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Structural modeling of the impact of supply chain complexity on competitiveness performance: A case study of Iran Khodro Company

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Supply chain complexity has emerged as a critical challenge for managers in the 21st-century, posing significant costs and operational difficulties. Despite its importance, limited research has focused on this issue. This study aimed to investigate the impact of supply chain complexity on competitiveness performance within the context of the Iran Khodro Company. To achieve this objective, the study examined the relationship between various sources of complexity (upstream complexity, domestic production, and downstream complexity) and competitiveness performance using a conceptual model. The statistical population for this study comprised all 218 Iran Khodro experts in 2022. Due to limitations in the statistical community, the entire population was selected as the sample. The study utilized two standard questionnaires, which underwent rigorous validation processes including content validity confirmed by experts, construct validity confirmed by confirmatory factor analysis, and reliability confirmed using Cronbach's alpha coefficient and the combined reliability index. Data analysis was conducted using structural equation modeling in the LISREL software. The results of hypothesis testing revealed a significant inverse effect of supply chain complexity on competitiveness performance. Furthermore, the study presented innovative recommendations to offer management insights for addressing the industry's existing challenges, particularly under the conditions of international sanctions.

***Keywords**: Competitiveness Performance, Iran Khodro Company, Supply Chain Complexity*

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1. Introduction

Effective supply chain management has become a critical factor in determining the competitive performance of businesses today. A well-designed and managed supply chain can yield significant benefits and enable organizations to deliver products or services with speed and quality. However, as supply chains grow in complexity, organizations face numerous challenges that can impact their market performance. Factors such as globalization, diversity, flexibility, and evolving customer needs and demands contribute to the increasing complexity of supply chains (Ates et al., [3]). Failure to properly manage these conditions and make decisions without considering their consequences can lead to disruptions (Tsapi et al., [31]), increased costs in the supply chain (Gerschberger et al., [14]), poor customer service (Fianko et al., [12]), and affect organizational performance and productivity, such as system predictability (Pavlov & Micheli, [25]). Experience shows that as the supply chain expands, complexity increases, leading to slower responses to changes, vulnerability, and numerous

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interruptions Managers must be sensitive to these complexities and coordinate the organization's plans, as a superficial view of these issues can result in costly and sometimes irreparable decisions for the organization.

In particular, when managers of organizations face many challenges in solving supply chain complexity factors (Chand et al., [6]), identifying the factors of complexity and solutions to deal with them has become one of the most important concerns. Therefore, reducing or managing complexity should be a strategic goal of the supply chain. In addition, efficient and effective supply chain management requires an understanding of the concept of complexity and how it interacts with other supply chain variables (Piya et al., [27]). Some researchers categorize supply chain complexity into two types: ineffective and strategic. In ineffective complexity, the level of complexity should be minimized to enhance the organization's performance, while strategic complexity refers to the necessary complexity for implementing an organization's strategy. Even to increase operational performance, strategic complexity must be buffered, not reduced. In this category, not only are the costs of complexity reduced, but complexity is also used as a strategic weapon to achieve a sustainable competitive advantage (Aitken et al., [1]). Managing a mission supply chain is challenging. While much attention has been paid to expanding the scope and depth of supply chain activities in companies, only some academic researchers and company managers have recognized the loss caused by the increase in complexity in the supply chain Recent studies show that complexity management in the supply chain is a driver for gaining a competitive advantage (Gružauskas & Burinskienė, [15]; Piya et al., [26]). Therefore, it becomes necessary to thoroughly investigate this matter in practical areas.

The complexity of Iran Khodro's supply chain, a leading player in the Iranian automobile industry, has been a concern for its managers. Both upstream and downstream disruptions have arisen in its supply chain. Upstream complexities can be categorized into three parts: supplier reliability, quality control, and logistics coordination, while downstream complexities encompass the distribution channel, supply and demand inconsistency, and after-sales services. In addition, sanctions have limited Iran Khodro's access to reliable international suppliers of raw materials and parts, leading to delays in procurement and possible disruptions in the production process. Limited access to international suppliers has forced the company to rely on alternative suppliers, making the quality control process more challenging. Additionally, logistical aspects of the supply chain, such as shipping and customs procedures, have become complicated due to increased international controls and restrictions, resulting in additional delays and compliance costs associated with alternative sourcing efforts. On the other hand, Iran Khodro operates within a complex distribution network to deliver cars to customers in various domestic and international markets. Managing logistics, coordinating shipments, and optimizing distribution channels to ensure timely and cost-effective delivery can be challenging. In addition, the company's access to international markets has been limited due to sanctions, affecting its ability to distribute and sell cars abroad, which has reduced the company's access to the market, and created challenges in managing distribution networks and coordination for exports. Additionally, managing after-sales service centers, spare parts availability, and ensuring timely customer support is crucial and challenging in maintaining a positive customer experience. The supply and access of some spare parts from international service networks have been affected by sanctions, making it difficult for the company to provide efficient after-sales service, which can negatively impact customer satisfaction and loyalty.

Accurate demand forecasting, production planning, inventory management, dynamic demand to prevent overproduction or storage, and continuous technical progress provide the necessary platform for the increasingly complex supply chain and company operations. Therefore, this study aims to investigate the impact of different sources of complexity, including upstream, domestic production, and downstream complexity, on the competitiveness of Iran Khodro Company. Understanding the

patterns of complexity and their impact on competitiveness can help solve the problem and provide the basis for the growth and expansion of the industry. The main goal of this study is to investigate the impact of supply chain complexity on the competitiveness of Iran Khodro Company, and the main question is whether the complexity of the supply chain affects the company's competitiveness. The paper is structured as follows: Section 2 discusses the theoretical framework of the research. Section 3 describes the method. The findings and conclusions are presented in Sections 4 and 5, respectively.

