services, thereby enhancing competitiveness in international markets. Nevertheless, despite their significance, these studies primarily focused on export diversification and upgrading, without sufficiently distinguishing between improvements in the export basket and the actual ability to enter and maintain a presence in new foreign markets.

In addition, other studies have explored the relationship between economic complexity, trade flows, and export destinations. Abdi, Zaidi, and Karim (2023) found that the impact of economic complexity varies across sectors, being more pronounced in manufacturing industries and technology-intensive products than in agriculture. Likewise, Şeker and Şimdi (2019) identified a long-run relationship between exports and economic complexity, suggesting that trade expansion may itself contribute to the accumulation of productive knowledge and the enhancement of complexity levels. From another perspective, Lyubimov (2021) argued that assessing export performance should not be limited to the nature of exported products but should also consider the characteristics of destination markets, since the income level and quality requirements of these markets are critical indicators of genuine export penetration. These findings highlight that the impact of economic complexity extends beyond increasing export volumes to improving countries' ability to access more advanced markets capable of absorbing sophisticated products. However, most of these studies relied on export values or trade volumes as indicators of external performance and did not directly examine export market penetration as a distinct outcome separate from export growth or diversification.

Despite the importance of these findings, transforming sophisticated productive capabilities into a sustainable presence in international markets requires several supporting factors. Cariolle and da Piedade (2023) demonstrated that digital infrastructure and access to information contribute significantly to export upgrading and participation in global value chains, particularly for differentiated products. Similarly, Chakraborty, Chaisse, and Pahari (2020) emphasized that compliance with technical and regulatory standards is essential for gaining access to international markets, especially in industries characterized by high technological content. Furthermore, Zhu et al. (2024) showed that trade policies and international initiatives can create new opportunities for exporters by facilitating the redirection of exports toward alternative markets when traditional markets become constrained. These studies suggest that the relationship between economic complexity and market access is shaped not only by productive capabilities but also by institutional, regulatory, digital, and trade-related factors that help convert these capabilities into tangible export outcomes.

Despite the valuable contributions of the existing literature, a clear research gap remains. The literature often conflates several related but distinct concepts, including export growth, export diversification, export upgrading, and export market penetration. Diversifying products or improving their quality does not necessarily imply successful entry into new markets or the maintenance of market presence. Likewise, an increase in export value may simply reflect expansion within existing markets rather than genuine market penetration. Therefore, relying solely on diversification indicators or trade volume measures is insufficient for assessing a country's ability to access new markets or expand into higher-quality and more sustainable export destinations.

Moreover, most previous studies have concentrated on the effects of economic complexity on trade volume, export competitiveness, or economic growth, while few have directly examined the impact of economic complexity and knowledge-based research capabilities on export market penetration as an independent outcome. In addition, the majority of empirical analyses have focused on average relationships between variables, whereas differences across various levels of trade performance have received limited attention, particularly in the context of Arab economies.

Building on this gap, the present study investigates the impact of economic complexity and knowledge-based research capabilities on export market penetration and trade performance in Algeria, Morocco, Saudi Arabia, and Tunisia during the period 2000–2022. Unlike previous studies that assess the impact of economic complexity on exports in general, this research specifically examines the extent to which productive and knowledge structures support access to new and higher-quality export markets. Furthermore, it accounts for heterogeneity in trade performance levels across the countries under investigation through the application of the RIF-Panel Quantile Regression methodology. By doing so, the study contributes to filling both a methodological and empirical gap in the literature by shifting the focus from export volume and diversification toward market penetration as an independent outcome, particularly within the context of Arab economies.

3. RESEARCH METHODOLOGY

This study adopts a distributional approach using the RIF-Panel Quantile Regression methodology to analyze the impact of economic complexity on trade performance in four Arab countries, Algeria, Saudi Arabia, Tunisia, and Morocco—during the period 2000–2022. These countries were selected based on the availability of consistent annual data and the existence of structural differences among them in terms of productive capacity, economic diversification, dependence on

natural resources, and trade openness. Such variation provides an appropriate framework for examining the impact of economic complexity on trade performance across different economic contexts.

The study covers a period of 23 years for each country, yielding approximately 92 observations in the panel dataset. Although the number of countries is relatively limited, the extended time span and balanced nature of the data provide a suitable basis for econometric analysis. Furthermore, the selected period encompasses significant economic and trade-related events, including the global financial crisis and the COVID-19 pandemic.

The distribution of countries across low (0.25), medium (0.50), and high (0.75) trade-performance quantiles further enhances the suitability of the sample for the unconditional quantile regression approach. The selected countries occupy different positions with respect to high-technology exports and total exports, thereby providing sufficient variation to assess the impact of economic complexity across different levels of trade performance.

