Future of Work and Digital Management Journal

Article type:
Original Research

Article history:
Received 16 May 2025
Revised 21 August 2025
Accepted 26 August 2025
Published online 01 September 2025

Identification and Prioritization of Factors Affecting Technological Foresight in the Iranian Saffron Packaging Industry

Rahimbakhsh. Parandoosh[1], Zahra. Dashtlaali[1*], Sayyed Mohammadreza. Davoodi[1]

1 Department of Management, Deh.C., Islamic Azad University, Isfahan, Iran

Corresponding author email address:
zahradashtlaali@iau.ir

How to cite this article:
Parandoosh, R., Dashtlaali, Z., & Davoodi, S. M. (2025). Identification and Prioritization of Factors Affecting Technological Foresight in the Iranian Saffron Packaging Industry. *Future of Work and Digital Management Journal, 3*(3), 1-15. https://doi.org/10.61838/fwdmj.104

ABSTRACT

In recent years, adherence to packaging standards in export products has become one of the main requirements of global trade. In this regard, the packaging industry, with its decisive role in preserving quality, safeguarding unique characteristics, and enhancing the added value of saffron, serves as a foundation for expanding domestic markets and ensuring sustainable presence in international markets. This study was conducted with the aim of identifying and prioritizing factors affecting technological foresight in the Iranian saffron packaging industry. The research is applied in nature, employs a descriptive–analytical method, and adopts a mixed (qualitative–quantitative) approach. In the qualitative phase, the statistical population consisted of academic experts and managers of saffron packaging companies (12 individuals), selected through purposive sampling until theoretical saturation was reached. Data were collected through semi-structured interviews based on theoretical foundations and analyzed using Braun and Clarke's thematic analysis method in Atlas.ti software. The output included five organizing themes (drivers, strategic factors, consequences, current status, and desired status), 19 basic themes, and one overarching theme. The quantitative phase was carried out using interpretive structural modeling (ISM) and the ISM questionnaire on a population of 15 individuals from the same target group, selected purposively. Data were analyzed using MICMAC software; the results revealed that the identified factors were categorized into seven hierarchical levels, among which "modern technologies and smart packaging" were identified as the most critical factor, located at the highest level of influence.

Keywords: Technological foresight, packaging industry, saffron packaging, window of opportunity.

Introduction

Technological catch-up and upgrading have emerged as critical themes in both academic discourse and industrial policy, particularly in relation to latecomer economies and industries seeking to overcome structural disadvantages and establish long-term competitiveness. The process of technological catch-up involves a multifaceted interplay of knowledge flows, institutional frameworks, industrial strategies, and global value chain dynamics, which collectively determine the extent to which countries and firms can move from dependency on external technologies to autonomous innovation and leadership. Historically, catch-up has been studied in contexts ranging from heavy manufacturing to advanced green technologies and, more recently, in food packaging, nanotechnology, and smart materials, reflecting the breadth of its applications in the contemporary economy [1-4].

The concept of catch-up cycles has been particularly significant in explaining how latecomer economies manage transitions across stages of industrial development. Industry leadership changes create "windows of opportunity" that can be strategically leveraged by emerging economies to move from imitation toward innovation [2, 5]. For example, research on

Korea's capital goods industry demonstrates that sectoral innovation systems provide a framework for understanding catch-up trajectories [1]. Similarly, studies on technological upgrading across emerging economies highlight that institutions, knowledge systems, and global interdependencies shape how nations and firms can strategically leapfrog [4, 6].

In this evolving landscape, food packaging technologies have increasingly become a focal point for catch-up studies, given their direct link to consumer safety, sustainability, and trade competitiveness. Innovative materials, such as carboxymethyl chitosan and nanocellulose-based composites, are advancing packaging systems toward functionality, biodegradability, and smart responsiveness [7, 8]. The integration of nanotechnology into sustainable packaging has been highlighted as a major driver of competitive advantage, with potential to transform global food supply chains [9]. Similarly, polysaccharide-based food packaging and intelligent applications demonstrate how developing economies can employ material science to align with international environmental standards [10]. These developments reveal that packaging is not merely a logistical concern but a site of technological contestation and industrial catch-up, particularly for export-driven industries such as saffron packaging in Iran.