1. Literature Review

In today's global landscape, gaining competitive advantage has become a fundamental challenge for countries on the international stage (Fosso Wamba et al., [13]). Meeting customer needs, continuously reviewing their preferences, being responsive and innovative, delivering high-quality products, and providing excellent service are essential aspects of a company's capabilities. This underscores the strong need for collaboration among companies and organizations involved in the production of a specific product, as well as the integration and coordination between them in the competitive market environment. Thus, The supply chain encompasses all activities related to the flow and transfer of goods from the raw material stage to the consumption of the final product by the consumer (Dehghan Khalilabad & Aref, [8]). Integrated supply chain management encompasses these activities, providing products, services, and information that create added value for customers (Arora et al., [2]). Today, supply chain management is a critical issue for many industrial sectors, and the global supply chain has created complex interdependencies between companies. This complexity has raised indicators of the challenges within the supply chain (Yeoman & Mueller Santos, [35], presenting difficult and challenging tasks for managers. Furthermore, the rapid advancement of technology, the short product life cycle, and globalization contribute to the expansion and perpetuation of supply chain complexity, potentially leading to negative consequences for supply chain efficiency.

1.1. Supply chain and its management

In recent decades, the increase in the level of competition has had a significant impact on industries; therefore, management science experts have focused their efforts on the creation, expansion, and application of mechanisms that can be used to improve the level of productivity and product quality, thus reducing costs (Savitri & Handayani, [29]). According to many experts, it is possible to achieve such goals by moving toward the supply chain. In essence, the supply chain consists of two or more organizations that are officially separate from each other and are related to each other through material, information, and financial flows (Deng et al., [9]). This attitude, has given rise to the concept of supply chain management. Supply chain management is a set of classified approaches to integrate the efficiency of suppliers, manufacturers, warehouses, and stores so that suppliers produce in the right amount and distribute at the right place at the right time, meeting service level requirements while minimizing system costs. Over the past few decades, supply chain management has been extensively studied and has gone through an evolutionary process from the 1970s to the 2000s. This evolution has been driven by the expansion of communication and the diminishing influence of geographical boundaries, leading organizations to become more competitive (Moradi et al., [24]).

1.2. The Complexity of the Supply Chain

The concept of supply chain complexity has been studied extensively by researchers. Wilding, [34] proposed three aspects of supply chain complexity: deterministic disorder, parallel interactions,

and reinforcement. Klassen expanded on this by considering the complexity of the supply chain as a three-dimensional structure involving the number, interconnectedness, and unpredictability of systems. Sun et al., [30] emphasized the high sensitivity of the supply chain to macroeconomic environments and uncertain market changes, dubbing the 21st century as the "century of complexity." Globalization has further complicated supply chains as companies are required to respond to diverse customer needs and perform a variety of activities, often leading to processes being dispersed outside of the companies' direct supervision and control (Hassan et al., [17]). This has led to an increased interest in complexity management among industrial companies, highlighting the importance of managing and optimizing supply chain complexity in the competitive landscape (Wang et al., [33]). The complexity of the supply chain is characterized by the dynamic and detailed complexity represented by the products, processes, and relationships within the supply chain. This complexity arises from the extensive interconnection of supply networks, where most suppliers are connected to multiple supply chains, ultimately producing a variety of products for different and often unpredictable consumers (Hidayati et al., [19]). Supply chain complexity can come from within the factory (domestic manufacturing complexity) or through the factory's relationship with upstream and downstream partners (upstream and downstream complexity). So, we have:

Upstream complexity: Upstream complexity refers to the dynamic and detailed complexity arising from industrial facilities at the supply base. Factors contributing to upstream complexity include the number of supplier relationships to be managed, delivery waiting time, supplier reliability, and scope of sourcing (Hasan et al., [17]).

Downstream complexity: Downstream complexity originates from the industrial facilities of downstream markets and is characterized by factors such as the number of customers, inhomogeneity of customer needs, average number of sectors and products covered, types of industrial processes, and stability of industrial schedules from one period to the next (Dhawan et al., [10]).

Domestic production complexity: Domestic production complexity pertains to the dynamic and detailed complexity within the industrial facilities for products, processes, and control and planning systems. Factors contributing to domestic production complexity include the intricacies of the production processes and the control and planning systems within the facilities (Dhawan et al., [10]).

Competitive performance: Competitiveness is a central issue in the global economy and is crucial for achieving desirable economic growth and sustainable development. It involves gaining a suitable and stable position in international markets. Competitiveness at the company level can be defined as the ability to design, produce, or provide products at a lower price or higher quality than competitors' products at an equal cost, or as a set of assets and processes that lead to competitive advantages for organizations and industries. Different definitions and perspectives on competitiveness exist, including those based on resources, economy, production, the point of view based on creativity and innovation, and the point of view based on the market (Chen & Zhao, [7]).

1.3. Conceptual model and research hypotheses

After studying and summarizing the literature, the proposed conceptual model is identified, as shown in Figure 1.

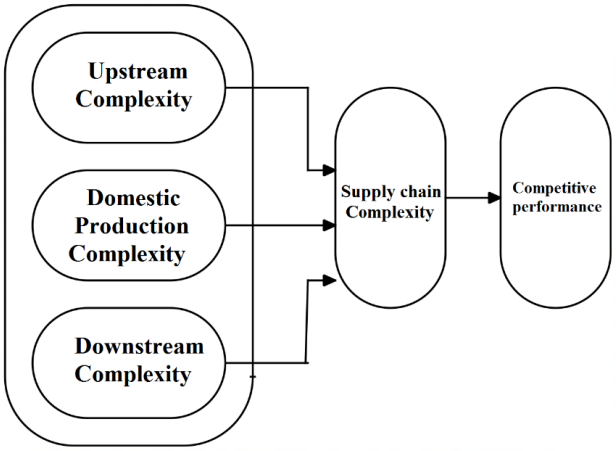

Figure 1. Conceptual model of the research

Based on this, the following hypothesis is proposed:

The main hypothesis:

The complexity of the supply chain has a significant impact on the performance of competitiveness in Iran Khodro Company.

