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The Role of Technological Achievement and Industrial Competitiveness in Trade Efficiency: Evidence from Iran's Industrial Trade with Vision Document Countries

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Highlights

- **The study examines the effects of Technological Achievement and industrial competitiveness on trade efficiency.**
- **While industrial achievement has a positive and significant impact, the competitiveness index has a negligible and statistically insignificant effect on trade efficiency.**
- **There is a bilateral relationship between trade and technical efficiency in Iran and its trading partners in the industrial sector.**

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Abstract

This study evaluates the effects of the Industrial Competitiveness Index and technological achievements on industrial trade efficiency in Iran and Vision Document countries. This article calculated industrial trade value using the Grubel-Lloyd index and data from 24 Vision Document countries. The data were categorized by four-digit HS codes from 2002 to 2023, sourced from the World Bank and the International Trade Development Organization. The ranks of trade and technical efficiency were measured using a data envelopment analysis (DEA) method. The ultimate models, including technical and trade efficiency equations, were estimated utilizing the two-step system generalized method of moments (SYS-GMM) model. The findings reveal that most variables influence trade efficiency significantly in the expected direction. While a one-unit increase in technological achievements resulted in a 0.057-unit enhancement in the trade efficiency index, Iran's industrial competitiveness with the Vision Document countries had a trivial effect. Oil sanctions exerted a more pronounced adverse effect, reducing the trade efficiency index by 0.225 units. In contrast, technical efficiency positively contributed to a 0.186-unit increase. These results advise policymakers to enhance industrial competitiveness through investments in technological infrastructure and human capital. Furthermore, fostering technological advancements through increased investments in research and development (R&D) in Iran's domestic industries and transferring advanced technologies from prosperous countries like the United Arab Emirates and Turkey is crucial for improving and sustaining Iran's industrial trade efficiency.

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1. Introduction

In today's globalized economy, competitiveness and technological advancement are key drivers of export growth and commercial efficiency. The United Nations Industrial Development Organization (UNIDO) defines industrial competitiveness as a nation's capacity to expand its presence in international and domestic markets while developing higher-value-added and technologically sophisticated industrial sectors and activities (UNIDO, 2021). Meanwhile, technological achievement, encompassing the successful generation or discovery of knowledge, scientific understanding, and technological progress, involves dimensions such as innovation, invention, and the practical application of scientific knowledge. Composite indices, such as the Technological Achievement Index, assess a nation's technological progress and capacity for participation in the global technology landscape (Desai et al., 2002).

Developing industrial competitiveness and adopting emerging technologies enable countries to capitalize on cumulative effects, increased production capacity, economies of scale, and enhanced bargaining power in trade agreements. These advantages can improve industrial trade efficiency by driving structural changes within the industry. This positive relationship is particularly evident in nations that have expanded exports by leveraging economies of scale and overcoming absolute cost advantages in technology-intensive, high-value-added industries (Institute for Trade Studies and Research, 2022). This efficient use of available resources generates efficiency gains, increasing technical and trade efficiency (Rasekhi et al., 2016).

The central question is how industrial competitiveness and technological advancement enable a country to achieve trade efficiency.

Prior studies demonstrate that technological advances drive structural change in industrial trade. Industries with significant technological opportunities and leadership in technological development enhance technical efficiency, contributing to more efficient international trade (Montobbio & Rampa, 2005). Developing high-value-added industrial technologies and improved technological capabilities underpins enhanced industrial competitiveness, leading to competitive advantage through expanded production capacity, infrastructure investment, strategic policy implementation, and cost reduction. This multifaceted approach promotes export growth and efficient industrial trade performance. Aligning industrial competitiveness with technological achievement establishes a competitive advantage in technology-oriented sectors, enabling resource-rich nations to specialize in high-tech exports, thereby enhancing industrial trade efficiency (Luh et al., 2016). Existing literature also examines factors influencing intra-industry trade efficiency, including regional trade agreements (RTAs), commercial costs, entry barriers, economic size, trade imbalances, technology disparities, foreign direct investment, human capital, R&D investment, and sanctions (Zhu, 2023; Tochkov, 2022; Łapińska et al., 2019; Nejati & Akhbari, 2019), as well as economies of scale, comparative advantage, product differentiation, consumer price indices, innovation, and market orientation (Sheidaei, 2022; Udriyah et al., 2019). Further research has explored the role of economic efficiency, political factors, government support, and competitive advantages derived from market structure and market share (Rasekhi et al., 2016).

Trade Studies and Research Institute data reveal a significant disparity in industrial export performance. In 2010 Iran exported $9.6 billion worth of industrial goods—far less than Turkey's $85.3 billion. By 2023, Iran's share of global trade had decreased to 0.33%, an 18% decline over the preceding five years. Conversely, Saudi Arabia and Turkey experienced considerable growth, increasing their shares to 1.11% and 1.29%, respectively. While global trade expanded by approximately $10 trillion during this period, Iran's contribution was only $14 billion (Maleki & Khalili-Asl, 2023). Statistical analyses further indicate a downward trend in the efficiency of Iran's industrial trade, and Iran's rank decreased from 0.89 in 2002 to 0.60 in 2023.

Despite the 1404 Vision Document's emphasis on achieving regional leadership in economic, scientific, and technological domains, the 2023 Industrial Competitiveness Index ranks Iran 57th globally, with a score of 4.5%, placing it seventh among countries with a Vision Document. This score represents a 28.8% decline compared to Turkey (12.1%), the United Arab Emirates (11.9%), and Saudi Arabia (9.2%) (Industrial Competitiveness Index Report, 2023). Moreover, in the Global Innovation Index, Iran ranks fourth regionally with a score of 34.5, following the UAE, Turkey, and Georgia. This performance is coupled with a decline in human capital, research, and infrastructure, indicating suboptimal outcomes (Global Innovation Index Report, 2021).

The preceding statistics reveal a significant disparity in innovation and industrial competitiveness indices between Iran and the countries outlined in the Vision Document. Moreover, Iran, with its low rank in trade efficiency and industrial export growth rate compared to other prosperous regional countries, has failed to close the significant gap in its economic performance. This divergence indicates a failure to develop a competitive and outward-looking economy, as emphasized in the Vision Document.

This research is outstanding and innovative in contrast to previous studies for several reasons. Firstly, it employs a composite index of technological achievement, offering a more comprehensive perspective. Secondly, while many Iranian studies have explored intra-industry trade and its influencing factors, the relationship between industry trade efficiency and technical efficiency has often been overlooked. Thirdly, despite numerous global studies on the effects of innovation and technology development on trade and the 1404 Vision Document's emphasis on Iran achieving a leading position in science, technology, and innovation in the region, this issue has been largely ignored among the Vision Document countries. Fourthly, while prior research has considered relative competitive advantage indices, the impact of the two aforementioned indices as sources of competitive advantage on industrial business efficiency has not been thoroughly investigated. Therefore, this study is one of the few conducted in this field, distinguishing itself from prior research.