The Iranian context presents a compelling case of technological catch-up dynamics within packaging and related industrial sectors. Studies in the steel industry illustrate how regime-based approaches and complex product systems interact to shape catch-up trajectories [11]. Research on the petrochemical industry emphasizes the need to identify and prioritize policies that address systemic failures and barriers to technological upgrading [12]. Similarly, evidence from the nuclear industry points to challenges of capability development under geopolitical and technological constraints [13]. In the defense and maritime industries, catch-up has been conceptualized through models of capability building, emphasizing the long-term requirements for sustaining technological authority [14]. These case studies underline the importance of both policy coherence and organizational learning in overcoming barriers to technological self-reliance.

Another dimension of technological catch-up involves the role of intellectual property rights (IPR) and governance structures. Policy frameworks that balance protection with diffusion can facilitate catch-up by ensuring both access to knowledge and incentives for local innovation [15]. The asymmetries embedded in global value chains (GVCs) also create both constraints and opportunities for latecomer economies. For instance, research on the coffee industry demonstrates how governance mechanisms and power imbalances shape the possibilities for emerging economies to achieve upgrading within global networks [16]. This resonates with findings in offshore oil and gas equipment manufacturing in China, where supply chain integration and government policy have been pivotal in enabling technological innovations [17].

The flow of knowledge across borders further conditions the speed and quality of catch-up. Patent metadata has been used to model the transmission of knowledge in solar technologies, demonstrating how international diffusion patterns impact national innovation systems [18]. International technology transfer models are also being revisited in light of digitalization and globalization, suggesting the need for frameworks that move beyond traditional North-South hierarchies [19]. For emerging economies, developing adaptive mechanisms to absorb external knowledge while simultaneously building local capacities is essential for long-term technological sovereignty [20].

At the micro-industrial level, product architecture and modularity have been identified as determinants of successful catch-up, particularly in green industries where innovation cycles are shorter and competitive pressures more intense [21]. Evidence from Chinese CNC machine tool industries illustrates how communities of practice and industrial value chains foster collective upgrading through shared knowledge and incremental improvements [22]. Similarly, studies on firm-level innovation performance reveal that both forward and reverse engineering strategies significantly impact technological outcomes in catch-up contexts [23]. These findings highlight that firms must strategically balance imitation, adaptation, and original innovation to sustain progress.

The Iranian experience also underscores the challenges of sustaining technological progress under conditions of sanctions and economic volatility. Studies in the oil turbo-compressor sector have conceptualized post-catch-up technological strategies that emphasize resilience, adaptability, and endogenous innovation [24]. Meta-synthesis research on sustainable transitions suggests that catch-up must increasingly be analyzed through the lens of sustainability and institutional transformation [25]. Similarly, catch-up in complex products such as deviated drilling equipment has been shown to require not only technical knowledge but also systemic integration of organizational and institutional capabilities [26]. These findings point to the multidimensional nature of catch-up, encompassing technological, organizational, policy, and social dimensions.

The role of research, development, and innovation (R&D&I) systems is central in shaping catch-up pathways. Latecomer economies must strategically invest in innovation ecosystems that allow for dynamic learning, iterative experimentation, and rapid scaling of technological advances. For example, research on windows of opportunity indicates that firms can transcend lagging positions by aligning internal strategies with external shifts in global markets [5]. Case studies in green technologies emphasize the transformative potential of aligning product architecture with sustainability imperatives [21]. These lessons are particularly relevant for food packaging, where environmental pressures and regulatory requirements create both challenges and new opportunities for industrial upgrading [7-10].