Sub-hypotheses:

1. The complexity of the upstream chain has a significant effect on the competitiveness of the Iran Khodro Company.
2. The complexity of domestic production has a significant effect on the competitiveness of the Iran Khodro Company.
3. The complexity of the downstream chain has a significant effect on the competitiveness of the Iran Khodro Company.

1.4. Research background

So far, many studies have been conducted in the field of supply chains, competitiveness, and their advantages and benefits. Table 1 mentions a number of them that are somewhat close to the subject of the current research. However, until now, the impact of the complexity of the supply chain, including the complexity of the upstream, domestic production, and downstream, on the performance of the organization's competitiveness has not been clearly discussed in the literature, so the current study supports this research gap and offers a suitable innovation. We hope that this study will lay the groundwork for future research.

Table 1. Research background

Researcher	Title	Key results
(Cahyono et al., [5])	The role of supply chain management practices on competitive advantage and performance of halal agroindustry SMEs	The results obtained from the data analysis showed tha chain management has a positive and significant rol competitiveness of meat products companies in Tehran.

(Kakaei et al., [20])	Investigating the role of supply chain management in competitiveness (case study: Tehran meat products)	The results obtained from the data analysis showed that supply chain management has a positive and significant role in the competitiveness of meat product companies in Tehran.
(Ates et al., [3])	A meta-analysis of supply chain complexity and firm performance	They showed that knowledge transfer has a positive effect on supply chain agility, and consequently, with the positive effect of supply chain agility on competitive advantage, product and supply complexity negatively moderates the relationship between knowledge transfer and competitive advantage.
(Birkie & Trucco, [4])	Do not expect others do what you should! Supply chain complexity and mitigation of the ripple effect of disruptions	The results of the research indicated that the complexity of the supply chain in the studied society has a negative and significant effect on performance
(rasouli ghahroudi & Dodanghe, [28])	The effect of knowledge transfer on the organization's competitive advantage performance: the role of supply chain agility, product complexity and supply	They showed that knowledge transfer has a positive effect on supply chain agility, and consequently, with the positive effect of supply chain agility on competitive advantage, product, and supply complexity negatively moderate the relationship between knowledge transfer and competitive advantage.
(Fernández Campos et al., [11])	Examining the intricacies, weaknesses and strengths of a supply chain based on the determined drivers	The results of the research indicate that for the success of the complexity management system, it is important to identify and understand the drivers because this justifies the unfavorable conditions in the supply chain.
(Lotfi & Sheybani, [23])	Examining the complexities, weaknesses and strengths of a supply chain based on the determined drivers	The results of the research indicate that for the success of the complexity management system, it is important to identify and understand the drivers, because this justifies the unfavorable conditions in the supply chain.
(Khatami firoozabadi etal., [21])	Supply chain complexity as a strategic asset and financial performance position	The results of the research indicated that the complexity of the supply chain in the studied society has a negative and significant effect on performance
(Turner et al., [32])	A framework for understanding managerial responses to supply chain complexity	The results showed that internal integration is a prerequisite for external integration. Also, internal integration and external integration have a positive effect on improving the company's competitive capabilities. It is worth mentioning that internal integration improves competitive capabilities through external integration.

2. Methodology

This research is practical in terms of the nature and descriptive method of the correlation type and from the point of view of the goal. A structural equation test was used to review and analyze the data and test the research hypotheses. Its statistical population includes all experts of Iran Khodro Company, whose number was 218 people in 2022, and due to the limitation of the statistical population, all its members were selected as a sample. In the present study, a questionnaire was used for data collection. The research questionnaire consisted of two parts: in the first part, demographic information, and in the second part, Hakimi et al.'s supply chain complexity questionnaire (18 questions) and Porter's questionnaire (20 questions) were used to examine competitiveness performance variables. In order to obtain information, questionnaires were distributed among the

sample members. In total, 211 questionnaires were returned from the sent questionnaires, of which 206 were correct and reliable for analysis. To validate the research tool, construct validity was used to ensure the appropriateness of the data from the Bartlett test and the KMO index and to measure the reliability of the Cronbach's alpha coefficient and the composite reliability index used. The data analysis method in the descriptive statistics section was performed using Excel and SPSS software, and its inferential statistics using structural equations and LISREL software. Finally, to check the appropriateness of the research model and the relationships between the variables from the fit index that can be seen in the final output of the software is used.

3. Research findings

As mentioned in the previous section, to ensure the appropriateness of the data, Bartlett's test was performed and the KMO index was checked. Table 2 shows the results of Bartlett's test and KMO index.

Table 2. Bartlett's test and KMO index

Supply chain complexity	KMO test		0.898
	Bartlett's test	The value of X^2	877.400
		Degrees of freedom	258
		Significance level (Sig)	0.000
Competitive performance	KMO test		0.848
	Bartlett's test	The value of X^2	921.350
		Degrees of freedom	249
		Significance level (Sig)	0.000

The KMO test value exceeded 0.6 and approached 1, while the significance coefficient of Bartlett's test was less than 0.05, indicating the suitability of factor analysis for identifying the structure and factor model. The t-value of both questionnaires was greater than 1.96 in the meaningful state, indicating a significant relationship between the questions and variables. Factor loadings were higher than 0.5 in the standard estimation mode, indicating the appropriateness of the questions for the research variables. Table 3 confirmed the convergent validity of the research variables, with CR<0.7, CR>AVE, and AVE>0.5. To assess the reliability of Cronbach's alpha coefficient and composite reliability index, 30 questionnaires were distributed within the statistical community, and the results are presented in Table 3.

Table 3. Cronbach's alpha coefficient, composite reliability and convergent validity

Variables	AVE	CR	Cronbach's alpha
Supply chain complexity	0.62	0.91	0.89
The upstream complexity	0.59	0.79	0.78
Complexity of domestic production	0.57	0.88	0.85
The downstream complexity	0.53	0.84	0.86
Competitive performance	0.51	0.93	0.89

The results displayed in Table 4 confirm the adequacy of the constructs' reliability, as both the composite reliability (CR) and Cronbach's alpha coefficients exceeded 0.7 for all variables. Additionally, the Average Variance Extracted (AVE) root of each construct surpassed the correlation coefficients of the construct with other constructs, signifying the satisfactory divergent validity of the constructs.

