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Key Success Factors for Export Structure Optimization in East Asian Countries Through Global Value Chain (GVC) Reorganization

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Abstract: Global value chains (GVCs) play a pivotal role in advancing export structure optimization in East Asia. As GVCs restructure and digital technology rapidly progresses, effectively leveraging these chains for export competitiveness has become essential. However, research has rarely examined the key factors in GVC restructuring or explored how innovation, policy frameworks, and market access contribute to export optimization. To address these research gaps, this study systematically identifies key success factors for promoting export optimization in East Asian countries under GVC restructuring, based on global value chain theory, resource-based theory, and innovation diffusion theory. Through a literature review and expert interviews, 14 pivotal factors were analyzed using DEMATEL (Decision Making Trial and Evaluation Laboratory), ISM (Interpretive Structural Modeling), and MICMAC (Cross-Impact Matrix Multiplication Applied to Classification) methods. Findings show that strengthening innovation capabilities, facilitating technology spillovers, investing in cross-border e-commerce, and improving market access policies are crucial drivers of export optimization. Policies that enhance market access, promote international standards, and support investments in digital platforms demonstrate strong influence within the GVC system. Collectively, these factors elevate East Asia's position and competitiveness within GVCs. This study contributes to the theoretical framework on GVC restructuring and export optimization, offering insights into resource-based and innovation diffusion strategies and practical guidance for export policy development.

Keywords: global value chain (GVC); export structure optimization; East Asian countries; trade; DEMATEL-ISM-MICMAC

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Academic Editor: Wen-Chyuan Chiang

Received: 14 November 2024
Revised: 1 December 2024
Accepted: 3 December 2024
Published: 2 January 2025

Citation: Pei, R.; Su, Z. Key Success Factors for Export Structure Optimization in East Asian Countries Through Global Value Chain (GVC) Reorganization. *Systems* **2025**, *13*, 22. https://doi.org/10.3390/systems13010022

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1. Introduction

In the context of accelerating globalization and the increasingly intricate international division of labor, the GVC has become a critical mechanism driving economic growth and enhancing national competitiveness [1,2]. Through GVC participation, countries and enterprises can integrate global resources, technologies, and markets across geographical boundaries, optimizing resource allocation and enhancing production efficiency [3,4]. East Asian countries, in particular, have gained a competitive edge in the global production and trade system, leveraging GVC participation to achieve remarkable export competitiveness [5,6]. By advancing production efficiency and technological capabilities, these countries have solidified their roles within the global supply chain and contributed to regional economic integration [7–10]. However, with ongoing shifts in the global economy and the accelerated pace of digital transformation, GVCs face profound structural

changes. As international trade evolves, countries are increasingly prioritizing supply chain resilience, security, and sustainability, making GVC restructuring a central focus for policymakers and corporate strategy planners [8].

Given this context, effectively leveraging the new opportunities provided by GVC restructuring to optimize the export structure of East Asian countries has become a core focus in both policy and academic circles. This process not only entails optimizing production efficiency and market layout but also requires companies to dynamically adjust to changing market demands. In this paper, export structure optimization refers to improving a country's export composition through GVC restructuring, technological innovation, cross-border e-commerce, and market access policies to boost. Historically, East Asian countries have functioned as the "world's factory" within the global supply chain, focusing primarily on labor-intensive manufacturing and assembly for global markets. In this "factory economy" model, countries specialized in mass production, cost efficiency, and serving as the backbone of global manufacturing networks [11]. In contrast, a "headquarters economy" emphasizes high-value-added activities such as research and development, innovation, product design, and strategic management. Countries transitioning to headquarters economies move beyond just manufacturing to become centers of innovation and global business leadership, driving technological advancements, intellectual property development, and strategic market positioning [7,12]. With the rapid development of digitalization and technological innovation, these countries must upgrade their export structure through value-added, innovation, and technology spillover effects, so as to transform into "world innovation centers" [13]. Ref. [12] emphasizes that while digitalization can enhance performance, it is not a guaranteed outcome and must be carefully managed to avoid exacerbating existing economic disparities. Ref. [14] further argues that factory economies encounter significant barriers in pursuing innovation-driven upgrades, primarily due to the lack of institutional support and infrastructure necessary to foster startups and integrate into global, technology-driven GVCs. In contrast, East Asian countries are presented with multiple opportunities for transformation and upgrading as they strive to achieve these goals. Rapid global market shifts, changing consumer preferences, and ongoing technological advances impose considerable pressure for adjustment. Moreover, the rise of digital trade platforms, cross-border e-commerce, and the internet of things presents new avenues for export optimization. However, sustaining competitiveness in this increasingly technology-driven environment remains a critical area of concern that demands further exploration [15]. These digital advancements offer East Asian countries significant potential for innovation-led export growth, but they also introduce new risks and uncertainties. In particular, cross-border e-commerce has expanded market reach, enabling diverse export models. By leveraging digital technologies, companies can more flexibly respond to global demand fluctuations, thereby achieving more efficient supply chain management and faster market responsiveness [16].

Against the backdrop of a reshaping global economy and rapid digital transformation, GVCs are undergoing significant change. As a central region in the global production network, East Asian countries have gained notable export competitiveness through GVC participation [5]. However, with swift shifts in global market demand and technology, these countries must seize new opportunities within GVC restructuring. Both current policy and academic research focus on how to leverage GVC restructuring to optimize export structures and sustain East Asia's competitive edge in global markets [11]. While existing research has investigated the impact of GVCs on export structures, many studies are limited to a single dimension, such as aggregate volume or industry chain upgrading, and lack systematic analysis of key success factors [17]. Specifically, the roles of innovation, technology spillovers, and policy support have yet to be clearly defined, especially regard-

ing how East Asian countries can strategically leverage these factors to adapt to dynamic markets in the context of GVC restructuring [3,18]. First, while the influence of GVCs on national and regional export performance has been noted, there is insufficient deep analysis on the role of innovation. Second, the current literature often focuses on trade policies and market demand adjustments but lacks a comprehensive examination of systematic impacts, such as technology spillovers within GVCs [5,11,15,17,19]. Additionally, research on digital technology applications in GVCs is limited, with few studies identifying key success factors for emerging technologies like IoT and e-commerce in export management [12,14,20,21]. Therefore, it is essential to conduct a thorough investigation into the systematic impact of GVC restructuring on export structure optimization in East Asia from a multidimensional perspective. This approach will not only provide strategic guidance for policy development but also establish a foundation for future academic research, enabling East Asian countries to strengthen their competitive positions in the global market.

To address these research gaps, this study systematically identifies key success factors for promoting export optimization in East Asian countries under GVC restructuring, based on global value chain theory, resource-based theory, and innovation diffusion theory. Through a comprehensive literature review and expert interviews, we screened 14 key factors, which were analyzed using the DEMATEL-ISM-MICMAC integrated approach for both qualitative and quantitative assessment. The study reveals that enhancing innovation capacity, technology spillover effects, investing in and developing cross-border e-commerce and digital trade platforms, and strengthening market access policies and trade process optimization are core factors driving export structure optimization in East Asia. The combined effect of these factors provides substantial support for increasing export competitiveness within the context of GVC restructuring.

Theoretically, this study enriches the research framework on GVC restructuring and export structure optimization while also deepening the application of resource-based and innovation diffusion theories in export strategy. From a managerial perspective, the study offers decision-making insights for East Asian countries in crafting export policies that support GVC restructuring, helping governments and businesses prioritize areas like technological innovation, digital trade platform development, and market access policy optimization. These findings are not only practically relevant to the East Asian region but also offer valuable insights for other emerging market economies aiming to optimize their export structures within the GVC framework.

The remainder of this paper is structured as follows: Section 2 presents the literature review; Section 3 outlines the DEMATEL-ISM-MICMAC integrated approach; Section 4 presents the research findings; and Section 5 provides conclusions and discussion, including study limitations and future research directions.

2. Literature Review

In this section, we provide a comprehensive overview of existing research and theoretical perspectives relevant to GVC restructuring and export structure optimization. The discussion is structured into two parts: a review of existing studies and an exploration of the key success factors for export structure optimization in East Asian countries. By bridging theoretical insights with practical applications, this literature review lays the foundation for the analytical framework developed in this study.