The study measured technical and trade efficiency using data envelopment analysis (DEA) in Vision Document Countries. Trade and technical efficiency equations are extracted using production functions. We used the System Generalized Method of Moments (SYS-GMM) and data from 2002 to 2023 to investigate the factors influencing these two types of efficiency.

The structure of the paper is as follows: Section 2 establishes the theoretical basis for the research. Section 3 details the research methodology used. Following this, Section 4 presents the model estimation and data analysis. The paper concludes with a summary of the findings and recommendations.

2. Literature Review

Like other fields of economics, international trade literature has witnessed the evolution of various theories to accommodate economic transformations, technological advancements, and changing trade dynamics. Scholars categorize these theories into traditional and modern perspectives, emphasizing different factors influencing trade patterns and their benefits. The literature on trade efficiency emerged alongside traditional theories and has continued to evolve with new trade theories, trade liberalization, the rise of the digital economy, and global infrastructure development. This body of literature encompasses studies and theories examining how the efficiency of goods and services is exchanged across borders, drawing on various disciplines, including economics, international trade, and trade theory.

2.1. Traditional and modern theories of trade

These theories, propounded by economists such as Adam Smith (1776), David Ricardo (1817), and Heckscher-Ohlin (1919), constitute a body of classical and neoclassical trade models. These models revolve around fundamental concepts like absolute advantage, comparative advantage, and factor endowment. They emphasize how differences in the efficiency of factor endowments, such as labor and capital, drive trade patterns. However, as economies have evolved, the limitations of traditional international trade theories cannot explain the real-world trade phenomena because oversimplified assumptions often do not hold, such as the absence of transportation costs and perfect competition. Moreover, these models neglect the role of technological change and economic dynamics over time, emphasizing excessive labor and capital while overlooking factors such as technology, human capital, and natural resources. Consequently, new trade theories have emerged as extensions of traditional trade theories.

The empirical evidence from the 1960s challenged traditional trade theories, leading to new trade theories pioneered by economists such as Krugman (1980). These theories emphasize increasing returns to scale and network effects in international trade, suggesting that trade efficiency stems from comparative advantage and economies of scale, product differentiation, and imperfect competition. Modern theories highlight the role of diverse consumer preferences (Krugman, 1980), consumer demand diversity (Globerman & Dion, 1990), heterogeneous consumer preferences (Hunter, 1991), technological change (Posner, 1961), market access (Amiti, 1998), advantages of information technology (Ismil & Mahdiyan, 2015), and political, social, and institutional factors (Silberberger & Kanbur, 2016) in explaining trade efficiency. These theories demonstrate that even countries with similar factor endowments can still benefit from trade. Moreover, they emphasize the importance of technology and government policies in shaping global trade patterns.

2.2. Trade Efficiency

The efficiency from trade gains represents a performance level that minimizes the inputs required to produce a given output and maximizes welfare because many production units may operate at inefficient scales (Sheidaei, 2022). In essence, trade efficiency (TE) is an economic paradigm where global producers specialize in producing one or more goods, thereby achieving lower production costs than non-specialized producers. Consequently, product prices and production costs decrease, resulting in cheaper and more affordable goods for consumers and higher profits for producers (Helpman, 1999). In this regard, Krugman (1995) argues that efficiency stems from the global concentration of production in a single location and the exploitation of external economies of scale.

Exploring new trade theories reveals three primary theoretical perspectives to explain the evolution of trade efficiency over time. First, demand-side theories emphasize overlapping preferences and similar demand structures, suggesting that demand for differentiated products increases as incomes rise. Second, supply-side theories focus on the potential for product differentiation, economies of scale, variety, trade liberalization, and economies of scope arising from various sources such as learning-by-doing, technology learning, innovation, and competitiveness, leading to increased specialization over time. Third, organizational theories highlight the impact of multinational corporations, trade barriers (such as tariffs, transportation costs, and standard market agreements), foreign direct investment, and international oligopolies. Pryor (1992) argues that neither demand nor supply-side explanation alone can fully account for trade efficiency, necessitating a combined approach. The industrial organization perspective further emphasizes factors such as market dominance, a competitive national environment, technological development, infrastructure, increased national and industrial competitiveness, and the ability to create competitive advantages as sources of reduced costs and improved trade efficiency.

The literature on trade efficiency emphasizes the role of factors such as reduced transaction costs, increased competitiveness, improved infrastructure, technological advancements, trade facilitation, and liberalization, as well as the importance of global supply chains. Consequently, competitiveness, technical efficiency, and trade liberalization, alongside other factors, can help countries make better use of their resources through specialization and economies of scale.

This efficient utilization of resources by firms or industries, coupled with increased efficiency gains associated with investment and capacity growth, enables countries to transition from an input-driven economy to an efficiency-driven one.

2.3. Industrial competitiveness and trade efficiency

The literature on industrial competitiveness offers three primary perspectives to explain firm, industry, and national performance. The resource-based view (RBV) posits that firms' unique resource endowments and effective exploitation drive heterogeneous performance. From this perspective, leveraging scarce resources contributes to superior firm performance, with sustained competitive advantage predicated on protecting these resources from imitation (Miller, 2019).

The market-based view, often conceptualized through the value chain framework, emphasizes collaborative interactions among producers, consumers, and multinational corporations (MNCs) as key drivers of competitive advantage. Porter argues that any business activity can be a competitive advantage achieved through cost leadership or differentiation. A firm or industry can gain a competitive advantage by performing value-creating activities at a lower cost than competitors or by offering products with superior quality and unique features (Zamora, 2016).

The knowledge-based view (KBV) emphasizes innovation as central to competitive advantage. Innovation, encompassing new product and process development, represents replacing obsolete knowledge with value-generating activities. This process enhances the innovative firm's performance. It generates positive externalities for related firms and regions, acting as a cornerstone of economic development and creative destruction, thereby sustaining competitive performance and industrial competitiveness (Melitz & Redding, 2021).

Since 2000, the Competitive Industrial Performance (CIP) has been a pivotal metric for assessing a nation's capacity to foster industrial development through enhanced competitiveness. The CIP is an output-oriented composite index underlying the idea that countries maximize economic efficiency in scarce resource allocation and can industrialize more effectively by promoting competitiveness. The index predominantly focuses on production-related metrics and is a strategic tool for evaluating a country's industrial performance and trade efficiency (Cheng et al., 2023).

Ricardo's theory of comparative advantage provides a foundational explanation for the relationship between industrial competitiveness and trade efficiency. As previously discussed, this theory posits that countries maximize economic welfare through trade by specializing in producing goods with a comparative advantage. By enhancing industrial competitiveness, as reflected in the CIP index, countries can produce goods with greater international demand, leading to increased exports and improved trade efficiency. Therefore, the CIP index is a proxy for a country's comparative advantages in manufacturing sectors (UNIDO, 2021).