Table 1. Distribution of Countries Across Trade Performance Quantiles

Indicator	0.25 Quantile (Low)	0.50 Quantile (Medium)	0.75 Quantile (High)
High-Technology Exports (HTE)	Algeria: Relies on available structural capacities to establish value-added activities.	Saudi Arabia and Tunisia: A stage characterized by a gap between innovation inputs and export outcomes.	Morocco: A stage of stable performance supported by institutional quality and country-specific advantages.
Total Exports (Ex.G.S)	Tunisia: Faces structural constraints limiting export volume competitiveness despite qualitative strengths.	Morocco and Algeria: A phase of structural stagnation requiring deep reforms.	Saudi Arabia: The primary driver of export flows due to its strong productive base.
Market Penetration (P.Ex.M)	Algeria: Constrained by rent-based economic structures and weak complexity-driven mechanisms.	Saudi Arabia and Tunisia: A transitional stage characterized by unstable market-access effects.	Morocco: An effective market penetration system based on productive complexity and strategic partnerships.

Source: Prepared by the authors based on estimations using R software.

The classification based on the Market Penetration Index also shows Algeria within the lower quantile due to constraints associated with its rentier economic structure, while Saudi Arabia and Tunisia occupy an intermediate position within the medium quantile. Morocco appears in the upper quantile owing to a more effective market-penetration framework based on productive complexity and high-quality trade partnerships.

To capture different dimensions of trade performance, the study employs three dependent variables that reflect export dynamics in terms of volume, technological content, and market penetration.

Table 2. Dependent Variables Representing Trade Performance

Variable	Symbol	Definition	Source
Exports of Goods and Services	Ex.G.S	Represents the total value of outgoing trade flows and reflects the quantitative export strength of the economy.	World Bank Data
High-Technology Exports	HTE	Refers to products characterized by high R&D intensity (e.g., aerospace, computers, pharmaceuticals, and scientific instruments). Used as an indicator of technological performance.	World Bank Data
Market Penetration Index	P.Ex.M	Measures a country's ability to enter new markets and increase its global market share, reflecting trade dynamism.	World Bank Data

Source: Prepared by the authors based on the referenced databases.

Table 2 presents the principal independent variables that reflect the knowledge-based and structural foundations of Arab economies from the perspective of economic complexity. The inclusion of these variables is methodologically important because of their direct relationship with a country's ability to generate knowledge, create value added, and strengthen its position in international trade.

Table 3. Main Independent Variables Representing Economic Complexity

Variable	Symbol	Definition	Source
Economic Complexity Index	ECI	Measures the accumulated productive knowledge within an economy and reflects the diversity and sophistication of exported products as well as the ability to produce rare and complex goods.	OEC Database
Trade Complexity Index	TCI	Focuses on the complexity of trade linkages, diversity of partners, and product variety within global value chains.	OEC Database
Research Complexity Index	RCI	Measures the sophistication and diversity of scientific and research outputs and is used to examine the relationship between academic innovation and the industrial base.	OEC Database

Source: Prepared by the authors based on the referenced databases.

The following table presents the control variables used to explain the economic phenomena under study, improve model specification, and account for structural factors surrounding export activities and economic complexity. These variables are methodologically important because they represent economic, institutional, and developmental determinants that influence countries' ability to generate value added, absorb technology, and enhance competitiveness in global markets.

Table 4. Control Variables

Variable	Symbol	Definition	Source
Gross Domestic Product	GDP	Reflects the overall size of the economy and the level of economic development. Commonly used as a control variable for productive capacity.	World Bank Data
Innovation Index	INOV	Measures a country's ability to generate new ideas, patents, and technologies and transform them into economic value.	World Intellectual Property Organization (WIPO)
Economic Freedom Index	EFI	Reflects the ease of doing business, freedom from trade restrictions, and the efficiency of government regulations.	Heritage Foundation
Human Development Index	HDI	A composite indicator (health, education, and income) reflecting the quality of human capital and its ability to absorb advanced technologies.	UNDP Human Development Reports
CO_2 Emissions	CO2	Used as an indicator of the environmental impact of industrial activity and the sustainability of technological transformation, particularly green technologies.	World Bank Data

Source: Prepared by the authors based on the referenced databases.

4. EMPIRICAL RESULTS

Diagnostic Econometric Analysis

Before discussing the estimation results, the diagnostic properties of the dataset were examined to ensure the suitability of the econometric models employed. Given that the study relies on panel data for four Arab countries over the period 2000–2022, comprising 92 observations, the correlation matrix revealed several strong relationships among the variables exceeding the conventional threshold of $|r| \geq 0.80$. The most notable correlations included the relationship between total exports and GDP (0.925), GDP and the Human Development Index (0.931), the Trade Complexity Index and the Human

Development Index (0.838), as well as the correlation between innovation and carbon dioxide emissions (0.835). In addition, a strong negative relationship was observed between the Economic Complexity Index and high-technology exports (-0.847), while a positive relationship emerged between high-technology exports and the Market Penetration Index (0.808).