2.1. Existing Research in the Field of GVC and Export Structure Optimization

Research on GVC reorganization has grown rapidly in recent years, primarily focusing on three main areas. First, many scholars have explored how GVC participation impacts national and regional export performance, particularly in enhancing export structure

diversity and adding value to exports [1,22,23]. For instance, ref. [22,23] emphasizes that GVCs provide a platform for countries and firms to improve product complexity and enhance national export competitiveness, particularly in East Asia. Ref. [24] highlighted that, although COVID-19 caused substantial short-term disruption to GVCs, it is unlikely to be the primary driver of long-term GVC evolution, with future restructuring more likely driven by strategic considerations. This study discusses the potential obstacles companies may face when reassessing location and control decisions within their value chains, suggesting that governance adjustments are essential for enhancing GVC resilience. However, most of these studies emphasize the direct effects of GVC participation on export performance, with limited exploration of deeper mechanisms such as the roles of technology spillovers and innovation in export optimization [18,20]. Ref. [17] argues that multinational firms' global risk management capabilities enhance their resilience and overall operational performance. That study, based on a resource-based view (RBV) and dynamic capabilities view (DCV), demonstrates that strengthening global risk management enables multinational firms to respond effectively to external shocks, improving operational outcomes and competitive advantage during crises.

Second, research on the export structure evolution in East Asian countries has mainly focused on the impact of macroeconomic factors, such as policy adjustments and market demand changes. Ref. [25] examined the role of different trade policies in transforming East Asian countries' export structures, noting that optimized market access policies help diversify export product categories. However, these studies often lack a systematic GVC perspective, especially concerning how technological innovation and diffusion effects can drive East Asia's export structure toward higher value-added segments [1,21]. Additionally, the existing literature on export structure evolution often emphasizes traditional trade policies, without fully integrating the systematic factors within GVCs.

Third, with the rise of digital technology, research increasingly examines digitalization's role in GVCs and its impact on export management [12,26]. The application of digital technology, such as cross-border e-commerce platforms and the Internet of Things (IoT), has facilitated easier coordination within GVCs, optimizing resource allocation [27]. Ref. [28] proposed an integrated framework for global strategy and GVC research, focusing on cross-border management, network optimization, underlying upgrades, and strategic co-evolution, highlighting the interplay between dynamic business strategies and GVC governance. This integrated perspective helps businesses and policymakers formulate strategies to respond to external disruptions such as digitalization and pandemics [16]. For example, ref. [29] explored the impact of cross-border e-commerce on export structure optimization, finding that it significantly improves market access for small and medium-sized enterprises (SMEs). However, most studies focus on the short-term benefits of digital technology for export efficiency, with limited identification of key long-term success factors. Particularly, further analysis is needed on how East Asian countries can utilize digital platforms to enhance export structure optimization within the context of GVC restructuring. Additionally, research evaluating the implementation of digital technologies rarely examines the synergies between different technologies, such as the integration of cross-border e-commerce with traditional trade processes [6,13]. Therefore, while research on GVC reorganization and East Asian export structure optimization has made significant progress, most studies examine the GVC-export structure relationship from a single perspective, lacking a systematic analysis of the key success factors driving export structure optimization in East Asia. Thus, this research aims to analyze the mechanisms for achieving export structure optimization under GVC reorganization from a multidimensional perspective.

2.2. Key Success Factors for Export Structure Optimization in East Asian Countries Under GVC Reorganization

In the context of GVC reorganization, global value chain theory, resource-based theory, and innovation diffusion theory each offer unique analytical perspectives on value addition, resource allocation, and institutional innovation. The integration of these theories provides a solid foundation for systematic research into export structure optimization in East Asian countries. These theories were chosen for their relevance in explaining how East Asian countries can position, adapt, and enhance export structures in dynamic global markets. By focusing on high-value segments of the value chain, resource integration capabilities, and institutional diffusion support, these theories provide clear strategic guidance for East Asian countries navigating the complexities of GVC restructuring [3,5].

First, global value chain theory is foundational in analyzing export structure optimization due to its systematic approach to international division of labor and value addition [3,30]. In GVC reorganization, the ability of East Asian countries to move up the value chain depends on indigenous innovation and technology spillovers. GVC theory reveals how East Asian countries can upgrade from low-cost processing centers to high-end manufacturing and R&D design hubs by controlling critical technologies and enhancing high value-added production stages. The theory dissects complex global production activities into various levels, providing East Asian countries with a framework to identify value addition points in global markets [7]. It underscores not only the importance of improving product technological content and innovation but also how integrating high-value-added segments can secure a lasting competitive advantage in international markets [7].

Second, the resource-based theory emphasizes the uniqueness of resources and resource integration capabilities, offering a core approach for enhancing competitive advantages in East Asia's export structure [31,32]. According to resource-based theory, competitive advantage arises from unique, hard-to-imitate resources, particularly those that can be effectively integrated within digital trade platforms [33]. By leveraging digital trade platforms, East Asian firms have achieved efficient resource allocation, significantly improving supply chain flexibility and market responsiveness while reducing cross-border transaction costs [34]. This theory supports East Asian firms in adapting quickly to changing market demands in complex GVCs, highlighting the critical role of digital technology in resource integration [34]. Resource-based theory thus provides a basis for international expansion and emphasizes unique resource configurations, enabling East Asian countries to sustain adaptability and optimized resource allocation in global competition [31].

Innovation diffusion theory introduces the key role of institutional and policy support in promoting innovation, complementing the analytical frameworks of GVC and resource-based theories. Innovation diffusion theory posits that innovation is driven by both technological and institutional factors, with stable policy and institutional support needed for its dissemination and application [35,36]. To optimize export structure in the context of GVC reorganization, East Asian countries must reduce cross-border trade barriers, simplify market access, and promote green supply chain standards for exports [37]. Innovation diffusion theory provides a framework for understanding how policy can facilitate innovation, enabling East Asian countries to rapidly introduce new technologies and high-value products into international markets [36,38]. Given the rising global standards for environmental and quality requirements, this theory guides East Asian countries in creating favorable policy environments to enhance international market access [36–38]. Global value chain theory, resource-based theory, and innovation diffusion theory collectively offer a comprehensive, multi-layered framework for export structure optimization in East Asian countries amid GVC reorganization. Together, they establish a systematic path for achieving export structure optimization, high-end industry positioning,

and technology-driven innovation diffusion, making the complexity of this process clearer within an academic framework.

3. Research Methodology

3.1. Research Process

Figure 1 illustrates the overall research process of this study, followed by a detailed breakdown of the integrated DEMATEL-ISM-MICMAC approach.

In the initial phase of this study, we conducted an extensive literature search and expert evaluation to identify critical success factors for optimizing the export structure of East Asian countries within the context of GVC restructuring. Databases such as Google Scholar, Web of Science, and SCOPUS were utilized to pinpoint 14 key success factors driving export structure optimization in this GVC restructuring context. To validate these factors, we conducted interviews with two experts who each have over sixteen years of experience in international trade and export management. Additionally, a comprehensive literature review was performed, examining global standards, regional policies, and regulatory guidelines impacting GVC restructuring and export optimization in East Asia. These assessments clarified the primary success factors promoting export structure optimization in the framework of the GVC (Table 1). Moreover, theoretical foundations such as Global Value Chain Theory, Resource-Based Theory, and Diffusion of Innovation Theory underpinned the identification and application of these critical success factors.