Porter's Diamond Model is another theory that sheds light on the factors influencing national competitive advantage and trade efficiency. Departing from traditional theories focusing on comparative advantage, Porter's model attributes absolute cost advantages to a firm's or industry's sustained competitive advantage and emphasizes the role of a nation's factor endowments, demand conditions, related and supporting industries, and firm strategy, structure, and rivalry in creating a competitive advantage. Porter argues that basic factors (natural resources, climate, location, etc.) and advanced factors (infrastructure, skilled labor, research facilities, and technological knowledge) can be sources of competitive advantage. The nature of domestic demand and the sophistication of domestic customers can also play a critical role. These factors, when combined, can create a competitive advantage that is difficult for other countries to replicate (Porter, 1990).

Rugman & D'Cruz (1993) critiqued Porter's Diamond Model, arguing that it was less applicable to small open economies. By introducing the 'Double Diamond Model,' they integrated national and international competitive advantage by considering the roles of trade agreements and foreign subsidies. Subsequently, academics and organizations have engaged in discussions about national and global competitiveness, linking national competitive advantages to the competitiveness of firms and industries. In other words, improvements in national and international competitive advantage are rooted in enhancing the competitiveness of firms within industries, ultimately leading to improved trade efficiency (Stavropoulos et al., 2018).

UNIDO defines industrial competitiveness as a nation's capacity to develop industrial sectors and activities with higher value-added and technological content. This competitive advantage facilitates trade efficiency. According to this definition, improving industrial competitiveness requires two essential elements: expanding production to increase domestic and international market presence and enhancing product quality. Accordingly, expanding industrial production, exporting manufactured goods, and advancing the technological ladder are crucial factors in creating a competitive advantage and strengthening a country's industrial trade efficiency. In other words, a higher industrial competitiveness index suggests that a country's industries are better positioned to compete in global markets. However, it is crucial to note that a high index value does not necessarily guarantee high competitiveness across all industries within a country (Cheng et al., 2023).

2.4. Technological achievements and trade efficiency

As countries sought sustainable economic growth, high-technology production emerged as a central focus. Technological advancements and international competitiveness became the foundation of economic efficiency in advanced economies. New global trade theories, emphasizing the importance of non-price factors in determining competitiveness, have highlighted the role of innovation in developing new products. New growth theories focusing on technology and innovation have made comparative advantages endogenous and emphasized the impact of technology and trade policies on specialization and growth. Furthermore, technological trajectories and innovative organizations, central to neo-Schumpeterian and evolutionary approaches, view technological differences between countries and industries as the basis for dynamic competition, market share acquisition, and trade efficiency (Guarascio et al., 2017).

Economic commentators have also observed that the direction of technological change plays a significant role in the speed at which industrial trade efficiency is affected by integration into the global economy. Consequently, trade has been described as both a 'highway of learning' and a 'handmaiden of growth.' They argue that global integration can positively and negatively affect private incentives and social benefits of investing in technology. On the positive side, economic integration can expand market size, create opportunities for new product development, and facilitate learning from abroad. On the negative side, firms may perceive international competition as a risk associated with investing in advanced technologies, leading to increased calls for government intervention in technology development (Grossman & Helpman, 1995).

Posner's (1961) technology gap theory suggests that trade is driven by product and process innovations introduced by pioneering firms or countries holding temporary monopolies in the global market. Thus, the technology gap can be a stimulant and a barrier to competition and trade. This theory emphasizes the role of endogenous technology as a determinant of comparative advantage and efficient trade (Brodzicki & Sledziewska, 2016).

Another related theory is Vernon's product life cycle model, which suggests that the production of a new product initially requires skilled labor and is concentrated in developed countries. As the product matures, production may shift to developing countries with lower labor costs as the product becomes standardized and can be produced using less skilled labor and mass production techniques. This theory posits that developed countries, with the necessary resources and capabilities, will export high-value, capital-intensive goods while importing goods produced with older technologies. This is based on the idea that technological advancements often arise from learning by doing, where repeated production activities lead to new and improved ways of doing things. When this knowledge is diffused among firms and industries, technological evolution is shaped by comparative advantage, influencing international trade patterns and efficiency (Grossman & Helpman, 1995).

Technological advancements are crucial in enhancing trade efficiency by reducing production and transaction costs, improving product quality, optimizing supply chains, and facilitating the global exchange of services and knowledge. As technology continues to evolve, we can expect trade efficiency to improve, creating new opportunities for both developed and developing countries.

2.5. Technical and trade efficiency

Various factors influence technical efficiency, including the quantity and quality of physical and human capital, technical knowledge, experience, managerial skills, market structure, and competitive intensity. While trade and industrial policies can also affect firms' and industries' technical efficiency, scholarly opinions diverge on this relationship (Hossain & Karunaratne, 2004). One view posits that trade expansion compels firms to invest in infrastructure, training, technology, and modernization to compete effectively with foreign producers, potentially increasing domestic production, productivity, and technical efficiency. Conversely, some theories suggest that increased exporter revenues from trade may diminish incentives for technological advancement and efficient production.

However, the theory of economies of scale posits that international markets eliminate inefficient firms while efficient firms enhance productivity through technological investment. Increased production volume yields cost reductions, thereby improving technical efficiency. Nevertheless, in oligopolistic markets, intense competition can drive excessive technological investment, creating barriers to entry that impede competitors' achievement of technical efficiency (Hart et al., 2015).

Furthermore, production and technical efficiency can, in turn, enhance trade efficiency. Antweiler & Trefler (2002) emphasize that large-scale production enables firms to develop efficient technologies by leveraging market dominance and increased market power. Consequently, if economies of scale drive trade, specialization by country or industry facilitates cost reduction and trade expansion, ultimately increasing intra-industry trade efficiency by reducing absolute cost advantages (Helpman, 1999). Chui et al. (2002) also highlight the importance of trade for growth, suggesting that trade policies may derive from growth performance and that comparative advantage is fundamental to markets' trading capacity and countries' production trade structures.

3. The Study Model

This section covered the approach utilized to investigate the effects of the industrial competitiveness index and technological achievement on the efficiency of Iran's industrial trade vis-à-vis the Vision Document countries. We divided this section into four subsections, which are as follows:

3.1. Econometric Modelling

Before proceeding to our empirical model, we present a conceptual framework to guide the analysis. The relation between industrial trade and technical efficiency is determined using the Cobb-Douglas production function in the following form:

$$Y_{it} = A(t)K_{it}^{\alpha}L_{it}^{\beta}e^{u_t} \quad (1)$$

Subscript $i = 1, \dots . N$ represents the country, and $t = 1, \dots . T$ is the period, Y is the actual income, and K and L denote capital stock and labor force, respectively. A(t) represents the technology level, α and β are constants, and u_t is an error term.