These findings suggested the potential presence of multicollinearity among some explanatory variables, which necessitated the use of the Variance Inflation Factor (VIF) test. The results confirmed high levels of multicollinearity in certain cases, particularly where the VIF value for the logarithm of GDP exceeded 500.

Based on these findings, the models were re-specified by excluding the variables exhibiting the highest degree of overlap, notably the Human Development Index and carbon dioxide emissions, while retaining the core economic complexity indicators and transforming GDP into its logarithmic form. This adjustment enhanced the stability of the estimations and improved the reliability of subsequent results. The model re-specification was guided by the principle of aligning the selected variables with the direct economic channels influencing trade performance while preserving country-specific fixed effects to control for unobserved structural differences among the economies under investigation.

Accordingly, the analysis focused on three econometric models representing the principal dimensions of trade performance: total exports, high-technology exports, and market penetration.

Model 1: Determinants of Total Exports

This model is based on the Trade Complexity Index (TCI), which is considered the most consistent explanatory variable given the nature of the dependent variable. The model also includes the Real Exchange Rate and the Market Penetration Index to capture the direct trade-related channels affecting export volume.

$$Q_{\tau}(Ex.G.S_{it}) = \alpha_{\tau,i} + \beta_{1\tau} tci_{it} + \beta_{2\tau} RE.Ex.rate_{it} + \beta_{3\tau} P.Ex.M_{it} + \varepsilon_{it}$$

Model 2: Determinants of High-Technology Exports

The model retains the two most statistically stable variables, namely the Research Complexity Index (RCI) and the Economic Complexity Index (ECI), while excluding variables that exhibited substantial multicollinearity. The Real Effective Exchange Rate is also maintained in the specification. This model emphasizes the role of knowledge-based and productive structures as key determinants of high-technology exports.

$$Q_{\tau}(HTE_{it}) = \alpha_{\tau,i} + \beta_{1\tau} rci_{it} + \beta_{2\tau} eci_{it} + \beta_{3\tau} RE.Ex.rate_{it} + \varepsilon_{it}$$

Model 3: Determinants of Market Penetration

This model focuses on the interaction between trade complexity, the quality of the economic environment as represented by economic freedom, and research complexity. It reflects the notion that successful penetration of foreign markets is the outcome of an integrated institutional, knowledge-based, and commercial framework.

$$Q_{\tau}(P.Ex.M_{it}) = \alpha_{\tau,i} + \beta_{1\tau} tci_{it} + \beta_{2\tau} efi_{it} + \beta_{3\tau} rci_{it} + \varepsilon_{it}$$

Cross-Sectional Dependence, Unit Root, and Cointegration Tests

The results of the Pesaran Cross-Sectional Dependence (CD) Test revealed the existence of interdependence among panel units. The probability values reached 0.045 for the high-technology exports model and 0.015 for the total exports model, both below the 5% significance level. These findings indicate the presence of cross-sectional dependence among the countries included in the sample.

Consequently, second-generation panel unit root tests, namely the Cross-Sectionally Augmented Dickey-Fuller (CADF) and Cross-Sectionally Augmented IPS (CIPS) tests, were employed. The results revealed a mixture of variables that were stationary at level, I(0), such as Total Exports (Ex.G.S), the Economic Complexity Index (ECI), and the Real Exchange Rate, alongside variables that became stationary after first differencing, I(1), including High-Technology Exports (HTE), the Trade Complexity Index (TCI), and the Research Complexity Index (RCI).

Furthermore, the cointegration test identified the existence of a long-run equilibrium relationship only in the total exports model, with a test statistic of −2.210, while no evidence of cointegration was found in the remaining models. These results support the adoption of the Unconditional Quantile Regression (RIF-Panel Quantile Regression) approach, given its suitability for addressing heterogeneity and capturing the nonlinear nature of several trade performance indicators.

2. Analysis of the Results of the Three Models

2.1. Analysis of the Results of Model 1: Total Exports

The results of the first model, which examines total exports, reveal substantial variation in the impact of trade complexity across different quantiles of the export-performance distribution. In the lower quantile (Q25), representing primarily the case of Tunisia, the coefficient of the Trade Complexity Index is positive but statistically insignificant. This suggests that economies characterized by relatively low export performance have not yet developed the productive and institutional capacities necessary to translate trade complexity into tangible export gains. Furthermore, the weak significance of the Market Penetration Index indicates that market-access channels play a limited role in explaining export performance at this level.