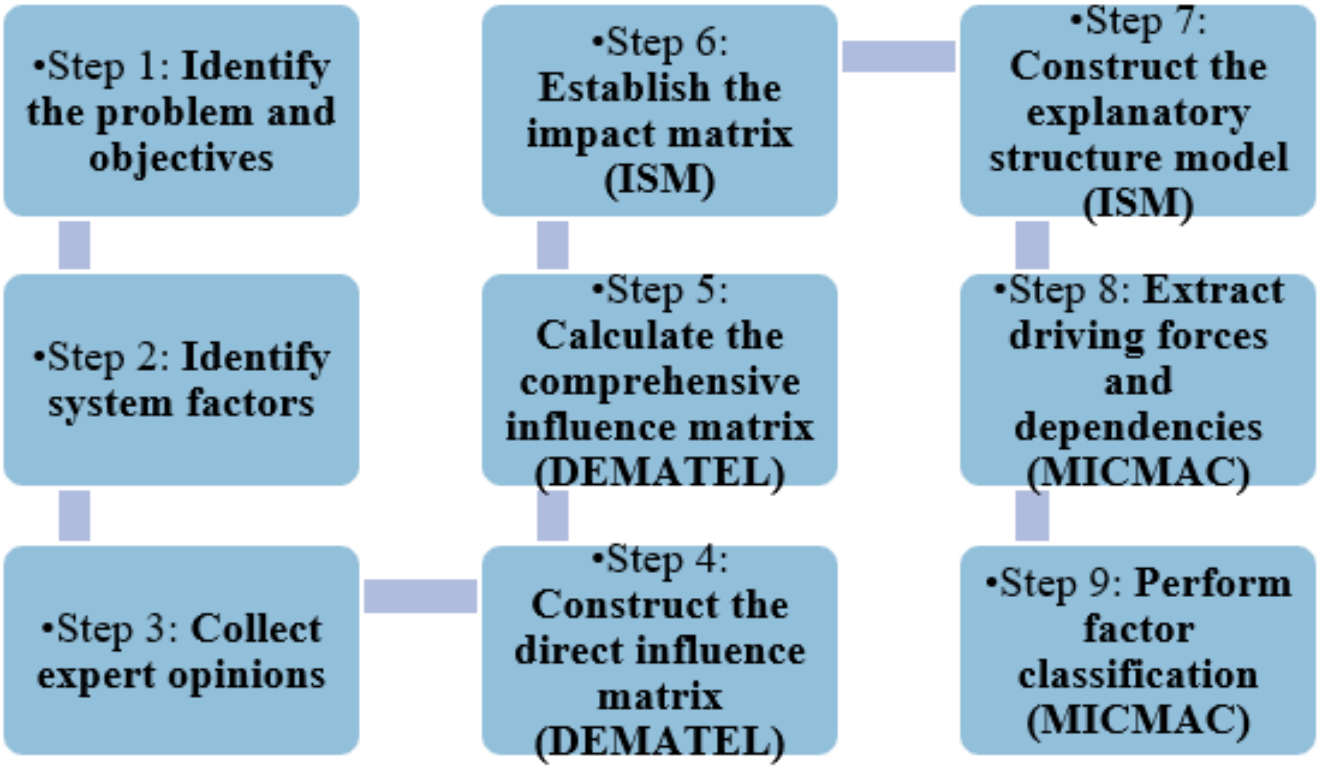


Figure 1. Overview of the research process.

In the second phase of the study, we contacted over 100 institutions from China, South Korea, and Japan involved in foreign trade, imports and exports, and related industries. From this group, 37 potential partners were identified. After introducing the study via email, we received positive responses from 11 institutions. Due to scheduling constraints, three experts were unable to participate, leaving a total of eight experts with over eight years of industry experience (Table 2). The selection criteria for the experts included more

than eight years of industry experience, with a preference for experts who are professors, researchers, or senior executives in companies. These experts possess not only extensive industry experience but also a strong academic background. The data collection period spanned from 6 May to 23 August 2024, and primarily involved email communication and online survey questionnaires. A mixed-method approach was employed, combining online surveys with telephone/video interviews to ensure the comprehensiveness and depth of the data. During the data collection process, we initially distributed the survey questionnaires to the experts via email, allowing them to complete the surveys according to their own schedules. Ultimately, all eight experts completed the questionnaires. To gain further insights from the experts, we conducted a total of five telephone or video interviews with three of the experts. The remaining five experts completed the surveys through email or online platforms. Although face-to-face interviews were initially considered, given the experts' schedules and geographical differences, email and online surveys were deemed the most effective and practical methods. The telephone/video interviews provided qualitative insights that complemented the quantitative data from the surveys, thereby enhancing the depth and correlation of the collected data. Thus, this study utilized a combination of online surveys distributed via email and telephone/video interviews, ensuring the breadth, flexibility, and depth of the data collection process.

Table 1. Critical success factors.

Code	CSF	Definition	Global Value Chain Theory	Resource-Based Theory	Innovation and Diffusion Theory	Source
C1	Enhancing independent innovation capabilities and technology spillover effects	Supporting domestic enterprises in mastering core technologies through R&D support and innovation policies can reduce dependency on external technologies and foster technology spillover effects. This approach allows East Asian countries to gain greater autonomy and competitiveness within the GVC.	√	√	√	[1–3,5–8,12,13,15,16,18–23,25–27,29,32–42]
C2	Deepening the integration of digital and intelligent manufacturing technologies	By leveraging IoT, big data, and artificial intelligence, manufacturing transformation can be accelerated, boosting levels of intelligent manufacturing. Digitalization makes supply chains more agile, enabling real-time responses to global market demand shifts, which is particularly suited for dynamic sectors like electronics and machinery manufacturing.	√	√	√	
C3	Promoting value-added production and upstream extension in the production process	Investing in high-value-added activities such as intermediate goods production and component manufacturing facilitates the shift from basic processing and assembly toward upstream R&D and design. This value-adding progression not only increases export profitability but also positions East Asia higher within the GVC.	√			
C4	Strengthening regional economic co-operation and market integration	The implementation of regional free trade agreements (FTAs) and the Regional Comprehensive Economic Partnership (RCEP) enhances policy coordination with key trade partners, eliminates trade barriers, and optimizes resource allocation within the region, thereby increasing multinational investment appeal in East Asia.	√			
C5	Facilitating human capital accumulation and fostering a highly skilled workforce	Governments and enterprises should prioritize vocational training and re-education to develop a skilled workforce supporting advanced manufacturing. This approach enhances the technological content of East Asian exports, improves production efficiency, reduces innovation costs, and accelerates industrial structural transformation.		√		

Table 1. *Cont.*

Code	CSF	Definition	Global Value Chain Theory	Resource-Based Theory	Innovation and Diffusion Theory	Source
C6	Increasing R&D investment to cultivate an ecosystem of innovative enterprises	Encouraging enterprises to invest in both fundamental and applied research, particularly in advanced manufacturing and high-tech fields, fosters a robust innovation ecosystem conducive to the emergence of new and high-value industries. This enhances the competitiveness of East Asian exports by endowing them with distinctive competitive advantages.		√	√	[1–3,5–8,12,13,15,16,18–23,25–27,29,32–42]
C7	Improving infrastructure and regional logistics networks	Infrastructure enhancement is crucial for supporting GVC restructuring. East Asian countries should improve ports, railways, and smart warehousing to build an integrated regional logistics network, reduce transport time and costs, and enhance responsiveness to international markets.	√	√		
C8	Strengthening supply chain resilience and diversified risk management	To mitigate the risks associated with global supply chain disruptions, East Asian countries must diversify supply chains by developing alternative supply sources to ensure production chain stability. This adaptability strengthens East Asia's GVC position and makes it an attractive location for multinational production facilities.	√	√		
C9	Advancing green transformation and environmental sustainability	Developing environmental regulations and incentive policies, along with promoting clean energy and low-carbon production technologies, aligns with global market environmental standards and enhances the brand value of exports, facilitating entry into higher-end markets.	√	√	√	
C10	Focusing on the international layout of high value-added industrial chains	Through policy guidance and investment, resources should be directed toward high-value industries such as electronics, medical equipment, and precision machinery. Establishing high-value-added industrial chains contributes to export revenue growth and improves the international positioning of regional products.	√	√	√	

Table 1. *Cont.*

Code	CSF	Definition	Global Value Chain Theory	Resource-Based Theory	Innovation and Diffusion Theory	Source
C11	Strengthening market access policies and optimizing cross-border trade processes	Streamlining export processes, simplifying customs procedures, improving clearance efficiency, and reducing trade barriers—particularly in high-value-added segments of the GVC—can significantly lower market entry costs and increase global market participation.	√			[1–3,5–8,12,13,15,16,18–23,25–27,29,32–42]
C12	Investing in and developing cross-border e-commerce and digital trade platforms	East Asian countries should strongly support the development of digital trade platforms, reducing transaction costs and expanding overseas market access channels. Cross-border e-commerce not only diversifies export pathways but also enables rapid responsiveness to global consumer demand.	√	√	√	
C13	Optimizing regulatory and governance structures to align with international standards	Through legislative reforms and governance improvements, East Asian countries must ensure compliance with international standards for quality, safety, and environmental requirements, thereby enhancing product access to international markets and minimizing losses due to non-compliance.	√	√	√	
C14	Promoting alignment with international standards and certification for enterprises	To compete in high-end markets, East Asian enterprises must accelerate alignment with international standards such as ISO and CE, undergoing systematic certification training and upgrades. Certification not only facilitates market access but also symbolizes product quality assurance and builds market trust.	√		√	

Table 2. Expert demographics.

Profile Information	Number of Respondents	Percentage (%)
Gender		
Male	5	62.5
Female	3	37.5
Years of Experience		
8–10 years	3	37.5
11–15 years	3	37.5
16+ years	2	25
Industry Type		
Import and export companies	3	37.5
Trade-related institutions	3	37.5
Logistics service providers	2	25
Position		
Senior Management	4	50
Middle Management	1	12.5
Technical/Operational Roles	3	37.5
N = 8		

This study collected expert opinions through emails, interviews, and surveys. Initially, we used a matrix-filling approach, but experts reported difficulties in matching factor codes with their names. To improve usability, we adopted a Likert-scale-based questionnaire [43,44] that provided detailed descriptions of the concepts, simplifying the completion process. Data from only one expert are presented in this paper (Table 3).