The endogenous growth theory suggests that economic growth is primarily the result of internal processes rather than external influences. This perspective highlights the importance of knowledge spillovers and innovation driven by trade (Spithoven & Merlevede, 2023). Technology can be embodied within intermediate inputs, capital goods, or individuals (representing their knowledge and expertise) or transacted in disembodied form (Mendi, 2007). It has a crucial influence on production. So, in this model, we determined technology endogenously as a function of trade. Therefore, we have (Rasekhi et al., 2016):

$$A(t) = \delta IT_{it}^{\gamma} \quad (2)$$

Where δ is the constant term, and IT shows industrial trade. Substituting Equation (2) into Equation (1), we have:

$$Y_{it} = \delta . IT_{it}^{\gamma} K_{it}^{\alpha} L_{it}^{\beta} e^{u_t} \qquad i = 1, \ldots..n, \quad t = 1, \ldots..T \quad (3)$$

Taking the logarithm of Equation (3), we have the functional form of Equation (4).

$$Ln(Y_{it}) = \varphi_0 + \varphi_1 Ln(IT_{it}) + \alpha Ln(K_{it}) + \beta Ln(L_{it}) + u_{it} \quad (4)$$

Where subscript i and t represent the country and time, respectively, $\varphi_1 = \delta\gamma$ is the coefficient of trade openness, u_{it} is the error term.

Considering the theoretical literature supporting the bidirectional causality between trade and technical efficiency—that is, $EE_{it} \Leftrightarrow ITE_{it}$ —denoting $Ln(Y_{it})$ and $Ln(IT_{it})$ as technical production efficiency and trade efficiency, respectively. We can rewrite the factors influencing efficiency as follows:

$$EE_{it} = f(ITE_{it}, Z_{it}, u_{it}) \quad (5)$$

$$ITE_{it} = f(EE_{it}, W_{it}, \varepsilon_{it}) \quad (6)$$

Where EE_{it} represents technical efficiency, ITE_{it} represents trade efficiency, Z_{it} and W_{it} are the factors affecting both efficiency types and u_{it}, ε_{it} are the error terms.

To measure technical and trade efficiency, we employ Data Envelopment Analysis (DEA)—detailed in the subsequent section—to calculate trade and technical efficiency over the study period. We then analyze the impact of relevant factors on these two types of efficiency, drawing upon the existing literature.

3.2. DEA Modelling

The growing importance of industrial trade has led to the development of various methodologies for assessing its efficiency. Two prominent approaches stand out in this regard: parametric and non-parametric methods.

The Data Envelopment Analysis (DEA)[1] is a non-parametric approach that uses input-output data and linear programming to assess efficiency. Originating from Farrell (1957), DEA was initially formulated by Charnes, Cooper, and Rhodes (1978) under the assumption of constant returns to scale (CCR) and

[1]. We used Deap 2.1 software to estimate technical efficiency within the DEA framework.

subsequently extended by Banker, Charnes & cooper (1984) to accommodate variable returns to scale (BCC). DEA evaluates the efficiency frontier by comparing the performance of Decision-Making Units (DMUs) in a multi-input, multi-output context. Unlike Stochastic Frontier Analysis (SFA), DEA obviates the need to specify a functional form, prior parameter estimates, or distributional assumptions for the error term (Fall et al., 2018). Given the research objective of minimizing inputs for a given output level and better controllability of costs (inputs) relative to revenues (outputs) in the context of technical efficiency and trade policy analysis, an input-oriented approach assuming variable returns to scale (VRS) is appropriate (Coelli, 1996; Cooper et al., 2007; Rasekhi, 2016). Efficiency analysis is conducted by solving the following linear program: Efficiency = output/Input

$$Min_{\lambda,\theta}\theta \quad \text{s.t:} \quad \theta x_j - \lambda X \geq 0, \quad Y\lambda \geq y_j, \quad \lambda \geq 0 \tag{7}$$

Where λ is a semi-positive vector in R^k, and θ is a real variable representing the efficiency score of a specific DMU, ranging from zero to one (100%); y_j represents the value of output produced via the k^{th} decision-making unit, x_j is the value of input j utilized by the k^{th} DMU. The minimization of θ is subject to the constraint that no DMU can operate beyond the production possibility frontier, and the weights must be non-negative. In this framework, weights are endogenously determined to maximize the relative efficiency of each Decision-Making Unit (DMU) (Suzuki & Nijkamp, 2017). Furthermore, to ensure the robustness of the analysis, the number of DMUs should be at least equal to $(m + p + 1)$ or $2(m + p)$ (Rasekhi, 2016).

To evaluate two criteria of efficiency for Iran and its trading partners, we calculate industrial trade efficiency using two outputs (IIT and net trade) and five inputs (Labor productivity (TPL), real effective exchange rate (RER), learning by exporting (LBX), economy of scale (ES), and the log of difference in production (LDP)). Similarly, technical efficiency is determined using one output (real gross domestic product (GDP)) and three inputs (labor force (LF), capital (KF), and Government Final Consumption Expenditure (G)) (Zhang, 2005; Backus, 1992; An & Iyigun,2004).

3.3. Econometric Estimation Technique

Having computed technical and trade efficiencies for the studied countries, we evaluate the factors influencing these efficiencies. Based on the literature and relevant theory, we categorize these factors as industry-specific or country-specific. Consequently, we specify an empirical model comprising a dynamic system of equations with the following functional form to analyze Iran's trade relations with its partners in the Vision Document region.

$$EE_{it} = \alpha_0 + \alpha_1 EE_{it-1} + \alpha_2 ITE_{it} + \alpha_3 LK_{it} + \alpha_4 LL_{it} + \alpha_5 LGC_{it} + u_t \tag{8}$$

$$ITE_{it} = \delta_0 + \delta_1 ITE_{it-1} + \delta_2 EE_{it} + \delta_3 ES_{it} + \delta_4 RER_{it} + \delta_5 ICP_{it} + \delta_6 TAI_{it} + \delta_7 Timb_{it} + Sanc_t + \varepsilon_t \quad (9)$$

Equations (8) and (9) define the variables: i and t represent time and countries, respectively. EE_{it} stands for technical efficiency, ITE_{it} is the industrial trade efficiency, LK_{it} represents the log capital stock, LL_{it} is the labor, LGC_{it} denotes the log of government consumption expenditure, ES_{it} represents the economy of scale, RER_{it} is the actual effective exchange rate, ICP_{it} signifies the industrial competitiveness performance, TAI_{it} is the technological achievement index, $Timb_{it}$ refers to the trade imbalance (% GDP), and $Sanc_t$ is Iran's oil sanctions against its trading partner. It is worth noting that all these variables are measured at the fixed price of the base year 2015. Additionally, u_t and ε_t represent error terms in the equations. (Zhang,2005; Desai, et al. 2002; Brodzicki & Slodzinski, 2016).

This study employs dynamic panel data models within a simultaneous equations framework, utilizing the Blundell & Bond (1998) system Generalized Method of Moments (SYS-GMM) estimator to address lagged technical and trade efficiency levels. This estimator is particularly suitable for analyzing linear or non-linear relationships in panel datasets characterized by a short time dimension (T) and a large cross-sectional dimension (N), especially when certain independent variables are potentially endogenous (i.e., correlated with past and potentially future, error terms) or when the lagged dependent variable is included as a regressor. Where within-panel heteroscedasticity and autocorrelation are typically assumed to be present, the practical implementation of SYS-GMM requires appropriate instruments, primarily internal instruments (lags of the independent variables). However, external instruments may also be employed (Roodman, 2009).