Table 4. Divergent validity check

Variables	1	2	3	4
The complexity of the upstream of the chain	0.59			
Complexity of domestic production	0.56	0.57		
The complexity of the downstream of the chain	0.54	0.67	0.53	
Competitive performance	0.57	0.66	0.70	0.50

3.1. Descriptive findings

Out of the 216 respondents in the system under investigation, 129 were men (60%) and 87 were women (40%). Among these respondents, 115 held bachelor's degrees (53%), 87 held master's degrees (40%), and 14 held PhDs (6%). Additionally, 34 individuals (15%) had 5–10 years of experience, 42 (19%) had 11–15 years of experience, 63 (29%) had 16–20 years of experience, 49 (22%) had 21–25 years of experience, and 28 (13%) had 26–30 years of experience.

3.2. Inferential findings: relationships between hypotheses

To examine the relationships expressed in the hypotheses, a structural equation test was conducted. As illustrated in Figure 2, the significance of the relationships between variables was determined based on the t-value. A t-value between +1.96 and -1.96 indicates a non-significant relationship at the 95% confidence level, while a t-value greater than +1.96 or smaller than -1.96 indicates a significant relationship at the 95% confidence level. Based on this criterion, all the relationships in the model were found to be significant.

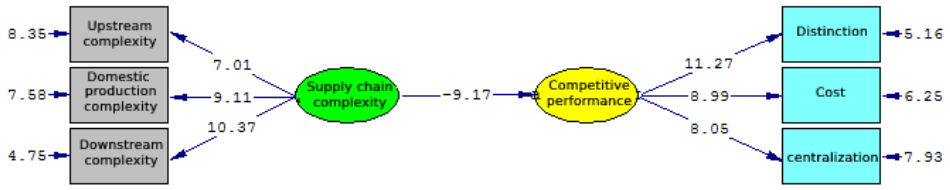

Figure 2. Significant values obtained from modeling the structural equations of the main hypothesis

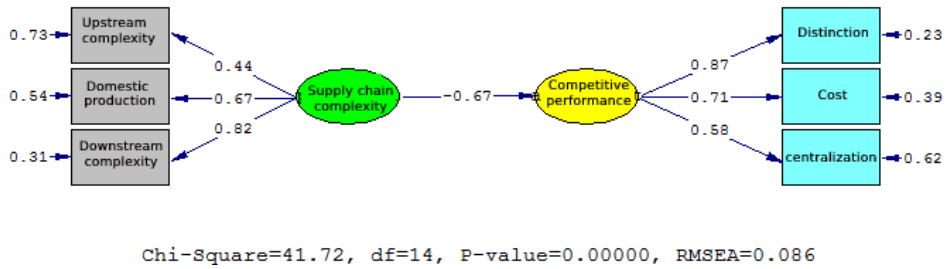

Figure 3.- Significant values obtained from modeling the structural equations of the main hypothesis

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Normed Fit Index (NFI) = 0.90
Non-Normed Fit Index (NNFI) = 0.93
Parsimony Normed Fit Index (PNFI) = 0.89
Comparative Fit Index (CFI) = 0.91
Incremental Fit Index (IFI) = 0.93
Relative Fit Index (RFI) = 0.94

Critical N (CN) = 116.56


Root Mean Square Residual (RMR) = 0.021
Standardized RMR = 0.029
Goodness of Fit Index (GFI) = 0.90
Adjusted Goodness of Fit Index (AGFI) = 0.92
Parsimony Goodness of Fit Index (PGFI) = 0.91
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Examining the main hypothesis: the complexity of the supply chain has a significant effect on the performance of competitiveness in Iran Khodro Company.

The significant difference between competition and complexity was -9.17. Furthermore, as depicted in Figure 3, the standard coefficient between supply chain complexity and competitiveness performance is -0.67, indicating a strong and inverse effect of supply chain complexity on competitiveness performance in Iran Khodro Company. This negative coefficient suggests that an increase in supply chain complexity leads to a decrease in competitive performance. The software outputs also indicated a correlation coefficient of -0.67 between these two variables. For a comprehensive overview of the structural equation modeling results, please refer to Table 5.

Table 5. The results of modeling the structural equations of the main hypothesis

Relationships of research variables	**Supply chain complexity – competitive performance**
t value	-9.17
direct effect (R)	-0.67
Indirect effect	-
total effect	-0.67
Result	confirmation
Relation	reverse

To validate the structural model, the fit indices of the model were assessed using structural equation modeling. As indicated in Table 6, the research model demonstrated a good fit, meeting the acceptance criteria for the indicators.

Table 6. Fit indices for the model

Variable	Index calculation	The right level	Result
χ^2/df	2.98	5<	Appropriate
RMSEA	0.098	0.1<	Appropriate
GFI	0.90	0.90>	Appropriate
RMR	0.021	0.5<	Appropriate
IFI	0.93	0.90>	Appropriate
CFI	0.91	0.90>	Appropriate
NFI	0.90	0.90>	Appropriate
NNFI	0.93	0.90>	Appropriate

Similarly, to test the sub-hypotheses of the research, the structural equation modeling method was used, and the fit indices were examined.

Sub-hypotheses:

1. The complexity of the upstream chain has a significant effect on the competitiveness of the Iran Khodro Company.
2. The complexity of domestic production has a significant effect on the competitiveness of the Iran Khodro Company.

3. The complexity of the downstream chain has a significant effect on the competitiveness of the Iran Khodro Company.

In the following, structural models are drawn to test the sub-hypotheses of the research.