Table 3. Original measurement table of one expert.

CSF	C1	C2	C3	C4	C5	C6	C7	C8	C9	C10	C11	C12	C13	C14
C1	0	4	4	4	4	3	4	0	3	3	4	0	0	0
C2	4	0	1	1	3	2	1	3	4	4	3	3	1	0
C3	2	0	0	0	3	4	4	0	4	2	4	2	1	0
C4	1	1	1	0	4	4	1	0	4	4	4	4	0	1
C5	4	4	4	3	0	4	3	4	3	3	4	4	2	4
C6	3	2	2	3	4	0	3	4	4	4	3	2	2	3
C7	4	3	4	2	4	3	0	3	3	4	4	2	2	4
C8	3	2	2	3	3	4	3	0	4	4	3	2	2	3
C9	4	3	2	4	4	4	3	4	0	4	3	3	2	3
C10	4	3	3	4	4	4	4	4	4	0	3	3	2	3
C11	4	3	4	3	4	3	4	3	4	4	0	3	2	4
C12	2	1	2	3	2	3	3	2	3	3	4	0	2	4
C13	3	2	2	3	4	4	3	3	4	4	3	3	0	2
C14	4	4	4	3	3	3	4	3	4	3	4	4	3	0

In the third phase of this study, we applied the DEMATEL-ISM-MICMAC integrated approach to conduct an in-depth structural analysis of the critical success factors driving

export structure optimization in East Asian countries through GVC restructuring. Although various quantitative models, such as ANP, AHP, Fuzzy DEMATEL, and SEM could be used to evaluate these factors (Table 4), the DEMATEL-ISM-MICMAC approach demonstrated unique advantages, particularly in analyzing complex systems with uncertain information.

Table 4. Comparison of DEMATEL-ISM-MICMAC integrated method with traditional methods.

Method	Application Area	Advantages	Disadvantages	Computational Complexity	Applicability
DEMATEL-ISM-MICMAC	Causal relationship analysis and hierarchical structure modeling in complex systems	Capable of identifying causal relationships, constructing hierarchical models, and classifying driving and dependent factors	High computational complexity, requires domain-specific knowledge for application	High	Complex systems, decision support, and factor analysis
ANP (Analytic Network Process)	Priority and dependency analysis in networked decision-making problems	Suitable for interdependent decision elements, able to handle complex networked relationships	Computationally complex, requiring extensive judgment matrix construction and consistency verification	High	Complex decision-making and networked issues
AHP (Analytic Hierarchy Process)	Factor weight allocation in multi-level decision-making problems	Simple and intuitive, ideal for decision problems with a clear hierarchical structure	Assumes independence among decision factors, not suitable for handling complex interdependencies	Medium	Multi-level decision-making
Fuzzy DEMATEL	Causal relationship analysis under uncertainty in complex systems	Able to process fuzzy information and uncertainty, particularly suited for causal analysis under uncertain conditions	Relies on fuzzy mathematical methods, which may introduce subjectivity	High	Uncertainty decision systems
Structural Equation Modeling (SEM)	Causal relationship and pathway analysis among factors	Suitable for verifying causal pathways and model fit among factors	High requirements for model assumptions, applicability limited by data quality	Medium	Causal relationship verification

Note: C represents Critical Success Factors (CSFs).

Firstly, DEMATEL reduces the need for extensive parameter estimation and large statistical datasets when handling complex systems. This method, grounded in graph theory and matrix analysis, utilizes expert insights to examine causal relationships within complex systems, thereby identifying strategic and critical factors through hierarchical structuring [43,45]. By numerically assessing relationships, DEMATEL builds a structural model of the system, showcasing its exceptional structural modeling capability. Building on DEMATEL analysis, the ISM method further enhances understanding of hierarchical relationships among elements. ISM is a progressive structural analysis approach that transforms the direct relationship matrix of a complex system into a directed graph to construct a multi-level system structure. This method clarifies dependencies and influence pathways among elements, making it especially effective for strategic issue analysis [46]. Through ISM, factors can be organized by their degree of influence and dependency, aiding decision-makers in prioritizing key, driving elements to optimize strategic planning.

MICMAC further amplifies the advantages of this integrated approach. By analyzing the direct influence matrix, MICMAC identifies the driving power and dependency of elements within the system, helping to clarify each element's role within the overall structure. MICMAC's categorization facilitates differentiated management strategies by

decision-makers based on factor types and highlights highly influential elements, thereby delineating pathways for system optimization [47].

Overall, the DEMATEL-ISM-MICMAC integrated method excels in its multi-layered, multi-dimensional analytical capabilities for complex systems [46]. DEMATEL offers a quantitative understanding of causal relationships, reducing data and parameter dependency, making it especially useful in information-scarce scenarios. ISM then reveals systemic influences among elements by building a hierarchical structure, providing decision-makers with a clear strategic roadmap. Finally, MICMAC refines the analysis of driving power and dependency, identifying the most impactful elements within the system. This integrated method not only deepens complex system analysis but also provides theoretical support and practical guidance for leveraging digital technologies to promote zero-carbon transition in Korean ports.

3.2. DEMATEL-ISM-MICMAC Integrated Method Overall Calculation Steps

Direct Influence Matrix. Using expert scoring, the influence of x_i on x_j is compared, with no self-influence (the diagonal is zero). The direct influence matrix A is obtained.

$$A = \begin{bmatrix} 0 & x_{12} & \cdots & x_{1n} \\ x_{21} & 0 & \cdots & x_{2n} \\ \vdots & \vdots & \ddots & \vdots \\ x_{n1} & x_{n2} & \cdots & 0 \end{bmatrix}$$

Normalized Influence Matrix. There are various methods for normalization; here, the row maximum method is used. The sum of each row of matrix A is calculated, and the maximum value is taken. All elements of matrix A are then divided by this maximum value to obtain the normalized influence matrix B.

$$B = \frac{x_{ij}}{\max\left(\sum_{j=1}^{n} x_{ij}\right)}$$

Total Influence Matrix. The Total Influence Matrix represents the combined direct and indirect effects of all elements within a system, showing the overall influence relationships between them.

$$T = \left(B + B^2 + \cdots + B^k\right) = \sum_{k=1}^{\infty} B^k = B(I - B)^{-1}$$

In the formula, I represents the identity matrix.

Calculate the influence, influenced, centrality, cause, and weight of each element.

The influence refers to the sum of each row in matrix T, representing the overall influence of each element on all other elements. It is denoted as D_i.

$$D_i = \sum_{j=1}^{n} x_{ij}, (i = 1, 2, \ldots, n)$$

The influenced degree refers to the sum of each column in matrix T, representing the overall influence each element receives from all other elements. It is denoted as C_i.

$$C_i = \sum_{j=1}^{n} x_{ji}, (i = 1, 2, \ldots, n)$$

Centrality indicates the position and significance of a factor within the evaluation system. The centrality of an element is the sum of its influence degree and influenced degree, denoted as M_i.

$$M_i = D_i + C_i$$

Causality (or cause degree) is obtained by subtracting the influenced degree from the influence degree of an element, denoted as R_i.

$$M_i = D_i + C_i$$

By normalizing the centrality, the weight of the indicator can be obtained.

Draw the Causal Diagram. Plot the centrality on the horizontal axis and the causality on the vertical axis to create the causal relationship diagram.

Calculate the Reachability Matrix. The overall influence matrix $H = T + I$, where T is the total influence matrix and I is the identity matrix. In matrix H, values smaller than the threshold λ are set to 0, and others are set to 1, resulting in the reachability matrix F.

$$h_{ij} = \begin{cases} 1 & h_{ij} \geq \lambda (i, j = 1, 2, \ldots, n) \\ 0 & h_{ij} < \lambda (i, j = 1, 2, \ldots, n) \end{cases}$$

where λ is the average value of the total influence matrix.

Calculate the reachability set, antecedent set, and intersection.

The reachability set $R_i = \{f_i | F_{ij} = 1\}$ represents the set of factors that can be reached from the given factor. It includes all factors corresponding to the columns with a value of 1 in each row.

The antecedent set $S_i = \{f_i | F_{ji} = 1\}$ represents the set of factors that can reach the given factor. It includes all factors corresponding to the rows with a value of 1 in each column.