SYS-GMM addresses the limitations inherent in difference GMM (DGMM), which relies solely on lagged levels of endogenous variables as instruments after first differencing the regressors. By employing a system of two equations—the original Equation and a transformed equation—which combines level and first-differenced regressions, SYS-GMM mitigates bias arising from unobserved individual effects and measurement error. The validity of these methods rests on their underlying assumptions, commonly assessed through over-identification tests, such as the Sargan and Hansen J statistics. These statistics test the validity of the instruments, while serial correlation in the error terms is examined separately. The Difference-in-Sargan/Hansen (C) test assesses the validity of specific subsets of instruments. In these tests, the null hypothesis is that the instruments are valid; rejection of the null hypothesis implies instrument insufficiency. The Sargan test applies to the difference GMM under the assumptions of homoscedasticity and the absence of serial correlation. Conversely, the Hansen J test, used with two-step SYS-GMM, utilizes an optimal weighting matrix without these restrictions and has an asymptotic distribution (Kripfganz, 2019). It is crucial to note that GMM estimators are consistent only without second-order serial correlation.

3.4. Variables and Data

This study uses the following relationships to quantify the industrial trade index and input-output variables for efficiency measurement. Bilateral trade flows are calculated as the sum of Iran's export and import value vis-à-vis Vision Document countries as follows:

$$TT_{ij} = \sum_{k}\left(X_{ij}^{k} + M_{ij}^{k}\right) = X_{ij} + M_{ij} \quad (9)$$

Where X_{ij}^{k} and M_{ij}^{k} denote the export and import value of commodity k between i and j countries at 4-digit Harmonized System (HS) codes, total trade can decompose into Intra-industry Trade (IIT) and Inter-Industry Trade:

$$IIT_{ij} = TT_{ij} - \left|X_{ij} - M_{ij}\right| \rightarrow \; INT_{ij} = TT_{ij} - IIT_{ij} \quad (10)$$

In this context, IIT represents Intra-industry Trade, while the absolute trade imbalance $\left|\mathrm{X_{ij}} - \mathrm{M_{ij}}\right|$ reflects inter-industry (or net) trade flows (Kandogan, 2003). Normalizing both sides by total trade yields the weighted Grubel-Lloyd index for IIT and its complement for INT. These indices are as follows:

$$IIT_{ij}^{k} = \left[\frac{\sum_{k}\left(X_{ij}^{k} + M_{ij}^{k}\right) - \sum_{k}\left|X_{ij}^{k} - M_{ij}^{k}\right|}{\sum_{k}\left(X_{ij}^{k} + M_{ij}^{k}\right)}\right] \quad (11)$$
$$INT_{ij}^{k} = 1 - IIT_{ij}^{k}$$

The index $\mathrm{IIT_{ij}^{k}}$ quantified the share of intra-industry trade in commodity k among Iran and its trading partners, assuming values between 0 and 1 (100%), where 0 indicates exclusive inter-industry trade and 1 denotes complete intra-industry Trade (Yazdani & Pirpour, 2020).

As mentioned earlier, IIT and INT are potential determinants of trade efficiency. Consequently, trade efficiency, assuming variable returns to scale, is calculated from the geometric mean of technical efficiency and technological change between two periods. This index is as follows:

$$M = \frac{D^{t+1}(x^{t+1}, y^{t+1})}{D^{t}(x^{t}, y^{t})}\left[\frac{D^{t}(x^{t+1}, y^{t+1})}{D^{t+1}(x^{t+1}, y^{t+1})} \times \frac{D^{t}(x^{t}, y^{t})}{D^{t+1}(x^{t}, y^{t})}\right]^{\frac{1}{2}} * 100 \quad (12)$$

Where M represents the Malmquist index. $x(x^{t}, \ldots, x^{t+\infty})$ The input vector includes product variety (PD), the absolute difference of export learning by exporting (LBX), the real exchange rate (RER), economies of scale (ES), and labor productivity between Iran and its trading partners. $y(y^{t}, \ldots, y^{t+\infty})$ is output vectors (including IIT and INT). $D(D^{t}, \ldots, D^{t+\infty})$ refers to distance functions. The ratio outside the bracket measures efficiency change, and the term inside measures technological change between the two periods. A value of M exceeding 100 (*i.e.*, M >100) indicates trade efficiency and productivity growth. In contrast, a value less than 100 indicates a decline in trade efficiency, and M = 100 signifies stagnation (Yazdani & Pirpour, 2020).

The analysis defines product differentiation as the difference between the average number of exported products $\left(M_{kj}\right)$ between Iran and partner countries.

$$DP_{kj} = \frac{1}{N_j}\sum_{k=1}^{Nj} M_{kj} \quad (13)$$

In Equation (13), N_j represents the number of product categories in country j (Zhang, 2005).

Learning by exporting represents the accumulation of export experience. It is quantified using the following formula:

$$LBDx_{it} = \frac{\sum_0^t (Exp_{it}/N_{it})}{max \sum_0^t (Exp_{it}/N_{it})} \quad (14)$$

Where Exp_{it} is the export of the country i at time t, and N_{it} represents its population in the same period (An & Iyigun, 2004).

We measured the Industrial Competitiveness Performance Index (ICP_{it}) by each country's industry competitiveness performance score. This index holds immense significance for sustainable industrial development, reflecting sectoral specialization, and is pivotal in shaping structural changes. It ultimately determines the industry's long-term contribution to sustainable development (International Industrial Development Organization, 2021). The technological achievement index (TAI_{it}) comprises components related to technology creation and patent rights, the dissemination of old technology, new technology, human skills, and research and development indicators. Each of these components is further subdivided into the following sub-components:

Technology Creation Component: This includes the number of patent applications by residents and non-residents and the number of patents registered in the target country.

Dissemination of New Innovation Component: This component encompasses sub-components such as the population percentage using the internet, the good export percentage with high and medium technology content by exporters of goods and services, and the number of articles published in scientific journals.

Dissemination of Old Technology Component: This component incorporates indicators related to household electricity consumption and the number of subscribers to mobile and fixed-line phones (per 100 people).

Human Skills Component: It includes sub-components like the percentage of individuals aged 15 and above with literacy skills and the percentage of enrollees in tertiary education.

Research and Development Component: This component consists of two sub-components: the number of researchers and technicians in the research and development sector (per million people). Initially, each of these components is indexed using the formula:

$Index - X = \frac{x_i^{real} - x_i^{min}}{x_i^{max} - x_i^{min}}$ Subsequently, Principal Component Analysis (PCA) transforms these indices into a unitary index (Dessai et al., 2002).