Table 05. Results of Model 1: Total Exports for Tunisia – Lower Quantile (Q25)

```
Call: rq(formula = Ex.G.S ~ tci + RE.Ex.rate + P.Ex.M + factor(Country.Name),
    tau = taus, data = my_data_clean)

tau: [1] 0.25

Coefficients:
                                 Value         Std. Error    t value
(Intercept)                       7.941228e+10  6.334855e+10  1.253580e+00
tci                               2.396310e+10  3.382662e+10  7.084100e-01
RE.Ex.rate                       -4.452489e+07  4.935062e+08 -9.022000e-02
P.Ex.M                           -6.573822e+09  9.204387e+09 -7.142100e-01
factor(Country.Name)Morocco       2.043277e+10  4.259635e+10  4.796800e-01
factor(Country.Name)Saudi Arabia  1.573633e+11  5.137120e+10  3.063260e+00
factor(Country.Name)Tunisia      -1.664446e+10  3.380196e+10 -4.924100e-01
                                 Pr(>|t|)
(Intercept)                       2.167700e-01
tci                               4.825100e-01
RE.Ex.rate                        9.285300e-01
P.Ex.M                            4.789600e-01
factor(Country.Name)Morocco       6.338800e-01
factor(Country.Name)Saudi Arabia  3.770000e-03
factor(Country.Name)Tunisia       6.249300e-01
```

Source: R software output.

In the median quantile (Q50), which mainly reflects the cases of Algeria and Morocco, the impact of trade complexity weakens further, and most explanatory variables lose statistical significance. This outcome points to the existence of structural bottlenecks within economies characterized by moderate levels of diversification. Although some indicators of trade integration have improved, neither Algeria nor Morocco appears to have reached a sufficient level of productive capacity and competitiveness to convert trade complexity into a substantial expansion of total exports.

Table 06. Results of Model 1: Total Exports for Algeria and Morocco – Median Quantile (Q50)

```
Call: rq(formula = Ex.G.S ~ tci + RE.Ex.rate + P.Ex.M + factor(Country.Name),
    tau = taus, data = my_data_clean)

tau: [1] 0.5

Coefficients:
                                 Value         Std. Error    t value       Pr(>|t|)
(Intercept)                       5.313096e+10  3.459085e+10  1.535980e+00  1.318700e-01
tci                               2.491661e+09  3.707834e+10  6.720000e-02  9.467300e-01
RE.Ex.rate                        1.353500e+08  2.893962e+08  4.677000e-01  6.423600e-01
P.Ex.M                           -5.869628e+08  5.574905e+09 -1.052900e-01  9.166400e-01
factor(Country.Name)Morocco      -2.202143e+10  2.440465e+10 -9.023500e-01  3.719000e-01
factor(Country.Name)Saudi Arabia  2.182561e+11  6.395714e+10  3.412540e+00  1.410000e-03
factor(Country.Name)Tunisia      -4.089275e+10  2.292093e+10 -1.784080e+00  8.147000e-02
```

Source: R software output.

In the upper quantile (Q75), represented most clearly by Saudi Arabia, the effect of trade complexity becomes more pronounced. This finding suggests that economies with a larger export base are better positioned to leverage trade complexity in support of export growth. At this level, price-related channels gain greater importance, while the influence of market penetration diminishes. This may indicate that Saudi Arabia has moved beyond the stage of expanding access to new markets and is instead focused on consolidating and strengthening its existing trade positions.

Table 07. Results of Model 1: Total Exports for Saudi Arabia – Upper Quantile (Q75)

```
Call: rq(formula = Ex.G.S ~ tci + RE.Ex.rate + P.Ex.M + factor(Country.Name),
    tau = taus, data = my_data_clean)

tau: [1] 0.75

Coefficients:
                                 Value         Std. Error    t value       Pr(>|t|)
(Intercept)                       6.090695e+10  1.062332e+10  5.733330e+00  0.000000e+00
tci                               2.654418e+10  3.616390e+10  7.340000e-01  4.669300e-01
RE.Ex.rate                        3.949374e+08  3.403981e+08  1.160220e+00  2.523600e-01
P.Ex.M                           -8.339741e+08  2.387788e+09 -3.492700e-01  7.285900e-01
factor(Country.Name)Morocco      -3.276397e+10  6.605589e+09 -4.960040e+00  1.000000e-05
factor(Country.Name)Saudi Arabia  2.367200e+11  5.481324e+10  4.318670e+00  9.000000e-05
factor(Country.Name)Tunisia      -6.885882e+10  2.233349e+10 -3.083210e+00  3.570000e-03
Messages d'avis :
1: Dans summary.rq(xi, U = U, ...) : 3 non-positive fis
2: Dans summary.rq(xi, U = U, ...) : 3 non-positive fis
```

Source: R software output.

Overall, the findings of the first model confirm that the impact of trade complexity on total exports in Arab countries is neither linear nor homogeneous. The effect remains limited in Tunisia, fluctuates in Algeria and Morocco, and becomes significantly more effective in the case of Saudi Arabia. These results highlight the importance of country-specific structural characteristics in determining the extent to which trade complexity can be transformed into stronger export performance.