Then, calculate the intersection $R_i \cap S_i$.

Factor Layering.

When a factor a_i satisfies $R(a_i) = R(a_i) \cap S(a_i)$, it indicates that a_i is the top-level factor. Remove the row and column corresponding to factor a_i in the reachability matrix M, recalculate the reachability set, antecedent set, and intersection, and continue this process to identify the next level until all factors are classified, forming the final factor hierarchy.

Calculate driving forces and dependencies. Driving forces indicate the degree of influence on other factors and are calculated by summing across the reach matrix. Dependencies indicate the degree of influence by other factors and are calculated by summing down the reach matrix.

Draw a driving force-dependency diagram. Plot a scatter diagram with driving forces as the abscissa and dependencies as the ordinate.

4. Results

4.1. DEMATEL Method Results

Based on the DEMATEL method, the comprehensive influence matrix was computed to capture the interdependencies among the critical success factors (Table 5). This matrix shows the degree to which each factor influences others, with higher values indicating a stronger influence.

Secondly, the results further detail multiple attributes of the 14 factors (C1 to C14), including their influence on other factors, degree of being influenced, centrality, causality, weight, as well as their ranking and classification (as either causal or outcome factors) in the analysis (Table 6).

In the context of GVC restructuring, optimizing the export structure of East Asian countries requires the interplay of multiple factors. Based on the analysis, the top three critical factors identified are enhancing independent innovation capabilities and technology spillover effects (C1), investing in and developing cross-border e-commerce and digital trade platforms (C12), and strengthening market access policies while optimizing cross-border trade processes (C11). These factors play indispensable roles in enhancing export structures, increasing the export of high-value-added products, and bolstering international competitiveness, thereby laying a strong foundation for East Asia's position in the global market.

Table 5. Comprehensive influence matrix (normalized scores of influences).

CSF	C1	C2	C3	C4	C5	C6	C7	C8	C9	C10	C11	C12	C13	C14
C1	0.1948	0.1407	0.2142	0.2105	0.2381	0.2681	0.2423	0.1679	0.1283	0.2326	0.1979	0.1965	0.2367	0.2004
C2	0.2165	0.1038	0.1329	0.1915	0.1080	0.1767	0.2231	0.1617	0.0698	0.1174	0.1503	0.1686	0.1128	0.2128
C3	0.1903	0.1908	0.1092	0.2017	0.2134	0.2376	0.1702	0.1323	0.1314	0.2249	0.1304	0.1455	0.1371	0.2125
C4	0.1365	0.1225	0.0907	0.1210	0.1409	0.1366	0.1399	0.1079	0.0682	0.1754	0.1572	0.1554	0.1681	0.1729
C5	0.2357	0.1743	0.1247	0.2295	0.1021	0.1492	0.1519	0.1401	0.0926	0.1369	0.1491	0.1131	0.1310	0.1681
C6	0.1578	0.0764	0.1200	0.1715	0.1314	0.0918	0.1204	0.0714	0.0809	0.1855	0.0744	0.0820	0.0803	0.1649
C7	0.2123	0.1230	0.1537	0.2289	0.1074	0.1556	0.1225	0.0881	0.0975	0.1481	0.1938	0.1607	0.1844	0.1123
C8	0.1666	0.2093	0.1808	0.2408	0.1065	0.1295	0.2027	0.0954	0.0944	0.1446	0.1253	0.2164	0.1135	0.1719
C9	0.1568	0.0966	0.1749	0.1283	0.0936	0.1943	0.2171	0.1482	0.0727	0.1041	0.1131	0.1086	0.1735	0.2030
C10	0.2429	0.1551	0.1129	0.1670	0.1266	0.1511	0.2334	0.1952	0.1211	0.1118	0.1274	0.1681	0.1136	0.1669
C11	0.3174	0.2315	0.2302	0.2817	0.2591	0.2897	0.2427	0.1922	0.1348	0.2785	0.1419	0.2399	0.2073	0.2294
C12	0.2666	0.2171	0.2368	0.2830	0.2124	0.2441	0.2033	0.2011	0.1276	0.2580	0.1286	0.1509	0.2374	0.1880
C13	0.2552	0.1557	0.1753	0.1999	0.1165	0.2234	0.2445	0.1034	0.1822	0.1609	0.1325	0.2178	0.1277	0.1325
C14	0.2823	0.2029	0.1636	0.2247	0.2080	0.2403	0.2113	0.1407	0.1425	0.1499	0.1701	0.2385	0.2154	0.1462

Note: C represents Critical Success Factors (CSFs). The values in Table 5 represent the influence between CSFs, with higher values indicating stronger interdependencies and greater influence one CSF has on another.

First, enhancing independent innovation capabilities and technology spillover effects (C1) ranks highest, with a weight of 0.08967 and centrality of 5.90031. This factor highlights the sustained drive toward export structure optimization through strengthened technology R&D. Improvements in independent innovation not only advance technological products themselves but also benefit other segments within the value chain through technology spillover effects, increasing overall industry innovation and efficiency. In the GVC, technology innovation and spillover effects serve as powerful means for East Asia to transition toward high-value-added, technology-intensive industries [1,5]. By fostering local R&D, East Asia can further reduce reliance on foreign technology, enhancing the uniqueness and competitiveness of export products and enabling local firms to secure greater bargaining power in international markets [7].

Second, investing in and developing cross-border E-Commerce and digital trade platforms (C12) holds a weight of 0.0808 and a centrality of 5.31675, underscoring the importance of digital trade platforms in enabling East Asian enterprises to swiftly access global markets. The growth of cross-border e-commerce not only reduces traditional trade barriers but also improves trade efficiency, allowing more small and medium-sized enterprises (SMEs) to engage in international trade. This transformation brings diversification to exports and enhances the value of export products. Through digital platforms, East Asian countries can more readily access new international markets and expand their export volume. Additionally, cross-border e-commerce platforms allow exporters to connect directly

with overseas consumers, reducing intermediary costs and enhancing firms' responsiveness to consumer demands [7,12]. In a highly competitive global market, this direct market access offers valuable growth opportunities for East Asian enterprises, enabling them to seize more high-value-added export opportunities.

Table 6. Factor analysis results: impact, centrality, and weighted rankings.

Factor	Degree of Influence	Degree of Being Influenced	Centrality	Causality	Weight	Ranking	Factor Attribute
C1	2.86884	3.03147	5.90031	−0.16263	0.08967	1	Outcome Factor
C2	2.1457	2.19947	4.34517	−0.05377	0.06604	10	Outcome Factor
C3	2.42741	2.21986	4.64727	0.20755	0.07063	8	Causal Factor
C4	1.89311	2.88015	4.77326	−0.98704	0.07254	6	Outcome Factor
C5	2.09824	2.16401	4.26225	−0.06577	0.06478	12	Outcome Factor
C6	1.60869	2.6878	4.29649	−1.07911	0.0653	11	Outcome Factor
C7	2.08818	2.72525	4.81343	−0.63707	0.07315	5	Outcome Factor
C8	2.19775	1.94557	4.14332	0.25218	0.06297	13	Causal Factor
C9	1.98451	1.54387	3.52838	0.44064	0.05362	14	Causal Factor
C10	2.19292	2.4285	4.62142	−0.23558	0.07023	9	Outcome Factor
C11	3.27627	1.99196	5.26823	1.28431	0.08006	3	Causal Factor
C12	2.95487	2.36188	5.31675	0.59299	0.0808	2	Causal Factor
C13	2.42739	2.23876	4.66615	0.18863	0.07091	7	Causal Factor
C14	2.73633	2.48167	5.218	0.25466	0.0793	4	Causal Factor

Note: C represents Critical Success Factors (CSFs).

Third, strengthening market access policies and optimizing cross-border trade processes (C11) holds a weight of 0.08006 and a centrality of 5.26823, indicating the critical role of policy support in export structure optimization. By improving market access policies and simplifying cross-border trade processes, East Asian countries can effectively reduce international trade barriers, offering local enterprises more accessible international pathways. Policy enhancements in market access directly reduce trade costs, enabling firms to control costs while enjoying greater market reach [6,40]. Especially when navigating complex trade policies and regulations across countries, streamlined processes and reduced bureaucratic steps can significantly improve East Asia's export efficiency. Furthermore, policy support can attract greater foreign investment into local markets and encourage local firms to expand globally, further boosting the share of high-value-added export products and enhancing the competitiveness of the export structure [7,13]. The effective implementation of these policies provides vital support for optimizing the export structure of East Asian countries in the global market.