At the same time, technological catch-up is not purely a technical or industrial phenomenon but deeply embedded in socio-economic and institutional frameworks. Studies show that the institution-led market has played a critical role in enabling Chinese enterprises to achieve technological catch-up [6]. An asymmetry-based view highlights the uneven playing field that shapes Chinese firms' strategies and outcomes [3]. Similarly, the Iranian case in the steel industry shows that structural and institutional barriers must be addressed to ensure that catch-up strategies lead to sustainable industrial upgrading [11]. The integration of social responsibility and ethical considerations has also been identified as a crucial component of sustainable catch-up, ensuring alignment between technological advances and societal well-being [27].

In sum, the literature suggests that technological catch-up is a complex, layered process that requires coordination between firms, governments, and global networks. From the role of innovation cycles and knowledge flows to the significance of governance frameworks and industrial ecosystems, the pathways to catch-up are shaped by a multiplicity of factors. Food packaging, particularly in export-oriented industries such as saffron, illustrates how latecomer economies can leverage both global trends in material science and local institutional strategies to achieve competitive upgrading. Drawing from cross-sectoral evidence—from oil and gas to green technologies, from nuclear to software industries—the study of technological catch-up reveals that success depends on the ability to simultaneously absorb, adapt, and innovate [1-27].

Against this background, the present study seeks to analyze and prioritize the factors influencing technological foresight in Iran's saffron packaging industry

Methods and Materials

The present study is applied in nature and employs a mixed-method approach. In the qualitative section, experts and university professors in the fields of business management, marketing, business, and market studies, as well as managers from the national packaging industry and saffron exporters, were invited for interviews. The sampling method used was purposive sampling. After 12 interviews with various individuals, data saturation was achieved in terms of sampling adequacy for deriving the qualitative model.

The inclusion criteria were: holding a PhD in business management or marketing (specifically for academic experts), having more than 10 years of work experience for faculty members, and extensive executive experience (more than 10 years) in saffron production and packaging for senior managers of saffron packaging industries. Semi-structured interviews were used in this research. In the first step, the qualitative part of the study was conducted using semi-structured interviews with academic experts and practitioners in the saffron packaging industry. The collected data were coded and analyzed using Braun and Clarke’s thematic analysis with the aid of ATLAS.ti software. The result of this stage was the identification of five main categories of factors (drivers, strategies, consequences, current status, and desired status), which formed the basis for the development of the study’s conceptual model.

In the second step, in the quantitative section, the data collection tool was a questionnaire based on interpretive structural modeling (ISM). The statistical population consisted of two related groups: academic experts with experience and expertise in packaging and saffron, as well as managers and specialists from companies active in the saffron packaging industry. Sampling was conducted purposively based on criteria such as relevant research or managerial background, familiarity with saffron packaging processes, and access to strategic information. In total, 15 individuals were selected as the sample. Data analysis was carried out using the ISM approach with the assistance of MICMAC software. The process included converting expert opinions into a pairwise relationship matrix, determining the direct reachability matrix, calculating indirect relationships, and then stratifying the factors. MICMAC, in addition to matrix calculations, enabled analysis of the influence and dependence among factors, allowing classification of factors into key, driving, independent, and marginal groups. Prior to the final implementation of the questionnaire, a pilot test was conducted with several experts. Any disagreements or ambiguities were resolved and refined through follow-up calls or short meetings. The final outputs included matrices, the ISM structural diagram, and the MICMAC influence–dependence map, which were used to explain the causal structure and determine priorities, and can be presented as tables and appendices in the methodology section.

Findings and Results

For the qualitative section, data were collected through interviews with 12 academic experts and executive managers. According to the findings, most interviewees were male (73%) and the minority female (27%). Regarding work experience, 9% had 5–10 years, 64% had 11–20 years, and 27% had more than 20 years of experience. In terms of education, 91% held doctoral degrees and 9% held master’s degrees.

At this stage, concepts and key points obtained regarding the structural model of technological foresight in Iran’s packaging industry (case study: saffron packaging) were listed from the interview process. For this purpose, phrases, concepts, and extracted statements from the interviews were subjected to detailed analyses and harmonization (selecting more accurate wording, removing overlapping concepts). As a result, 203 statements were obtained.