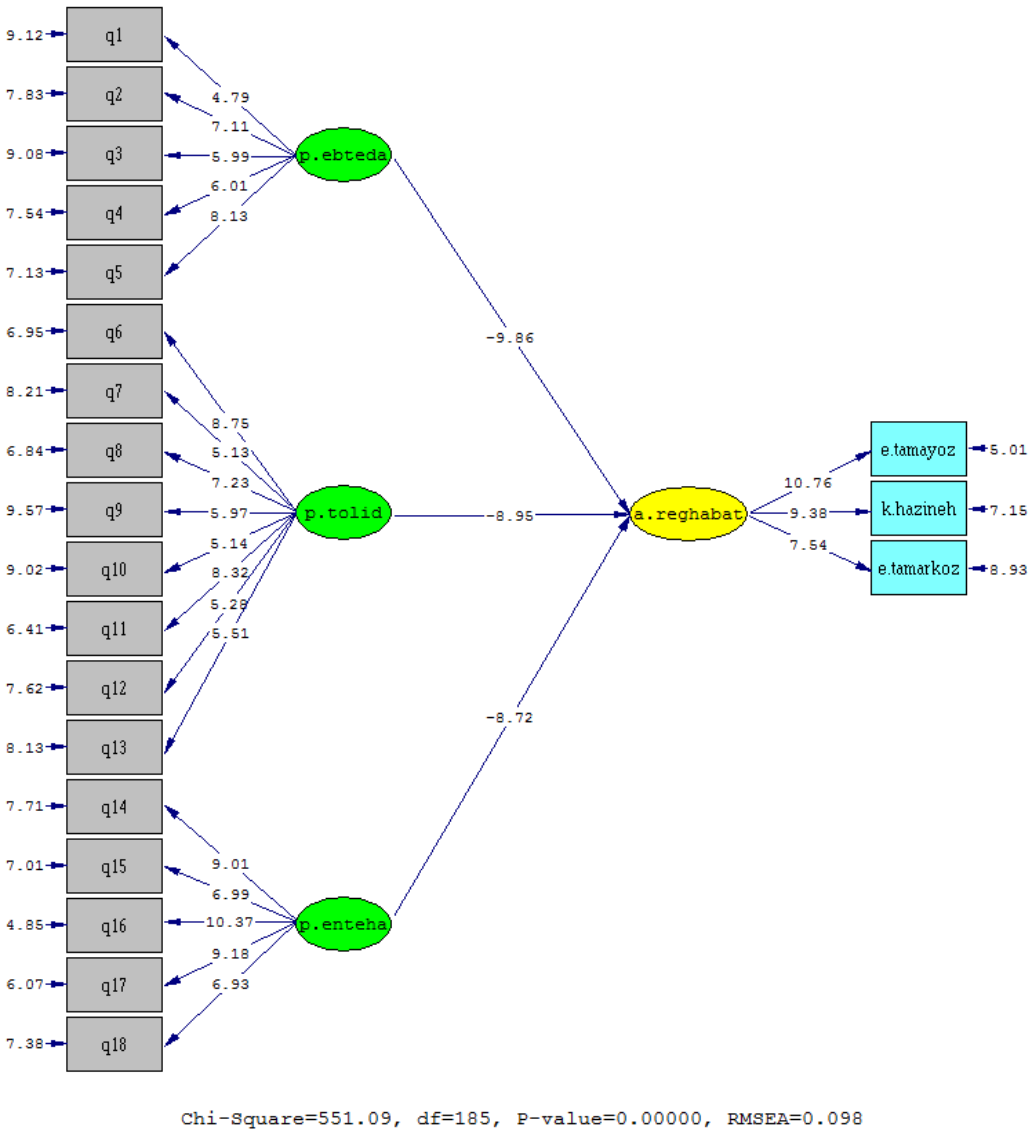

Figure 4. Significant values obtained from structural equation modeling of sub-hypotheses