Beyond these top three factors, other factors also contribute significantly to export structure optimization. For instance, deepening the integration of digital and intelligent manufacturing technologies (C2), with a weight of 0.06604 and centrality of 4.34517, enhances production process efficiency and quality, enabling East Asian countries to better meet the dynamic demands of global markets. Promoting value-Added production and

upstream extension (C3), with a weight of 0.07063 and centrality of 4.64727, demonstrates how value-adding production processes can further elevate East Asia's position in the GVC. Improving infrastructure and regional logistics networks (C7), with a weight of 0.07315 and centrality of 4.81343, ensures the smooth flow and efficient transport of exports, which is crucial for timely responses to international market demands. Additionally, advancing green transformation and environmental sustainability (C9) and focusing on high value-added industrial chains (C10) contribute significantly to environmental alignment and high-value product positioning, enhancing East Asia's brand competitiveness in global markets [39].

In summary, enhancing independent innovation capabilities, developing digital trade platforms, and optimizing market access policies constitute the core framework for advancing export structure optimization in East Asian countries. These factors not only directly boost the export share of high-value-added products but also establish a solid foundation for export structure optimization from multiple perspectives, including market access, technology advancement, and digital application. This comprehensive approach ensures that East Asian countries achieve a stronger market position and sustained growth momentum within the restructured GVC [5,17].

Subsequently, a cause–effect diagram was plotted with centrality on the x-axis and causality on the y-axis (Figure 2).

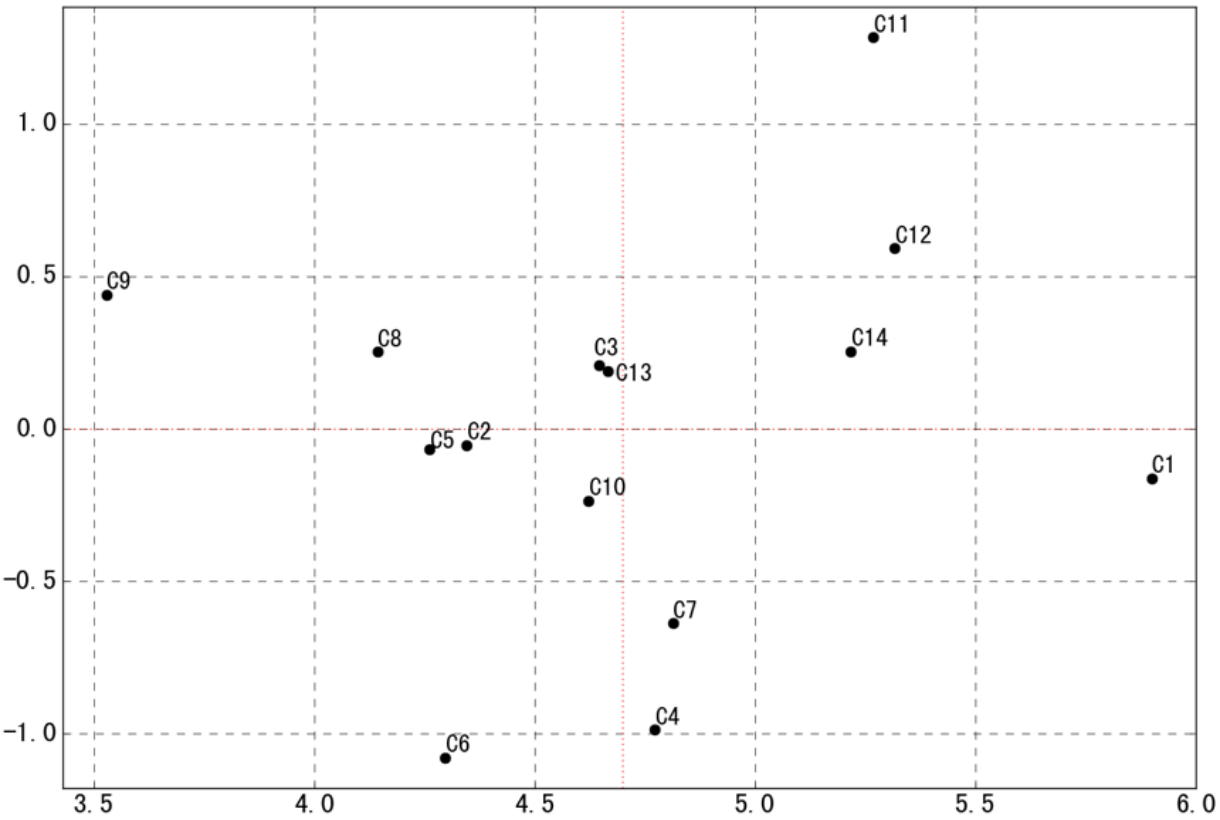


Figure 2. Centrality-cause degree scatter plot.

4.2. ISM

Reachability matrices are used to display direct influence relationships between critical success factors (CSFs). They are a tool used in decision structure analysis to depict the interactions between factors. The value of each matrix indicates whether a CSF (represented in the row) can directly influence another CSF (represented in the column). The construction of such a matrix helps to clearly identify the relationships and interdependencies between

the various critical factors. By analyzing the reachability matrix, it is possible to determine which factors have a proactive or dominant role in the system, thus providing a basis for further influence and dependency analysis. This structured representation provides an intuitive framework for understanding the cause-and-effect relationships and interactions in complex systems and provides critical support for subsequent decision modeling and strategy optimization (Table 7).

Secondly, based on the reachability matrix, the reachability set, antecedent set, and intersection set were established (Table 8).

By analyzing the reachability set, antecedent set, and intersection set, the hierarchical positioning of various factors within the system was determined (Table 9).

In the process of GVC restructuring, the hierarchical classification of factors through the ISM method helps to clarify each factor's role and impact on the optimization of East Asian countries' export structure. Factors at each level perform distinct functions, forming a bottom-up support system that ultimately drives the achievement of top-tier strategic goals. At the foundational level, C4, C6, and C9 serve as foundational factors supporting GVC restructuring. These factors provide sustainable support for the system by promoting regional co-operation, enhancing innovation capacity, and advancing green development. In the context of globalization and value chain restructuring, these foundational factors ensure that adjustments to East Asia's export structure address not only economic but also social and environmental benefits, thereby laying a stable groundwork for higher-level factors [18,22].

In the lower-middle and middle levels, factors increasingly focus on operational aspects. C5, C7, and C8 form the lower-middle level, focusing on establishing robust infrastructure and human resources capable of withstanding supply chain risks. In the middle level, factors such as C1, C2, C10, and C13 play a more direct role. These factors support the optimization of export structure by enhancing innovation capacity, driving technology integration, and aligning regulatory standards to improve the value of East Asian export products.

Table 7. Reachability matrix.

CSF	C1	C2	C3	C4	C5	C6	C7	C8	C9	C10	C11	C12	C13	C14
C1	1	0	0	0	1	1	1	0	0	1	0	0	1	0
C2	0	1	0	0	0	0	1	0	0	0	0	0	0	0
C3	0	0	1	0	0	1	0	0	0	1	0	0	0	0
C4	0	0	0	1	0	0	0	0	0	0	0	0	0	0
C5	1	0	0	1	1	0	0	0	0	0	0	0	0	0
C6	0	0	0	0	0	1	0	0	0	0	0	0	0	0
C7	0	0	0	1	0	0	1	0	0	0	0	0	0	0
C8	0	0	0	1	0	0	0	1	0	0	0	0	0	0
C9	0	0	0	0	0	0	0	0	1	0	0	0	0	0
C10	1	0	0	0	0	0	1	0	0	1	0	0	0	0
C11	1	1	1	1	1	1	1	0	0	1	1	1	0	1
C12	1	0	1	1	0	1	0	0	0	1	0	1	1	0
C13	1	0	0	0	0	1	1	0	0	0	0	0	1	0
C14	1	0	0	1	0	1	0	0	0	0	0	1	0	1

Note: C represents Critical Success Factors (CSFs). Specifically, a value of 1 in the matrix indicates that the CSF in the row has a direct impact on the CSF in the column, while a value of 0 indicates that there is no direct impact between the two.

Table 8. Calculation of reachability set, antecedent set, and intersection set.