Through continuous comparison of responses from the interviews, similar responses were aligned and related concepts were extracted. Furthermore, closely related statements were merged and categorized into five themes.

Category One: Drivers of the technological foresight model in Iran’s saffron packaging industry

This category included 43 basic themes grouped under four sub-categories: "modern technologies and smart packaging, sustainability and social responsibility, market developments and demand, and conditions and infrastructure of the saffron industry."

Category Two: Effective strategies in the technological foresight model in saffron packaging

This category included 26 themes, which were grouped into four sub-categories: "innovation and research and development (R&D), collaborations, networking and international growth, social and ethical responsibility, and product market and production processes."

Category Three: Consequences of implementing the technological foresight model in Iran's saffron packaging industry

This category included 41 themes grouped into three sub-categories: "research, innovation and quality improvement; challenges, limitations, and infrastructure; and opportunities, market, and sustainable development."

Category Four: Current status of Iran's saffron packaging industry

This section included 41 basic themes categorized into four groups: "branding and marketing challenges, production, processing and quality challenges, economic and structural challenges, and workforce and skills challenges."

Category Five: Desired status of Iran's saffron packaging industry

This section included 48 basic themes categorized into four sub-categories: "standardization and packaging quality, training, awareness and empowerment, export development and international support, and product diversification and innovation."

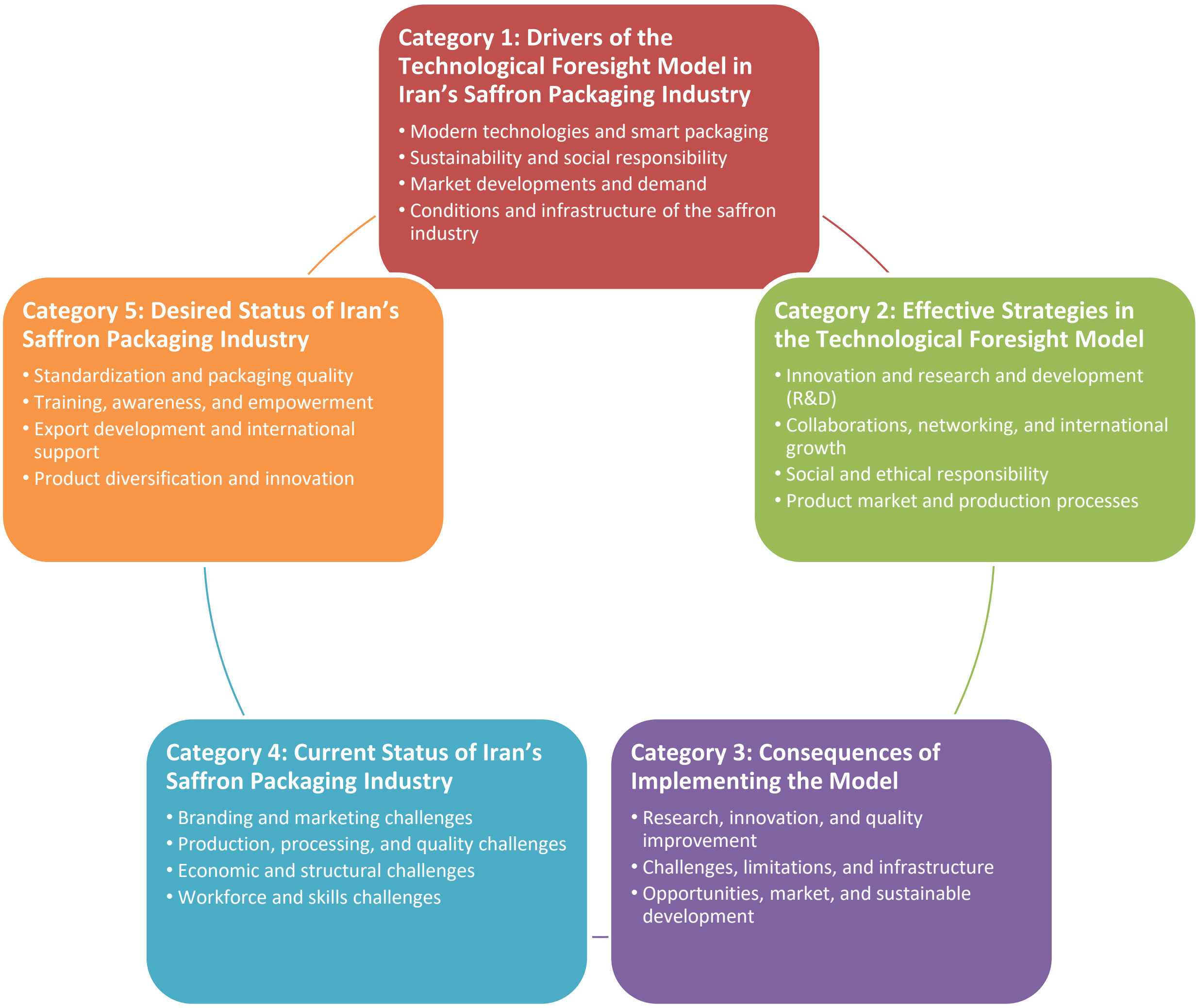
In this stage, efforts were made to place similar and parallel categories under the main themes based on conceptual commonalities. After preparing and arranging the table of concepts and preliminary categories as the first step of qualitative data analysis, the concepts were grouped at a higher and more abstract level to derive the main themes. After comparing the grouped categories, related categories were classified under an overarching theme. Based on existing titles in relevant theories or concepts derived from the research literature, comprehensive titles were assigned to these codes.