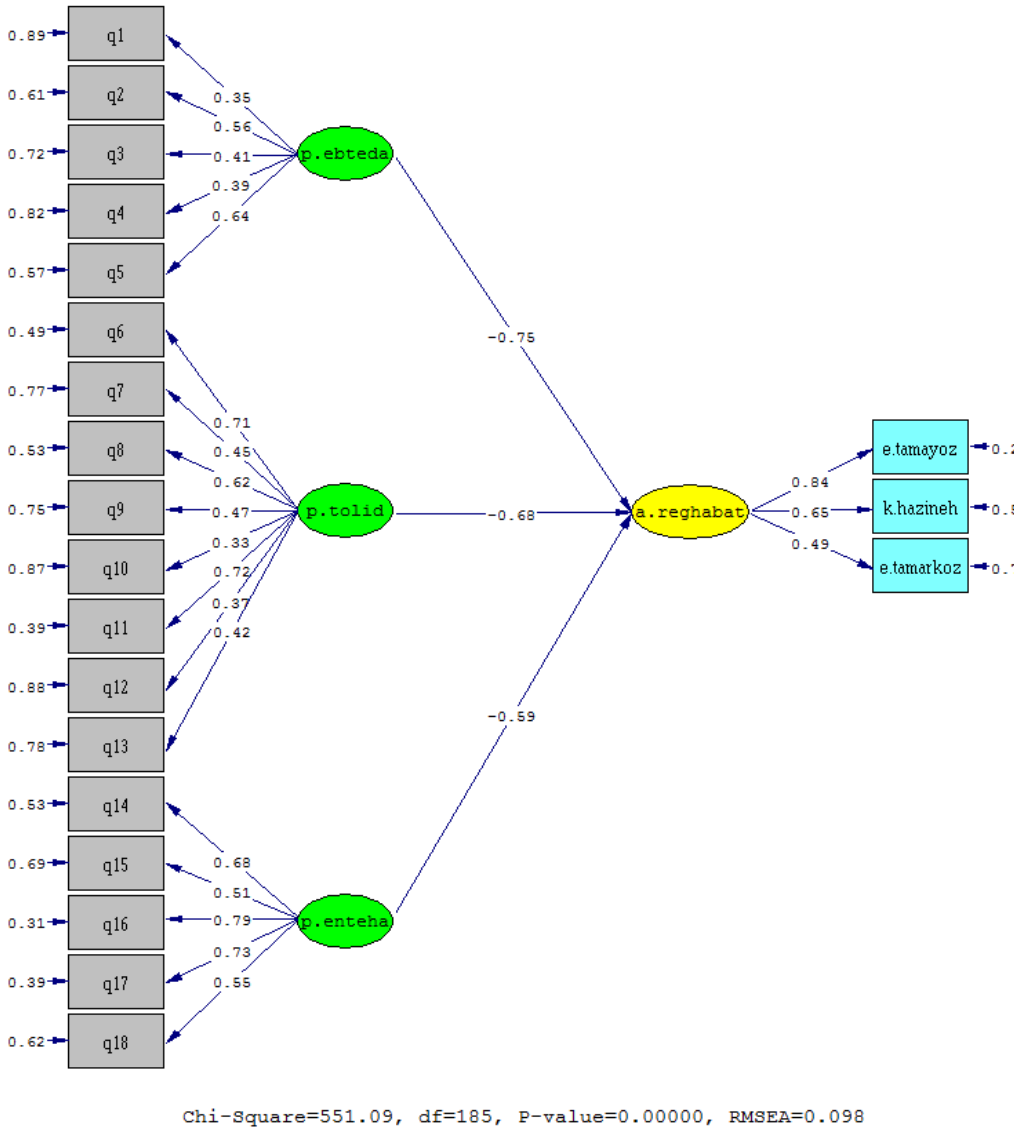

Figure 5. Values of standardized coefficients resulting from structural equation modeling of sub-hypotheses

Normed Fit Index (NFI) = 0.91
Non-Normed Fit Index (NNFI) = 0.92
Parsimony Normed Fit Index (PNFI) = 0.93
Comparative Fit Index (CFI) = 0.92
Incremental Fit Index (IFI) = 0.94
Relative Fit Index (RFI) = 0.91

Critical N (CN) = 125.91

Root Mean Square Residual (RMR) = 0.035
Standardized RMR = 0.031
Goodness of Fit Index (GFI) = 0.91
Adjusted Goodness of Fit Index (AGFI) = 0.91
Parsimony Goodness of Fit Index (PGFI) = 0.93

First sub-hypothesis: The competitiveness of Iran Khodro Company is significantly affected by the complexity of its upstream chain.

Based on Figure 4, the value of 9.86 indicates a significant impact of the complexity of the upstream chain on the competitiveness performance of Iran Khodro Company, as it is greater than 1.96. Figure 5 shows that the standard coefficient of complexity of the upstream chain on competitiveness performance is -0.75, indicating a significant and inverse relationship between the two.

Second sub-hypothesis: The complexity of domestic production significantly affects the competitiveness of Iran Khodro Company.

The value of -8.95 indicates a significant impact of domestic production complexity on competitiveness performance in Iran Khodro Company, as it is greater than 1.96. Figure 5 shows that the standard coefficient between domestic production complexity and competitiveness performance is -0.68, indicating a strong and opposite effect.

Third sub-hypothesis: The competitiveness of Iran Khodro Company is significantly affected by the complexity of its downstream chain.

The value of -8.72 indicates a significant impact of the complexity of the downstream chain on competitiveness performance, as it is greater than 1.96. However, this relationship is inverse, meaning that as the complexity of the upstream of the chain increases, the competitiveness performance decreases. Figure 5 shows that the standard coefficient of downstream complexity on competitiveness performance is -0.59, indicating a moderate effect between 0.3 and 0.6.

Table 7. The results of modeling structural equations of sub-hypotheses

Relationships of research variables	Upstream complexity on Competitive performance	The complexity of domestic production on the performance of competitiveness	Downstream complexity on competitive performance
t value	-9.86	-8.95	-8.72
direct effect (R)	-0.75	-0.68	-0.59
Indirect effect	-	-	-
total effect	-0.75	-0.68	-0.59
Result	confirmation	confirmation	confirmation
Relation	reverse	reverse	reverse

The fit indices of the structural equation modeling are presented in Table 8. As can be seen, the research model has a good fit and the acceptance level of the indicators is met.

Table 8. Fit indices for the model

Variable	Index calculation	The right level	Result
^{2}/dfX	2.97	5<	Appropriate
RMSEA	0.098	0.1<	Appropriate
GFI	0.91	0.90>	Appropriate
RMR	0.035	0.5<	Appropriate
IFI	0.94	0.90>	Appropriate
CFI	0.92	0.90>	Appropriate
NFI	0.91	0.90>	Appropriate
NNFI	92/00.92	0.90>	Appropriate

4. Conclusion and managerial insight

In this study, we investigate the impact of supply chain complexity on the competitiveness performance of Iran Khodro Company across three dimensions: upstream complexity, domestic production, and downstream complexity. We utilize a conceptual model and analyze the data using structural equation modeling. Our results demonstrate that supply chain complexity has a significant inverse effect on competitiveness. As supply chain complexity increases, creativity and innovation within the chain decrease, and the system responds slowly to environmental changes, ultimately leading to decreased competitiveness performance. In other words, reducing supply chain complexity leads to improved competitiveness performance. These findings are consistent with previous studies by Rasouli ghahroudi & Dodangheh, [28] , and Hakimi et al. [16]. To provide management insight, we recommend that Iran Khodro managers review existing processes, identify bottlenecks, and simplify the flow of materials, information, and funds while implementing agile and flexible supply chain practices. Additionally, the company should invest in new technologies and automation. This approach will reduce manual errors, increase productivity, and accelerate the response time to market changes. Considering the sanctions that have increased the complexity of the company's supply chain, we recommend actively managing the complexity while leveraging it as a strategic advantage to achieve a sustainable competitive advantage while reducing complexity costs. With this insight, competitive priorities and emerging challenges in the supply chain field can be effectively addressed and managed. Furthermore, we recommend the following strategies to streamline the company's supply chain and bolster its competitive position:

1. Diversify the supplier base and localize supply: Given the restricted access to reliable international suppliers due to sanctions, Iran Khodro should prioritize diversifying its supplier network within the domestic market. This entails identifying and cultivating partnerships with domestic suppliers capable of providing essential raw materials and components. By reducing dependence on international suppliers, the company can mitigate risks associated with sanctions and establish a more resilient supply chain.