CSF	Up to Set $R_i=\{f_i \mid F_{ij}=1\}$	Pre-Set $S_i=\{f_i \mid F_{ji}=1\}$	Intersection $R_i \cap S_i$
C1	1	1, 5, 6, 7, 10, 13	1, 5, 10, 11, 12, 13, 14
C2	2	2, 7	2, 11
C3	3	3, 6, 10	3, 11, 12
C4	4	4	4, 5, 7, 8, 11, 12, 14
C5	5	1, 4, 5	1, 5, 11
C6	6	6	1, 3, 6, 11, 12, 13, 14
C7	7	4, 7	1, 2, 7, 10, 11, 13
C8	8	4, 8	8
C9	9	9	9
C10	10	1, 7, 10	1, 3, 10, 11, 12
C11	11	1, 2, 3, 4, 5, 6, 7, 10, 11, 12, 14	11
C12	12	1, 3, 4, 6, 10, 12, 13	11, 12, 14
C13	13	1, 6, 7, 13	1, 12, 13
C14	14	1, 4, 6, 12, 14	11, 14

Note: C represents Critical Success Factors (CSFs).

Table 9. Key Factors in Hierarchical Classification.

Level	Fcatoors
Top Level	C11
High Level	C14
Mid-High Level	C12
Middle Level	C3
Low-Middle Level	C1, C2, C10, C13
Lower Level	C5, C7, C8
Foundation Level	C4, C6, C9

At the upper-middle and upper levels, factors exhibit stronger driving forces and have significant impacts on the overall strategy for GVC restructuring. C12, an upper-middle-level factor, expands market reach for East Asian export products by developing cross-border e-commerce platforms, greatly enhancing the efficiency of GVC restructuring through digital support. C14, positioned at the upper level, further strengthens the global recognition and competitiveness of East Asian products, enhancing the trust and quality assurance of export goods in high-end markets by aligning with international standards.

At the top level, C11 serves as the core driving force in the entire hierarchy. By optimizing market access policies and streamlining cross-border trade processes, East Asian countries can effectively reduce trade barriers, making it easier for export goods to enter international markets. This top-tier factor plays a leading role in enhancing East Asian countries' export structure, bringing direct market-driven outcomes that leverage the support provided by factors at other levels. Figure 3 illustrates the hierarchical structure of factors under the ISM method.

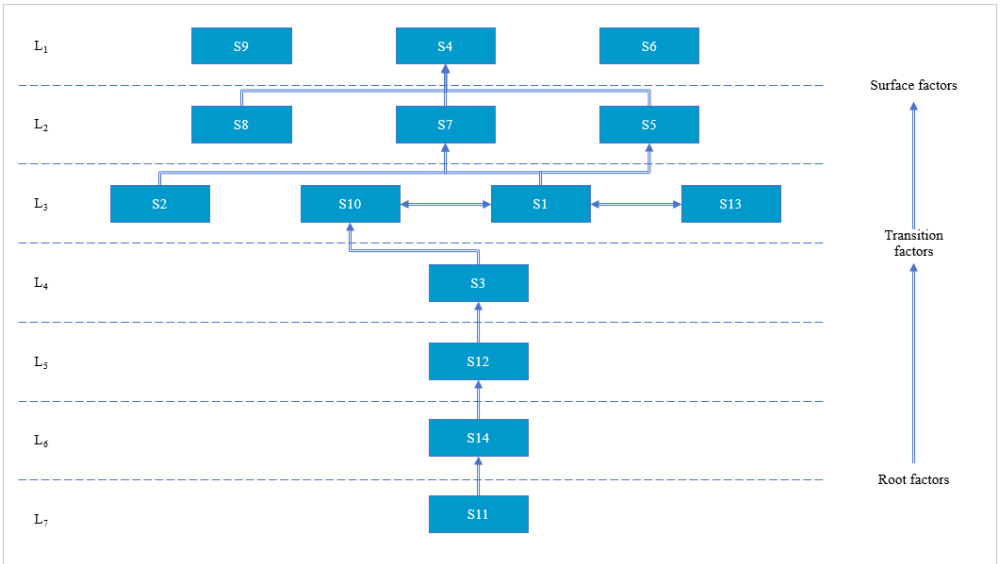


Figure 3. ISM hierarchical structure for export structure optimization in East Asia.

4.3. MICMAC

Firstly, we analyzed the driving power and dependency of the 14 factors (Table 10).

Table 10. Driving power-dependency analysis of key factors.

Factor	Driving Power	Dependency	Driving Power Classification
C1	6	7	Moderate Driving Power
C2	2	2	Low Driving Power
C3	3	3	Low Driving Power
C4	1	7	Low Driving Power
C5	3	3	Low Driving Power
C6	1	7	Low Driving Power
C7	2	6	Low Driving Power
C8	2	1	Low Driving Power
C9	1	1	Low Driving Power
C10	3	5	Low Driving Power
C11	11	1	Very High Driving Power
C12	7	3	High Driving Power
C13	4	3	Moderate Driving Power
C14	5	2	Moderate Driving Power

Note: C represents Critical Success Factors (CSFs).

The results in Table 10 indicate that, among the factors with very high driving power, C11 provides a significant competitive advantage for East Asian exports by improving trade access and simplifying procedures. Efficient market access policies break down trade barriers, enhancing the circulation efficiency and competitiveness of goods in international markets, thereby serving as a critical force in export structure optimization [5]. C12, which exhibits high driving power, has opened new market channels for products from East Asia. These platforms not only expand the market reach of export goods but also support the restructuring of the value chain and the in-depth expansion into international markets through digital means. At the same time, C1 is also a key factor. By strengthening

innovation capacity, East Asian countries drive technological advancement and generate spillover effects, providing technical support to industries within the region and enhancing regional competitiveness.

At the moderate driving power level, C6 has a limited driving force but plays a crucial role in shaping an environment conducive to innovation. Increased R&D investment supports the growth of innovative enterprises, enabling stronger competitiveness within the restructured value chain. C7 also has moderate driving power, providing foundational support for GVC restructuring. A well-developed logistics network reduces export costs and increases the responsiveness of international trade, ensuring material support for the globalization of export goods. C10 enhances the added value of export products, thereby boosting East Asia's competitiveness in global markets.

Low driving power factors play a supportive role in the optimization process. While C2 has limited driving power, it offers long-term value in improving flexibility and production efficiency in manufacturing. C3 aids in extending the industrial chain and increasing production value in East Asia. Additionally, although C4 has a smaller impact, it lays an essential foundation for the smooth implementation of GVC restructuring by reducing regional trade barriers and enhancing economic co-operation within the region [20]. C5, though low in driving power, provides essential support to the economic system. C8 also has low driving power but plays an important role in managing risk associated with dependence on single markets and external shocks. C9 holds a position in GVC restructuring as well; although its short-term effects may be limited, it aligns with global sustainability goals in the long run. Moreover, C13 provides necessary support for compliance and trade facilitation, while C14 enhances the recognition and competitiveness of East Asian exports in the international market.

Based on Table 10, we constructed a driving power-dependency diagram, with driving power on the x-axis and dependency on the y-axis (Figure 4).