Moreover, EE_{it} is the efficiency score for decision-making units under variable returns to scale, quantifying technical or technological efficiency in production. The industrial trade efficiency ITE_{it} signifies an efficiency score and ranking determined through non-parametric data envelopment analysis (DEA) employing linear programming. This metric ranges from zero to 100% (Coelli, 1996). Labor productivity is measured by per capita value added (Brodzicki & Slodzinski, 2016); economies of scale by the value added of manufacturing industries (Loertscher & Wolter, 1980); and the real effective exchange rate, representing the value of foreign currency in domestic currency, is calculated as the nominal exchange rate and the ratio of U.S. consumer price index to domestic consumer price index, based on constant 2015 prices. Moreover, input-output variables for technical efficiency are gross domestic product constant 2015 prices, KF (% GDP) as an indicator for capital stock gross capital formation, GC (% GDP) government Consumption expenditure, and LF labor force, which comprises individuals aged 15 and above who are producing goods and services within a specified timeframe. It involves employed and unemployed individuals actively searching for job opportunities; this data is obtained from the World Bank and the United Nations.

4. Empirical Results

Following the definition of efficiency and the previously proposed Equations (8) and (9), this section investigates the influence of the Technological Achievement (TAI) and the Industrial Competitiveness Performance (ICP) Indices on Iran's industrial trade efficiency and the Vision Document countries. We assess the determinants of production-related technical efficiency and their impact on industrial trade efficiency. However, due to the inherent challenges posed by the explanatory variables' endogeneity and the model's dynamic structure, it is imperative to employ the SYS-GMM method to ensure efficient and consistent estimation. Before model estimation, addressing the potential for spurious regression is crucial. To this end, we performed the Pesaran cross-sectional dependencies test because the first-generation stationarity tests are invalid in cases involving cross-sectional dependencies. Owing to detecting the cross-sectional dependency, the Pesaran cross-sectional augmented Dickey-Fuller test was employed (Baltaghi, 2006). Table 1 presents the results of the stationarity tests.

The CD Pesaran test indicates the cross-sectional dependence among the variables at the 5% significance level. Moreover, the second-generation Pesaran's Cross-sectionally Augmented Dickey-Fuller (CADF) test confirms that all independent variables are stationary, except for government consumption expenditure and economies of scale, indicating that most variables are integrated of order zero, denoted as I (0).

Table 1. Tests for Stationarity, Cross-Sectional Dependence, and Westerlund Tests)

Variable	Cross-Section Dependence Test	P-Value	Augmented Dickey-Fuller-Pesaran Test	P-Value
ITE_{it}	6.420	0.000	-1.644	0.673
EE_{it}	20.860	0.000	-1.849	0.318
$Timb_{it}$	6.830	0.000	-2.710	0.000
TAI_{it}	29.340	0.000	-2.800	0.000
Es_{it}	24.910	0.000	-0.890	0.969
ICP_{it}	49.650	0.000	-2.270	0.006
RER_{it}	59.040	0.000	-2.090	0.000
LL_{it}	27.360	0.000	-2.190	0.000
LK_{it}	15.840	0.000	-2.380	0.000
LGC_{it}	11.320	0.000	-0.790	1.000
Westerlund Test for Cointegration in Equation (8)			Variance ratio = -2.429	0.008
Westerlund Test for Cointegration in Equation (9)			Variance ratio = -1.729	0.042

***Source**: Research finding.*

The dependent variables' non-stationarity, industrial trade, and technical efficiency create dynamic conditions suitable for estimation using the two-step System Generalized Method of Moments (SYS-GMM). Additionally, the Westerlund cointegration test rejects the null hypothesis of no cointegration, confirming a long-run relationship among the variables and alleviating concerns about spurious regression. The estimation results and diagnostic statistics for Equations (8) and (9) are presented in Table 2.

Table 2 shows that certain variables in the industrial trade efficiency equation display the expected signs and are statistically significant at the 5% level. The Wald statistic ($p < 0.05$) confirms the overall validity and robustness of the estimated regression equations. Over-identification tests, such as the Sargan and Hansen J statistics, ensure the instrument matrix's validity in both equations. Therefore, the two-step System Generalized Method of Moments (SYS-GMM) estimator effectively eliminates fixed effects and ensures that specification bias is not present in the model.

Empirical estimations indicate that the lagged industrial trade efficiency variable increased the trade efficiency index by 0.351 units. As established in the literature, Trade efficiency enhances future improvements in trade performance by generating benefits such as economies of scale, factor endowments, specialization, product diversification, cost reduction, improved product quality, and revenue diversification. Moreover, inter-firm imitation within a country allows successful exporters to incentivize other firms to enter the export market. Production technical efficiency exerts a significant positive effect of 0.432 units on trade efficiency. Theoretically, international markets tend to eliminate inefficient firms. Efficient firms leverage cost advantages, achieve market dominance, and invest in infrastructure, training, and technology to facilitate large-scale production. This efficient resource allocation is pivotal in the national transition from an input-driven to an efficiency-driven economy (Hart, 2015).

Table 2. Results of Estimation Using Two-Stage System Generalized Method of Moments (SYS-GMM)

Variable	Industrial trade efficiency equation				Technical efficiency equation			
	Coefficient	Standard Deviation	Z Statistic	Significant Level	Coefficient	Standard Deviation	Z Statistic	Significant Level
Cons	0.141	0.113	1.240	(0.216)	0.533	0.138	3.870	(0.004)
ITE_{it}	-	-	-	-	0.608	0.202	3.010	(0.003)
ITE_{it-1}	0.351	0.159	2.210	(0.027)	-	-	-	-
EE_{it}	0.423	0.150	2.830	(0.005)	-	-	-	-
EE_{it-1}	-	-	-	-	-0.137	0.045	-3.050	(0.002)
$Timb_{it}$	-0.020	0.044	-0.470	(0.640)	-	-	-	-
TAI_{it}	0.057	0.025	2.290	(0.022)	-	-	-	-
LL_{it}	-	-	-	-	-0.003	0.001	-2.850	(0.004)
RER_{it}	0.081	0.058	1.410	(0.158)	-	-	-	-
LK_{it}	-	-	-	-	0.029	0.032	0.900	(0.368)
Es_{it}	0.002	0.001	4.200	(0.000)	-	-	-	-
LGC_{it}	-	-	-	-	0.039	0.013	3.020	(0.003)
$ICPI_{it}$	0.0001	0.001	0.021	(0.830)	-	-	-	-
$Sanc_{it}$	-0.221	0.048	-4.590	(0.000)	-	-	-	-

The validation tests and statistics of the SYS-GMM model's reliability

	Industrial trade efficiency equation	Technical efficiency equation
Sargan's J-Test	χ^2 =8.530 (0.860)	χ^2= 16.790 (0.468)
Hansen's J-Test	χ^2 =11.020 (0.684)	χ^2= 15.310 (0.573)
Wald- test	12897.590 (0.000)	12372.330 (0.000)
Number of observations	504	504
Number of groups	24	24
Number of Instruments	24	24

***Source**: Research finding.*

The real exchange rate (RER) is a multifaceted factor with a nuanced and intricate influence on industrial trade efficiency. Theoretically, the exchange rate operates through direct and indirect channels. The real effective exchange rate (RER) changes are expected to enhance industrial trade efficiency. An increase in the RER raises the relative price of foreign goods, encouraging consumers to substitute domestic goods for foreign ones and potentially expanding trade and production through increased exports and reduced imports. Indirectly, the exchange rate affects the domestic money supply via the increased value of the central bank's foreign assets, which can negatively impact output and exacerbate inflation, thereby contracting exports and trade (Samsami & Tootoonchi, 2010).