2. Enhance quality control and localization efforts: With the necessity to engage alternative suppliers, Iran Khodro must place significant emphasis on enhancing the quality control process. The company should establish rigorous quality assessment procedures for its suppliers and ensure consistent adherence to quality standards.

3. Strengthen logistics and local distribution channels: In light of the sanctions, optimizing internal logistics operations is imperative. Iran Khodro should invest in enhancing logistics infrastructure, encompassing transportation, storage facilities, and customs procedures. This will enable the company to minimize delays and costs, ensuring more efficient movement of goods within the country.

4. Expand into non-sanctioned markets: Iran Khodro should concentrate on broadening its presence in non-sanctioned markets to counter the limitations of international market access. Diversifying export destinations will reduce the company's reliance on a single market and mitigate the impact of sanctions. This involves conducting thorough research to identify new market opportunities, establishing partnerships with local distributors, and adapting products to align with the specific requirements of these markets.

5. Foster collaboration and knowledge exchange: Addressing the intricate supply chain challenges posed by sanctions necessitates close collaboration with other domestic manufacturers and industrial organizations. Iran Khodro should actively engage in knowledge-sharing and collaboration platforms to exchange best practices, insights, and solutions related to supply chain management. Leveraging

collective knowledge and experience will enable the company to navigate the complexities of the sanctions-driven environment more effectively.

6. Continuously adapt to the changing sanctions landscape: Given the dynamic nature of sanctions, Iran Khodro should establish a dedicated team or department responsible for monitoring and comprehending the evolving sanctions landscape. Staying abreast of updates and developments will allow the company to proactively adjust its supply chain strategies and operational practices to minimize disruptions.

By implementing these measures while considering the impact of sanctions, Iran Khodro can streamline its supply chain, foster creativity and innovation, and enhance its competitive standing. These efforts will enable Iran Khodro to effectively navigate the supply chain complexities caused by sanctions, establish a stable supply chain, and successfully position itself in the Iranian automotive industry. In comparison to earlier research, this study's main contribution and benefits can be divided into two parts:

1. Focus on automotive industries: Despite the limited research on the impact of supply chain complexity on competitiveness, there is a significant gap in the literature regarding studies focusing on the automotive sector and related industries. Furthermore, none of the existing studies have thoroughly examined the influence of upstream complexity, domestic production, and downstream complexity on competitiveness performance.

2. Lack of structural modeling analysis: Unlike previous research that often relied on qualitative or survey-based methods, this study utilized structural modeling techniques to analyze the impact of supply chain complexity on competitiveness. Furthermore, the study doesn't just identify problems in Iran Khodro's supply chain but also provides innovative solutions to address these challenges within the constraints of sanctions. The proposed recommendations emphasize the importance of simplification, localization, and collaboration, offering practical and actionable insights.

Moving forward, future research could benefit from conducting longitudinal studies or adopting a dynamic perspective to capture changes, trends, and their effects over time. This approach would provide a deeper understanding of how supply chain complexities evolve and their long-term impact on competitive performance, allowing for the development of effective adaptive strategies. Additionally, integrating external factors such as market dynamics, economic conditions, industry regulations, and political instability, as well as internal factors like supplier relationships, inventory management, demand forecasting, and distribution networks, into future studies would contribute to a more comprehensive understanding of the relationship between supply chain complexity and competitiveness. Finally, considering the roles of technology and innovation in supply chain management, such as automation, artificial intelligence, and digitalization, would also be a valuable area for future research. Assessing how technological advancements affect supply chain complexity and, ultimately, competitive performance could provide further insights into optimizing supply chain operations.

Conflict of interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

References

[1] Aitken, J., Bozarth, C., & Garn, W. (2016). To eliminate or absorb supply chain complexity: a conceptual model and case study. Supply Chain Management: An International Journal, 21(6), 759–774. https://doi.org/10.1108/SCM-02-2016-0044

[2] Arora, K., Abbi, P., & Gupta, P. K. (2022). Analysis of Supply Chain Management Data Using Machine Learning Algorithms. In Innovative Supply Chain Management via Digitalization and Artificial Intelligence (pp. 119–133). Springer.

[3] Ates, M. A., Suurmond, R., Luzzini, D., & Krause, D. (2020). A meta-analysis of supply chain complexity and firm performance. Academy of Management Proceedings, 2020(1), 14065.

[4] Birkie, S. E., & Trucco, P. (2020). Do not expect others do what you should! Supply chain complexity and mitigation of the ripple effect of disruptions. International Journal of Logistics Management, 31(1), 123–144. https://doi.org/10.1108/IJLM-10-2018-0273

[5] Cahyono, Y., Purwoko, D., Koho, I., Setiani, A., Supendi, S., Setyoko, P., Sosiady, M., & Wijoyo, H. (2023). The role of supply chain management practices on competitive advantage and performance of halal agroindustry SMEs. Uncertain Supply Chain Management, 11(1), 153–160.

[6] Chand, P., Thakkar, J. J., & Ghosh, K. K. (2018). Analysis of supply chain complexity drivers for Indian mining equipment manufacturing companies combining SAP-LAP and AHP. Resources Policy, 59, 389–410.

[7] Chen, J., & Zhao, D. (2022). Complexity of domestic production fragmentation and its impact on pollution emissions: Evidence from decomposed regional production length. Structural Change and Economic Dynamics, 61, 127–137.

[8] Dehghan Khalilabad, M., & Aref, M. (2022). Investigating the Impact of Supply Chain Quality Management Practices and Capabilities on Operational and Innovation Performance (A Case Study of Food Industry Companies in Mashhad). Iranian Journal of Supply Chain Management, 23(73), 1-12 (in persian).

[9] Deng, W., Feng, L., Zhao, X., & Lou, Y. (2020). Effects of supply chain competition on firms' product sustainability strategy. Journal of Cleaner Production, 275, 124061.