2.2. Analysis of the Results of Model 2: High-Technology Exports

The analysis of the second model, which examines the impact of economic complexity on high-technology exports across different quantiles, reveals a nonlinear relationship. The stimulating effect of the Economic Complexity Index (ECI) is confined to the lower levels of the high-technology export distribution and gradually diminishes as countries move toward higher quantiles. This dynamic suggests that economic complexity acts as an entry threshold, enabling countries with limited technological performance to gain access to technology-intensive markets. However, once countries surpass this stage and achieve more advanced levels of innovation, the explanatory power of economic complexity weakens, giving way to other determinants that play a more decisive role in shaping technological export performance.

Table 08. Results of Model 2: High-Technology Exports for Algeria – Lower Quantile (Q25)

```
Call: rq(formula = HTE ~ eci + rci + RE.Ex.rate + factor(Country.Name),
    tau = taus, data = my_data_clean)

tau: [1] 0.25

Coefficients:
                                 Value         Std. Error    t value       Pr(>|t|)
(Intercept)                      -5.857823e+08  2.472446e+08 -2.369240e+00  2.238000e-02
eci                               5.882811e+08  2.844181e+08  2.068370e+00  4.465000e-02
rci                              -5.554684e+07  1.743054e+07 -3.186750e+00  2.680000e-03
RE.Ex.rate                        2.250064e+06  1.324367e+06  1.698970e+00  9.655000e-02
factor(Country.Name)Morocco       8.538464e+08  1.139697e+08  7.491870e+00  0.000000e+00
factor(Country.Name)Saudi Arabia  1.464151e+08  4.721518e+07  3.101020e+00  3.400000e-03
factor(Country.Name)Tunisia       1.091314e+09  1.198628e+08  9.104690e+00  0.000000e+00

Call: rq(formula = HTE ~ eci + rci + RE.Ex.rate + factor(Country.Name),
    tau = taus, data = my_data_clean)
```

Source: R software output.

The issue of disconnected scientific research is also reflected in the statistical behavior of the **Research Complexity Index (RCI)**. Its impact appears negative in the lower quantile and subsequently loses statistical significance in the higher stages of the distribution. This finding highlights a structural gap between academic outputs and industrial requirements within Arab economies, where research efforts often fail to be transformed into tangible value added within the structure of technology-based exports.

Table 09. Results of Model 2: High-Technology Exports for Saudi Arabia and Tunisia – Median Quantile (Q50)

```
Call: rq(formula = HTE ~ eci + rci + RE.Ex.rate + factor(Country.Name),
    tau = taus, data = my_data_clean)

tau: [1] 0.5

Coefficients:
                                Value         Std. Error    t value       Pr(>|t|)
(Intercept)                    -3.585246e+08  3.253057e+08 -1.102120e+00  2.765400e-01
eci                             1.968410e+08  2.458096e+08  8.007900e-01  4.276600e-01
rci                            -1.943692e+07  2.310771e+07 -8.411400e-01  4.049200e-01
RE.Ex.rate                      2.433517e+06  2.211472e+06  1.100410e+00  2.772800e-01
factor(Country.Name)Morocco     8.922660e+08  1.820850e+08  4.900270e+00  1.000000e-05
factor(Country.Name)Saudi Arabia 1.914029e+08  4.481221e+07  4.271220e+00  1.100000e-04
factor(Country.Name)Tunisia     9.540531e+08  1.246538e+08  7.653620e+00  0.000000e+00

Call: rq(formula = HTE ~ eci + rci + RE.Ex.rate + factor(Country.Name),
    tau = taus, data = my_data_clean)
```

Source: R software output.

The results further demonstrate the persistent statistical significance of country-specific effects across all performance levels. This finding indicates that technological advancement in Arab countries is not driven solely by quantitative measures of economic or research complexity. Rather, it is fundamentally shaped by the structural and institutional characteristics unique to each country. Such heterogeneity suggests that technological success is strongly influenced by national environments and historical **2**development trajectories whose impact may exceed that of general theoretical determinants.

Table 10. Results of Model: High-Technology Exports for Morocco – Upper Quantile (Q75)

```
Call: rq(formula = HTE ~ eci + rci + RE.Ex.rate + factor(Country.Name),
    tau = taus, data = my_data_clean)

tau: [1] 0.75

Coefficients:
                                Value         Std. Error    t value       Pr(>|t|)
(Intercept)                    -2.377461e+08  3.004108e+08 -7.914000e-01  4.330500e-01
eci                             1.376601e+07  2.878384e+08  4.783000e-02  9.620800e-01
rci                             5.604851e+06  3.416075e+07  1.640700e-01  8.704400e-01
RE.Ex.rate                      2.421489e+06  2.857187e+06  8.475100e-01  4.014000e-01
factor(Country.Name)Morocco     1.018337e+09  2.555452e+08  3.984960e+00  2.600000e-04
factor(Country.Name)Saudi Arabia 2.325707e+08  5.310757e+07  4.379240e+00  7.000000e-05
factor(Country.Name)Tunisia     9.924915e+08  1.274134e+08  7.789540e+00  0.000000e+00
```

Source: R software output.