The model's estimation results indicate that the real exchange rate does not significantly impact industrial trade efficiency. Despite the theoretical potential for an increase in the real effective exchange rate (RER) to enhance industrial trade efficiency, the exchange rate has not generated fundamental changes in Iran and approximately half of the Vision Document countries. It is essential to mention that numerous countries, such as Azerbaijan, Kazakhstan, Iran, Kyrgyzstan, Lebanon, Pakistan, Sudan, Syria, Turkey, Turkmenistan, and Uzbekistan, have experienced double-digit inflation rates exceeding 10% in recent years. Also, countries Azerbaijan, Turkmenistan, Lebanon, Jordan, Iraq, Uzbekistan, Pakistan, Kyrgyzstan, Tajikistan, and Afghanistan have registered lower GDP per capita based on purchasing power parity in recent years than Iran. Variations in the exchange rate within this group indicate that production growth, investment in export-oriented industries, and other policy interventions primarily influence industrial trade. Therefore, exchange rate fluctuations, which theoretically should accelerate exports, have not promoted export growth or industrial trade efficiency. Moreover, the dependence of most regional countries' industrial trade on imported raw materials, intermediate goods, and capital goods means that increasing exchange rates contribute to stagflation, production instability, and reduced technical efficiency by raising production costs, thus hindering improvements in industrial trade efficiency.

Finally, the effect of economies of scale, consistent with theory, is estimated at 0.002, as specialization fosters opportunities to leverage economies of scale for cost reduction and trade expansion (Helpman, 1999).

The technological achievement and industrial competitiveness indices are two variables considered in the trade efficiency equation. While industrial competitiveness demonstrated a negligible and statistically insignificant effect, technological achievement positively and significantly impacted trade efficiency, with a coefficient of 0.057. The theoretical role of technology in establishing comparative advantage is a cornerstone of international trade literature. Technology can act as either a facilitator or an impediment to trade relations. Based on the technology gap and endogenous growth theories, technology is a key source of comparative advantage, and policies fostering technological advancement enhance specialization, growth, and trade efficiency. The technology gap theory posits that continuous technological change creates trade opportunities and efficiency gains even among countries with similar resource endowments and consumer preferences. Technological lag can hinder a nation's competitiveness against more advanced economies. Conversely, access to new technologies empowers developing countries to improve product quality, expand their global market share, and enhance trade efficiency.

The theoretical literature on industrial competitiveness links trade efficiency to specialization in production, enhanced technological capabilities, the development of higher value-added industrial technologies, and increased technological content. Consequently, more industrially competitive countries exhibit superior technical efficiency due to their role in fostering learning, technical and structural capacity building, external economies, and accelerated productivity growth. These countries can produce internationally demanded goods and establish entry barriers, creating new competitive advantages with sustained effects on export expansion and industrial trade efficiency. Moreover, related and supporting industries play a crucial role in this process. They contribute to further competitive advantage by offering higher-quality, lower-cost inputs and enhancing industrial trade efficiency (Cheng et al., 2023).

Regarding the lack of impact of industrial competitiveness on trade efficiency in Iran and the Vision Document countries, it is argued that over the past two decades, Iran and more than half of these countries have experienced setbacks in their industrial development strategies. These setbacks stem from challenges such as lagging behind regional competitors, persistent (and sometimes intensifying) raw material exports, a declining share of industrial value-added, premature deindustrialization, and sub-optimal capacity utilization in manufacturing. The paucity of fundamental drivers for production enhancement and technical prerequisites, alongside a lack of robust institutional and supportive infrastructures in Iran, can hinder even competitive industries from leveraging their export potential and comparative advantages. Beyond these institutional deficits, the industrial sector's contribution to Iran's export volume remains constrained. Domestically competitive industries within the Iranian economy face impediments to effective global market participation due to sanctions, restricted technology imports, and dependence on foreign raw materials.

Notably, while industrial performance shows progress in transforming industrial trade structures, it has regressed in evolving the industrial production structure. This implies that the scope of industrial production and trade is confined mainly to resource-based commodities or products with medium-low technological complexity, produced through basic processes and low-level skills. Consequently, this divergence hinders the potential for enhanced trade efficiency derived from improved industrial competitiveness.

Iranian oil sanctions have reduced the industrial trade efficiency index by 0.228. Theoretical literature suggests that sanctions diminish target country welfare and efficiency by increasing costs, disrupting supply chains, misallocating resources, restricting financial flows, and complicating exchange rate dynamics and third-country interactions. However, sanctions can positively impact trade efficiency by prompting trade partner diversification, domestic industrial growth, and the formation of trade and regional agreements (Caruso, 2003; Dizaji & Farzanegan, 2024). Beyond restricting the exportation and importation of raw materials, components, and finished goods, sanctions against Iran severely limit access to the international financial system, notably disrupting connectivity with the SWIFT (Society for Worldwide Interbank Financial Telecommunication) network. This compels Iranian firms to seek potentially less efficient and reliable alternative suppliers. Consequently, reliance on indirect import routes escalates transportation, transaction, and financial exchange costs while heightening risks and price volatility and reducing supply chain transparency due to protracted delivery times. The curtailment of international banking relations further impedes the utilization of crucial instruments like letters of credit, undermining Iranian industries' competitiveness and trade efficiency in regional and global markets. Moreover, prolonged oil sanctions have noticeably shifted the composition and number of nations importing Iranian crude oil, diminishing Iran's petroleum revenues and foreign currency reserves and eroding its industrial competitiveness vis-à-vis its trading partners, particularly regarding access to international technology and expertise.

In Table 2, the estimation of the technical efficiency equation reveals that industrial trade efficiency and government consumption expenditure exert positive and significant effects on technical efficiency. Although the capital stock ratio demonstrates a positive relationship, it lacks statistical significance. The insignificant impact of capital stock on technical efficiency in these countries may also stem from insufficient capital infrastructure for electronic services, limited investment in science, research, and innovation (R&D), declining capital stock growth rates during the study period, and the fact that average capital stock in 87.5% of the Vision Document countries was lower than that of Iran.