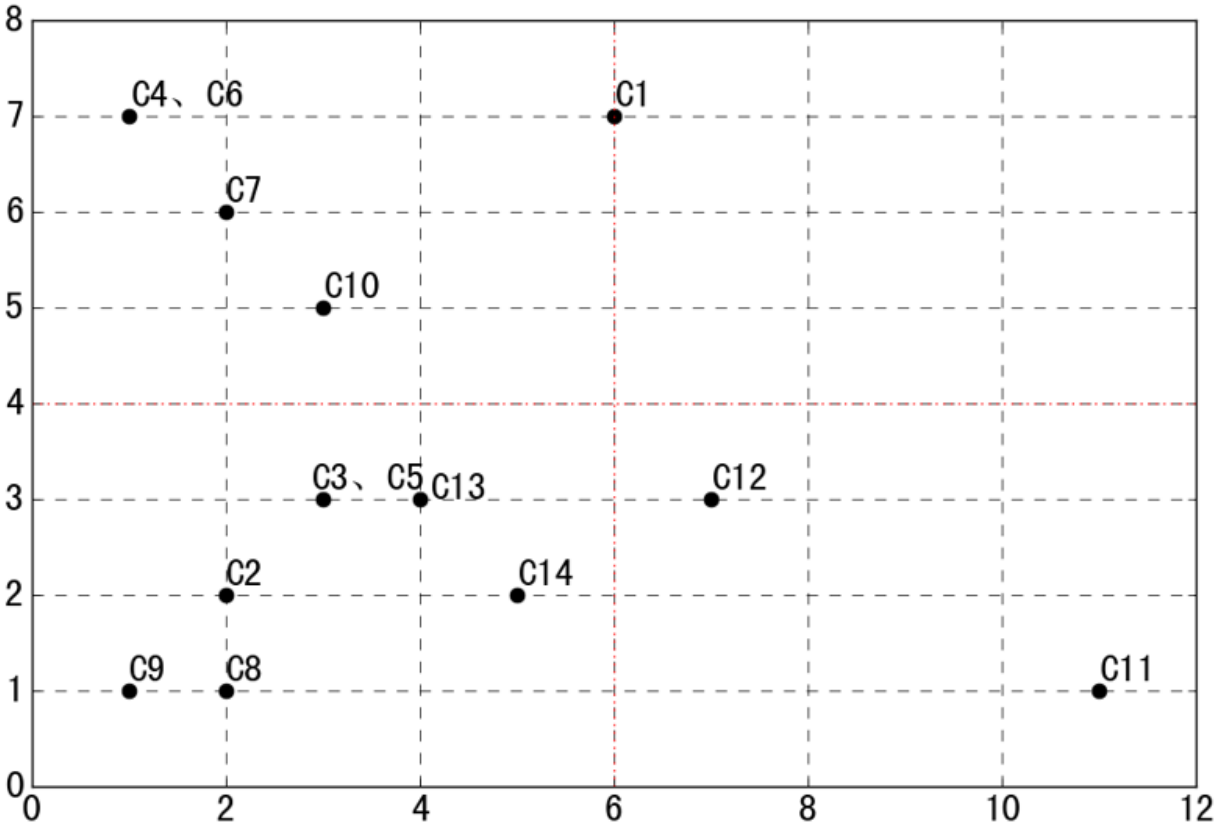


Figure 4. Driving power-dependency diagram of key factors.

Based on the results of the MICMAC analysis, and in conjunction with the theoretical frameworks of GVC theory, the resource based theory, and innovation diffusion theory, this study identifies the key drivers behind the optimization of East Asia's export structure. The driving power-dependency analysis highlights the critical role of C11 (Very High Driving Power) and C12 (High Driving Power) in reshaping the region's global positioning. These factors, through enhancing trade access and expanding market channels via digital platforms, align with GVC theory, which emphasizes reducing trade barriers and fostering deeper market integration. C1 (Moderate Driving Power), with its focus on strengthening innovation capacity, reflects the RBV by demonstrating how technological advancements can bolster regional industries and create a sustainable competitive advantage. Similarly, C7 (Moderate Driving Power), by improving logistics and reducing export costs, plays an essential role in maintaining supply chain efficiency and further enhancing global competitiveness. The findings underscore that while high-driving power factors like C11 and C12 directly influence the integration of East Asia into global markets, moderate-driving factors such as C1 and C7 provide crucial support for long-term export competitiveness and the sustainable growth of the region's export-driven economy (Boschma, 2024).

5. Conclusions and Discussion

With the restructuring of Global Value Chains (GVCs) and advancements in digital technology, optimizing the export structure of East Asian countries has become a crucial pathway to enhancing their global competitiveness. This study explores key success factors for driving export structure optimization in East Asian countries from a strategic perspective. By integrating expert insights and the DEMATEL-ISM-MICMAC approach, we conducted a systematic quantitative and qualitative analysis of 14 critical factors. On this basis, we developed a comprehensive analytical framework that incorporates Global Value Chain Theory, Resource-Based Theory, and Diffusion of Innovation Theory, providing a deep analysis of these factors and their complex interrelationships.

The results indicate that Enhancing Independent Innovation Capabilities and Technology Spillover Effects (C1), Investing in and Developing Cross-Border E-Commerce and Digital Trade Platforms (C12), and Strengthening Market Access Policies and Optimizing Cross-Border Trade Processes (C11) are core factors driving export structure optimization in East Asian countries. Additionally, Strengthening Market Access Policies and Optimizing Cross-Border Trade Processes (C11), Aligning Enterprises with International Standards (C14), and Investing in Cross-Border E-Commerce and Digital Trade Platforms (C12) exhibit strong driving forces within the system. This study aims to provide systematic strategic guidance for policymakers, export firms, and stakeholders in East Asia to optimize export structures and enhance competitiveness within the GVC framework. Furthermore, it offers valuable insights for other emerging economies seeking export optimization amid GVC restructuring.

5.1. Theoretical Implications

This study makes significant theoretical contributions on multiple levels. First, it advances the theory of export structure optimization in the context of GVC restructuring. While existing research discusses the impact of GVCs, most studies focus primarily on trade policy and macroeconomic factors, with limited attention to the deeper mechanisms of export structure optimization through innovation capacity, market access, and digital technology integration. By combining Global Value Chain Theory, Resource-Based Theory, and Diffusion of Innovation Theory, this study identifies and validates key success factors for export structure optimization in East Asia under GVC restructuring, addressing a theoretical gap in this field.

Secondly, this study deepens our understanding of resource allocation and innovation diffusion in GVC restructuring. The findings reveal that technology innovation and digital trade platforms significantly enhance export value and stimulate industry-wide progress through technology spillovers. In contrast to studies by [22,28], which analyzed the positive effects of GVC on East Asian export structure, our study constructs a comprehensive theoretical framework to elucidate the complex relationship between GVC restructuring and export structure optimization. This study also provides theoretical support for policymakers, emphasizing the need to balance technological advancement, resource allocation, and policy support in promoting GVC participation in East Asia, offering a new theoretical perspective for export optimization policy within the GVC context.

5.2. Managerial Applications

To drive export structure optimization in East Asian countries, governments, enterprises, and stakeholders should adopt coordinated management measures to ensure the effective and sustainable application of GVC restructuring and digital technology [12,22]. First, export firms should focus on the dual impact of independent innovation and technology spillover in market strategy planning. Technology innovation not only enhances the value-added of export products but also promotes the overall competitiveness of upstream and downstream industries, fostering regional economic growth [3,24]. Firms should make long-term plans for resource allocation, innovation capacity building, and investment in cross-border e-commerce platforms to secure a sustained competitive advantage. Establishing systematic technology evaluation and feedback mechanisms is also essential to ensure continuous support from technological innovation for export structure optimization.

Secondly, governments play a crucial role in GVC restructuring by providing policy support and institutional innovation, which ensure a favorable environment for corporate innovation and smooth trade processes [25,28]. Governments should create policy frameworks that support innovation and market access, fostering cross-sector and cross-border co-operation to optimize the export management environment. Additionally, governments should encourage digital trade platforms and cross-border e-commerce through financial incentives and international co-operation. Digital collaboration should extend beyond domestic markets to global value chain partners, ensuring East Asia's sustainable competitiveness within the GVC restructuring context [5,25].

For other stakeholders within the supply chain, such as logistics companies and industry associations, digital technology serves as an effective tool for cross-border trade and a critical means of enhancing supply chain transparency and compliance. Logistics companies should invest in intelligent cargo systems, blockchain-enabled logistics tracking systems, and digital operations platforms to achieve more efficient and transparent cross-border trade processes. Furthermore, collaboration with global supply chain partners is essential to ensure the coherence and sustainability of logistics and export processes. Training employees in digital skills and raising environmental awareness are also key to advancing green export structure optimization. Although some factors, such as brand development, financial service support, and intellectual property protection, have lower influence, they provide essential support for export optimization in specific contexts. Through these measures, East Asian countries can maintain continuous export structure optimization and a competitive edge within the restructured global value chain.

5.3. Limitations and Future Research

While this study provides an in-depth analysis of key success factors for export structure optimization in East Asia through the DEMATEL-ISM-MICMAC approach, some limitations remain. First, the data primarily come from expert opinions, which, while

ensuring professional insight, may lack broader applicability. Future research should consider incorporating real trade and international data to validate the generalizability of the results. Secondly, this study focuses on East Asian countries, yet policy environments and technological applications vary widely across regions. Future research should expand to other emerging economies to provide more comprehensive export optimization strategies. Additionally, future studies should explore how to optimize the synergy between GVC restructuring and export structure optimization within a multi-stakeholder collaboration framework, providing systematic solutions for export structure optimization in global emerging markets.

Author Contributions: Methodology, R.P.; Software, R.P.; Validation, R.P. and Z.S.; Formal analysis, Z.S.; Investigation, Z.S.; Resources, R.P.; Data curation, R.P.; Writing—original draft, R.P.; Writing—review & editing, R.P. and Z.S.; Supervision, R.P. and Z.S.; Project administration, R.P. and Z.S.; Funding acquisition, R.P. and Z.S. All authors have read and agreed to the published version of the manuscript.

Funding: This study did not receive external funding.

Data Availability Statement: The article contains some data. If you need complete data, please contact the corresponding author to request it.

Conflicts of Interest: The authors declare no conflict of interest.

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