Based on these findings, it can be concluded that the transition from low to high technological performance requires a shift in policy focus away from merely improving economic complexity indicators toward implementing qualitative institutional and structural reforms. In particular, greater emphasis should be placed on bridging the gap between research and industry, strengthening innovation ecosystems, and accounting for country-specific structural characteristics. Such reforms are essential for transforming scientific and technological capabilities into sustained growth in high-technology exports.

2.3. Analysis of the Results of Model 3: Export Market Penetration

The results of the fourth model reveal significant structural differences among Arab countries regarding their ability to penetrate global markets. Performance is distributed across three distinct groups: a lower quantile characterized by limited market access, represented by Algeria; a middle quantile reflecting economies in transition, such as Saudi Arabia and Tunisia; and an upper quantile characterized by well-established competitive advantages, exemplified by Morocco. This distribution highlights substantial differences in the capacity of each economy to transform trade complexity, research capabilities, and external integration into effective export competitiveness.

The results for the lower quantile indicate a complete absence of statistical significance for all explanatory variables, including trade complexity, research complexity, and economic openness. This finding reflects a rentier economic structure that remains disconnected from the dynamics of complex trade activities. Neither trade complexity nor research complexity generates a measurable impact in an economy that relies predominantly on undiversified primary exports. Likewise, economic openness does not translate into export expansion but is instead associated with increased imports without a corresponding ability to integrate into global value chains. These findings point to a profound structural gap that renders modern growth drivers—such as complexity, research, and external integration—ineffective in the absence of a competitive productive base.

Table 11. Results of Model 3: Export Market Penetration for Algeria – Lower Quantile (Q25)

```
Call: rq(formula = P.Ex.M ~ tci + efi + rci + factor(Country.Name),
    tau = taus, data = my_data_clean)

tau: [1] 0.25

Coefficients:
                                 Value    Std. Error t value  Pr(>|t|)
(Intercept)                       0.23128  8.52171    0.02714  0.97847
tci                               0.39882  0.66454    0.60014  0.55156
efi                               0.42126  1.97188    0.21363  0.83184
rci                              -0.26197  0.22007   -1.19040  0.24042
factor(Country.Name)Morocco       4.95448  0.28552   17.35250  0.00000
factor(Country.Name)Saudi Arabia  2.81442  0.62006    4.53898  0.00005
factor(Country.Name)Tunisia       3.72394  0.45625    8.16210  0.00000
```

Source: R software output.

In the cases of Saudi Arabia and Tunisia, the results reflect a transitional stage in which early signs of progress coexist with persistent structural constraints. Research complexity exhibits a limited but statistically significant negative effect, suggesting that existing research efforts in both countries have not yet been transformed into genuine industrial or export capabilities. In Saudi Arabia, the dominant role of the oil sector constrains the ability of emerging industrial complexity to generate deep export advantages. In Tunisia, logistical and institutional barriers continue to limit the country's ability to fully capitalize on its existing industrial complexity, particularly in electronic component value chains. These findings highlight the persistence of the gap between research and production and indicate that trade complexity has not yet reached the threshold necessary to enhance market access capabilities significantly.

Table 12. Results of Model 3: Export Market Penetration for Saudi Arabia and Tunisia – Median Quantile (Q50)

```
Call: rq(formula = P.Ex.M ~ tci + efi + rci + factor(Country.Name),
    tau = taus, data = my_data_clean)

tau: [1] 0.5

Coefficients:
                                 Value    Std. Error t value  Pr(>|t|)
(Intercept)                       6.36057  5.33157    1.19300  0.23941
tci                               0.34366  0.36779    0.93439  0.35532
efi                              -1.10016  1.27623   -0.86204  0.39345
rci                              -0.22820  0.12914   -1.76716  0.08430
factor(Country.Name)Morocco       5.14959  0.18467   27.88530  0.00000
factor(Country.Name)Saudi Arabia  3.16856  0.41003    7.72756  0.00000
factor(Country.Name)Tunisia       4.11240  0.28248   14.55800  0.00000
```

Source: R software output.

At the upper quantile of export market penetration, the characteristics of advanced export competitiveness become more evident. Morocco emerges as an example of an economy capable of transforming productive complexity into expanded international market shares. The Trade Complexity Index is both statistically significant and economically strong, demonstrating that commercially advanced economies are able to leverage product sophistication to build sustainable competitive advantages based on knowledge, technology, and quality.