Conversely, the labor force negatively and significantly impacts trade relationships. This impact can be attributed to several factors: low labor quality and human development indices, deficiencies in labor health indicators, skill shortages, limited specialization, the prevalence of unskilled labor, the underutilization of skilled labor, persistent barriers to productive labor, and disparities in labor knowledge and experience across international interactions. These combined factors have constrained productivity growth, knowledge spillovers, and technical and technological efficiency development.

A crucial aspect of SYS-GMM estimation is instrument validity. Instrumental variables are required to eliminate the model's endogeneity bias. In equations (8) and (9), the core instruments are the dependent and independent variables in levels, first differences, and strictly exogenous variables from the other Equation. We should carefully choose the lag of the dependent variable to avoid overidentification. Table 3 assesses the exogeneity validation for a subset of instrumental variables and serial correlation in error terms within the System Generalized Method of Moments (SYS-GMM) framework.

Table 3. Results of Difference-In-Hansen Tests and Serial Correlation in Error Terms

Difference-in-Hansen Tests	Industrial trade efficiency equation	Technical Efficiency Equation
Difference-in-Hansen GMM instrument for level	$\chi^2 = 7.47\ (0.487)$	$\chi^2 = 1.15\ (0.563)$
Difference-in-Hansen IV-instrument for level	$\chi^2 = 4.91\ (0.671)$	$\chi^2 = 5.11\ (0.530)$
Difference-in-Hansen GMM instrument for the differenced Equation	$\chi^2 = 7.32\ (0.495)$	$\chi^2 = 5.56\ (0.851)$
Difference-In-Hansen IV-instrument for the differenced Equation	$\chi^2 = 3.45\ (0.840)$	$\chi^2 = 6.77\ (0.343)$
AR (1)-Arellano-Bond test	$\chi^2 = -3.12\ (0.002)$	$\chi^2 = -3.29\ (0.001)$
AR (2)-Arellano-Bond test	$\chi^2 = 0.23\ (0.820)$	$\chi^2 = 0.11\ (0.911)$

***Source**: Research finding.*

Examining the exogenous nature of a subset of instrumental variables using the Difference-in-Hansen test (both with and without additional instruments) indicated two key points: Firstly, considering the Chi-Square statistics and its p-value ($p > 0.05$), the instruments demonstrate the requisite validity and exogeneity in both levels and first differences. Secondly, the model exhibits complete dynamic specification, remaining correctly specified even with or without the inclusion of additional instruments, and demonstrates its robustness. The Arellano-Bond test confirmed the absence of second-order autocorrelation in the error terms.

5. Concluding Remarks

Enhancing technical and industrial trade efficiency is crucial for developing economies, particularly Iran. Given the finite nature of resources and the imperative to transition from resource-based to efficiency-driven growth, it is essential to examine Iran's technical and trade efficiency relative to the Vision Document countries. Despite limited research, no study has adequately investigated whether prioritizing technological achievements and industrial competitiveness specifically stimulates Iran's industrial trade efficiency and Vision Document countries. While existing research has explored the causal link between economic efficiency and trade or the determinants of trade flows, it has neglected the specific roles of technological achievements and industrial competitiveness. Therefore, given the imperative for Iran's integration into the global economy and the importance of developing science, knowledge, technology, and competitiveness to improve its industrial trade efficiency relative to the Vision Document countries, a pragmatic focus on these indicators in industrial and trade policy is essential. This study hypothesizes that industrial competitiveness and technological advancements positively influence the industrial trade efficiency of Iran and the Vision Document countries by enhancing comparative advantage, economies of scale, product quality, cost reduction, and embodied technology in production. Consequently, this paper assesses the impact of these factors on Iran's industrial trade efficiency with the Vision Document countries from 2002 to 2023, employing the System Generalized Method of Moments (SYS-GMM) estimator.

The empirical findings indicate that the technological achievement index has increased trade efficiency by 0.057. This effect is attributable to recent import policies in Iran and some Vision Document countries, which have focused on acquiring technological products for imitation, replication, and the production of newer, domestically produced goods. Consequently, these countries have incorporated domestically produced goods—similar to foreign products but at lower cost and made more rapidly—into their export portfolios, supplementing raw material exports. However, the industrial competitiveness performance index has not contributed to industrial trade efficiency due to insufficient structural, technical, and systemic production capacities and a failure to develop advanced technologies, thus hindering the creation of competitive advantages for enhancing production and trade efficiency. Furthermore, inconsistencies across economic, trade, and industrial policies, import dependency, and supply constraints exacerbate these challenges.

This study found that technical efficiency had the most significant impact on industrial trade efficiency. These findings align with theoretical foundations and provide reliable evidence of countries that rely on resource-based economies. Furthermore, given their dependence on imported intermediate, capital, and raw materials for production and exports, exchange rate appreciation in these economies can lead to higher import costs, instability, and reduced trade efficiency. We expected that exchange rate appreciation would improve trade efficiency by enhancing industrial competitiveness. However, inflationary pressures, the absence of fundamental supporting factors, and inadequate technical infrastructure for production enhancement offset this effect.

The economic trajectories of prosperous nations in the region demonstrate that Turkey's focus on industrial cluster development, value chain strengthening, export-oriented industry support, and investment in transportation and logistics infrastructure have facilitated its increased share in global markets. Similarly, the United Arab Emirates, through initiatives like "Operation 300 Billion," has prioritized advanced industry development, digital production, and foreign direct investment attraction. Establishing specialized industrial and technology-focused free zones with comprehensive investor facilities has fostered the growth of strong domestic brands in sectors such as aerospace, steel, and armaments. Moreover, within the framework of Vision 2030 and the National Industrial Development and Logistics Program (NIDLP), Saudi Arabia has adopted a macro-oriented approach centered on economic diversification and has effectively enhanced industrial competitiveness through investments in infrastructure and technology localization. In contrast, Iran confronts infrastructural deficits, a lack of cohesive industrial strategy, and foreign trade constraints. Nevertheless, regional experiences suggest that adopting strategies such as industrial cluster development, targeted export support, production digitalization, and the creation of investment-attractive industrial zones could potentially improve Iran's industrial competitiveness; however, the successful implementation of these strategies necessitates careful consideration of its unique economic and political context, particularly the impact of sanctions. Based on these findings, we propose the following policy recommendations:

Since technological advancements can enhance industrial trade efficiency, policymakers should prioritize reducing or eliminating import barriers for advanced technology goods to facilitate the influx of advanced industrial and capital equipment.

Industrial and trade development programs should prioritize expanding the number of import markets and diversifying the types of imported capital goods and new products. Facilitating imports from advanced economies provides access to more technologically advanced inputs, enhancing export portfolio diversification and sophistication.

Policymakers should foster industrial trade efficiency by enhancing learning opportunities, knowledge accumulation, and strategies for developing technical efficiency.

Economic planners should continuously monitor and mitigate the exchange rate volatility to promote efficient trade relations.

To further enhance industrial trade efficiency, industrial development managers and planners should support inventors, leverage technology-based capacities, and promote the commercialization of inventions and innovations.

Author Contributions

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The authors declare no conflict of interest.

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