[10] Dhawan, K., Tookey, J. E., GhaffarianHoseini, A., & Poshdar, M. (2023). Using Transport to Quantify the Impact of Vertical Integration on the Construction Supply Chain: A New Zealand Assessment. Sustainability, 15(2), 1298.

[11] Fernández Campos, P., Trucco, P., & Huaccho Huatuco, L. (2019). Managing structural and dynamic complexity in supply chains: insights from four case studies. Production Planning and Control, 30(8), 611–623. https://doi.org/10.1080/09537287.2018.1545952

[12] Fianko, A. O., Essuman, D., Boso, N., & Muntaka, A. S. (2023). Customer integration and customer value: contingency roles of innovation capabilities and supply chain network complexity. Supply Chain Management: An International Journal, 28(2), 385–404.

[13] Fosso Wamba, S., Queiroz, M. M., Tan, K. H., & Huo, B. (2023). Guest editorial: Digital transformation strategy and impacts during emergency situations. Industrial Management & Data Systems, 123(1), 1–9.

[14] Gerschberger, M., Fawcet, S. E., Fawcett, A. M., & Gerschberger, M. (2023). Why supply chain complexity prevails: mapping the complexity capability development process. The International Journal of Logistics Management.

[15] Gružauskas, V., & Burinskiene, A. (2022). Managing supply chain complexity and sustainability: the case of the food Industry. Processes, 10(5), 852.

[16] Hakimi, I., Nejad, A. S., Alipour, H., & Mortazavi, K. (2017). Studying the impact of supply chain complexity on competitiveness capabilities. Journal of Scientific Research and Development, 2(6), 205–210.

[17] Hasan, I., Habib, M. M., & Mohamed, Z. (2023). Key Factors That Can Enable Transparency in the Volatile Agri-Food Supply Chain. International Supply Chain Technology Journal, 9(01).

[18] Hassan, S. T., Batool, B., Wang, P., Zhu, B., & Sadiq, M. (2023). Impact of economic complexity index, globalization, and nuclear energy consumption on ecological footprint: First insights in OECD context. Energy, 263, 125628.

[19] Hidayati, J., Vamelia, R., Hammami, J., & Endri, E. (2023). Transparent distribution system design of halal beef supply chain. Uncertain Supply Chain Management, 11(1), 31–40.
[20] Kakaei, H., Ahmadfar, J., Noraee, E., & Salehian, H. (2023). Examining the role of supply chain management in competitiveness (case study: meat products of Tehran). Scientific Journal of New Management and Accounting Research Approaches, 6(23), 894–906.
[21] Khatami, mohammad ali, Olfat, L., Amiri, M., & Sharifi, H. (2018). Supply chain complexity as a strategic asset and financial performance position. Journal of Asset Management and Financing, 6(4), 57–78.
[22] Lopes, J. M., Gomes, S., & Mané, L. (2022). Developing knowledge of supply chain resilience in less-developed countries in the pandemic age. Logistics, 6(1), 3.
[23] Lotfi, A., & Sheybani, G. (2019). Examining the complexities, weaknesses and strengths of a supply chain based on the determined drivaers. The Third International Conference on Customer-Oriented Management in Mining, Steel and Cement Industries.
[24] Moradi, H., Rabbani, M., Babaei Meybodi, H., & Honari, M. . T. (2021). Development of a Hybrid Model for Sustainable Supply Chain Evaluation with Dynamic Network Data Envelopment Analysis Approach. Iranian Journal of Operations Research, 12(2), 1–13.
[25] Pavlov, A., & Micheli, P. (2022). Rethinking organizational performance management: a complexity theory perspective. International Journal of Operations & Production Management, ahead-of-print.
[26] Piya, S., Khadem, M., Al Kindi, M., & Shamsuzzoha, A. (2020). Measuring supply chain complexity based on multi-criteria decision approach. Proceedings of the International Conference on Industrial Engineering and Operations Management, 0(March), 2937–2944.
[27] Piya, S., Shamsuzzoha, A., & Khadem, M. (2022). Analysis of supply chain resilience drivers in oil and gas industries during the COVID-19 pandemic using an integrated approach. Applied Soft Computing, 121, 108756.
[28] rasouli ghahroudi, mehdi, & Dodanghe, A. (2020). The effect of knowledge transfer on the organization's competitive advantage performance: the role of supply chain agility, product complexity and supply. The Second National Conference of New Ideas in Business Management, [in persian].
[29] Savitri, B. A., & Handayani, A. (2023). Analysis of Quality Cost Optimization at PT. XYZ in Gresik Regency. Journal Universitas Muhammadiyah Gresik Engineering, Social Science, and Health International Conference (UMGESHIC), 2(1), 52–62.
[30] Sun, C., Rose, T., Ehm, H., & Herbig, T. (2016). Best practice sharing for complexity management in supply chains of the semiconductor industry. Procedia CIRP, 41, 538–543.
[31] Tsapi, V., Assene, M.-N., & Haasis, H.-D. (2022). The Complexity of the Meat Supply Chain in Cameroon: Multiplicity of Actors, Interactions and Challenges. Logistics, 6(4), 86.
[32] Turner, N., Aitken, J., & Bozarth, C. (2018). A framework for understanding managerial responses to supply chain complexity. International Journal of Operations and Production Management, 38(6), 1433–1466. https://doi.org/10.1108/IJOPM-01-2017-0062
[33] Wang, H., Gu, T., Jin, M., Zhao, R., & Wang, G. (2018). The complexity measurement and evolution analysis of supply chain network under disruption risks. Chaos, Solitons & Fractals, 116, 72–78.
[34] Wilding, R. (1998). The supply chain complexity triangle: uncertainty generation in the supply chain. International Journal of Physical Distribution & Logistics Management, 28(8), 599–616.
[35] Yeoman, R., & Mueller Santos, M. (2020). A complex systems model for transformative supply chains in emerging markets. International Journal of Emerging Markets, 15(1), 50–69. https://doi.org/10.1108/IJOEM-02-2017-0044