Table 13. Results of Model 3: Export Market Penetration for Morocco – Upper Quantile (Q75)

```
Call: rq(formula = P.Ex.M ~ tci + efi + rci + factor(Country.Name),
    tau = taus, data = my_data_clean)

tau: [1] 0.75

Coefficients:
                                 Value    Std. Error t value  Pr(>|t|)
(Intercept)                      14.00164  5.65747    2.47489  0.01735
tci                               1.02569  0.37786    2.71445  0.00952
efi                              -2.85494  1.34007   -2.13044  0.03890
rci                              -0.20898  0.11176   -1.86984  0.06832
factor(Country.Name)Morocco       5.45148  0.23705   22.99753  0.00000
factor(Country.Name)Saudi Arabia  2.62690  0.38362    6.84758  0.00000
factor(Country.Name)Tunisia       3.87595  0.27844   13.92019  0.00000
Message d'avis :
Dans summary.rq(xi, U = U, ...) : 4 non-positive fis
```

Source: R software output.

5. DISCUSSION OF RESULTS

The estimation results reveal that the impact of economic complexity on trade performance in Arab countries is neither linear nor homogeneous. Instead, it varies according to a country's position within the trade performance distribution and the specific indicator used to measure performance. This finding is partially consistent with previous studies that emphasized the positive role of economic complexity in export diversification, quality upgrading, and competitiveness enhancement, including those of Gnangnon (2022), Canh and Thanh (2020), and Bayar (2022). However, the present study extends these findings by demonstrating that the benefits of economic complexity do not emerge automatically; rather, they remain conditional upon productive capacities, institutional quality, and the existing level of trade performance.

In the total exports model, the impact of trade complexity is limited or statistically insignificant in the lower quantile, consistent with Tunisia's position as an economy with a relatively modest export base that is unable to convert trade complexity into substantial export gains without stronger productive and institutional foundations. In the median quantile, represented mainly by Algeria and Morocco, the relationship appears less stable, suggesting that improvements in complexity indicators alone are insufficient to increase total exports in the presence of persistent constraints related to productive diversification and competitiveness. By contrast, the impact becomes more evident in the upper quantile, corresponding to Saudi Arabia, where a larger export base and broader productive capacities enable trade complexity to be translated into more stable export performance.

Regarding high-technology exports, the findings support the argument of Abdi, Zaidi, and Karim (2023) that the effects of economic complexity vary across sectors. The Economic Complexity Index recorded a positive and statistically significant coefficient of 5.88×10^8 at a significance level of $p = 0.044$, suggesting that the development of productive and knowledge-based capabilities can enhance technological value added during the early stages of industrial development. In contrast, the Research Complexity Index exhibited a negative and statistically significant coefficient of -5.55×10^7 at $p = 0.0027$, revealing a striking gap between scientific research outputs and the requirements of high-technology manufacturing and exports.

With respect to export market penetration, the results support the conclusions of Lyubimov (2021), Cariolle and da Piedade (2023), and Chakraborty, Chaisse, and Pahari (2020), who argue that export performance should not be assessed solely through export volume or diversification but should also incorporate the ability to gain effective access to international markets. The findings indicate that trade complexity becomes more influential when accompanied by an institutional and commercial environment capable of transforming product quality and trade linkages into actual market presence. This pattern is particularly evident in Morocco, where the impact of trade complexity on market penetration reached approximately 1.02. Conversely, the Economic Freedom Index recorded a negative and statistically significant coefficient of −2.85, indicating that trade openness alone does not automatically generate export gains unless it is directed toward deeper integration into value chains and the strengthening of export-oriented productive capabilities.

Overall, the results suggest that the relationship between economic complexity and trade performance in Arab countries is conditional and nonlinear. Its effectiveness depends on the degree of productive diversification, the quality of linkages between scientific research and industry, and the nature of integration into international markets. The study contributes to the literature by shifting the focus from the traditional emphasis on export volume and diversification toward the analysis of export market penetration as an independent dimension of trade performance. It demonstrates that economic complexity generates commercial gains only when supported by productive and institutional structures capable of transforming knowledge into effective export value.

6. CONCLUSION

This study examined the impact of economic complexity on the trade performance of four Arab countries—Algeria, Saudi Arabia, Tunisia, and Morocco—during the period 2000–2022. The analysis focused on three principal dimensions of trade performance: total exports, high-technology exports, and export market penetration. To achieve this objective, three complexity indicators were employed: the Economic Complexity Index (ECI), the Trade Complexity Index (TCI), and the Research Complexity Index (RCI). The study adopted the RIF-Panel Quantile Regression methodology, enabling the analysis of effects across different levels of trade performance rather than restricting the analysis to average effects.

The findings reveal that the relationship between economic complexity and trade performance in Arab countries is both nonlinear and conditional. In the total exports model, the impact of trade complexity remained limited in the lower and middle quantiles, particularly in Tunisia, Algeria, and Morocco, while becoming more pronounced in the upper quantile represented by Saudi Arabia. This suggests that trade complexity does not automatically translate into export gains unless it is supported by productive and institutional structures capable of converting complex trade linkages into actual export flows.

In the high-technology exports model, the results indicate that economic complexity can contribute to the creation of technological value added during the early stages of industrial development. However, the negative effect of research complexity reveals a significant gap between scientific research outputs and the requirements of high-technology manufacturing and exports. This finding suggests that academic knowledge can only be transformed into technological trade performance through effective technology-transfer mechanisms and stronger linkages between research institutions and industry.

With regard to export market penetration, the results demonstrate that trade complexity is most effective when accompanied by an institutional and commercial environment capable of transforming product quality and trade relationships into actual market presence, as illustrated by the Moroccan case. The findings also show that economic openness alone does not guarantee export gains unless it is directed toward deepening value-chain integration, strengthening productive capacities, and complying with international quality and regulatory standards.

The principal contribution of this study lies in highlighting the nonlinear and conditional nature of the relationship between economic complexity and trade performance within the Arab context. Moreover, the study shifts the discussion from the traditional focus on export volume and diversification toward export market penetration as an independent dimension of trade performance, while examining heterogeneous effects across different performance quantiles rather than relying solely on average relationships.

Despite the significance of these findings, the study remains limited by its sample, which includes only four Arab countries, and by its reliance on aggregate indicators that may not fully capture sectoral and institutional differences affecting the relationship under investigation. Therefore, the results should be interpreted as a comparative analysis of the selected contexts rather than as a universal generalization applicable to all Arab economies.

Based on these findings, the study recommends the adoption of more selective industrial and trade policies aimed at transforming economic complexity from a latent capability into effective export value. This requires strengthening the links between scientific research and manufacturing, directing innovation toward export-oriented sectors, improving institutional and regulatory environments, enhancing product quality, and promoting deeper qualitative integration into global value chains. Trade openness without a competitive productive and knowledge base is unlikely to generate genuine market penetration or ensure the transformation of economic complexity into sustainable trade performance.

References

1. Abdi, A. H., Zaidi, M. A. S., & Karim, Z. A. (2023). Economic complexity and bilateral trade flows in selected COMESA and East Asia countries. Technological and Economic Development of Economy, 29(3), 846–873. https://doi.org/10.3846/tede.2023.18682.

2. Białowąs, T., & Budzyńska, A. (2022). The importance of global value chains in developing countries' agricultural trade development. Sustainability, 14(3), 1389. https://doi.org/10.3390/su14031389.

3. Canh, N. P., & Thanh, S. D. (2020). The dynamics of export diversification, economic complexity and economic growth cycles: Global evidence. Foreign Trade Review, 57(3), 234–260. https://doi.org/10.1177/0015732520970441.

4. Cariolle, J., & da Piedade, C. (2023). Digital connectedness and exports upgrading: Is sub-Saharan Africa catching up? The World Economy, 46(11), 3325–3344. https://doi.org/10.1111/twec.13501.

5. Chakraborty, D., Chaisse, J., & Pahari, S. (2020). Global auto industry and product standards: A critical review of India's economic and regulatory experience. Journal of International Trade Law and Policy, 19(1), 8–35.

https://doi.org/10.1108/JITLP-10-2019-0063

6. Gnangnon, S. K. (2022). Effect of economic complexity on services export diversification: Do foreign direct investment inflows matter? International Journal of Development Issues, 21(3), 413–437. https://doi.org/10.1108/IJDI-01-2022-0023
7. Olasehinde-Williams, G., & Oshodi, A. F. (2021). Can Africa raise export competitiveness through economic complexity? Evidence from (non)-parametric panel techniques. African Development Review, 33(3), 426–438. https://doi.org/10.1111/1467-8268.12587
8. Şimdi, H., & Şeker, A. (2019). The relationship between economic complexity index and export: The case of Turkey and Central Asian and Turkic Republics. Economy of Regions, 15(3), 659–669. https://doi.org/10.17059/2019-3-3
9. Shahzad, U., Madaleno, M., Dagar, V., Ghosh, S., & Doğan, B. (2022). Exploring the role of export product quality and economic complexity for economic progress of developed economies: Does institutional quality matter? Structural Change and Economic Dynamics, 62, 40–51. https://doi.org/10.1016/j.strueco.2022.04.003
10. UNCTAD. (2023). Global Trade Update: March 2023. United Nations Conference on Trade and Development. (UN Trade and Development (UNCTAD))
11. World Bank. (2026). World Development Indicators. World Bank DataBank. (databank.worldbank.org)
12. World Trade Organization. (2023). World Trade Statistical Review 2023: Chapter II – Highlights of world trade in 2022. WTO