The purpose of the thematic network is to establish relationships among the generated categories. This process is usually carried out according to a paradigmatic model, helping the theorist to conduct the theorizing process more effectively. In the thematic network stage of the present study, the relationship between the main category and other categories was identified. At this stage, main and subcategories were linked together to collect theoretical concepts aimed at understanding the factors influencing the "technological foresight model in Iran's packaging industry (case study: saffron packaging)." These efforts allowed the researcher to integrate the concepts obtained in earlier stages and use them to present the thematic network.

This section describes how the data were analyzed and how basic, organizing, and global themes were extracted from the raw data derived from interviews. After transcribing the interviews, quotations that explicitly or implicitly addressed the research questions were selected, and from these, the basic, organizing, and global themes were extracted. The thematic network included 19 organizing themes arranged under five main global themes that had been identified from the outset. The thematic network is presented in Figure 1. As shown, in drawing the thematic network, only global themes and organizing themes were used, categorized under the global themes.

Figure 1.

Thematic Network of the Technological Foresight Model in Iran's Packaging Industry (Case Study: Saffron Packaging Industry)



• Synthesis of Expert Opinions on the Relationship Between Variables

At this stage, given the use of the ISM questionnaire, experts were invited to respond to the questions and exchange information through a brainstorming session. The experts accepted the invitation and either attended a one-hour session or sent their representatives. The main question had been shared with them in advance so they could attend with full awareness. The factors identified by the researcher were presented one by one and discussed by the participants. After collecting the questionnaires, the opinions of the experts were aggregated. The aggregation of opinions was carried out based on the frequency of responses. Finally, the synthesis of opinions was calculated.

• Formation of the Reachability Matrix

By converting the symbols of the relationships in the SSIM matrix into zeros and ones according to the following rules, the reachability matrix can be obtained. The rules are as follows:

a) If cell (i, j) in the SSIM matrix takes the symbol V, then the corresponding cell in the reachability matrix is assigned the value 1, and its reciprocal cell (j, i) is assigned 0.

b) If cell (i, j) in the SSIM matrix takes the symbol A, then the corresponding cell in the reachability matrix is assigned 0, and its reciprocal cell (j, i) is assigned 1.

c) If cell (i, j) in the SSIM matrix takes the symbol X, then both the corresponding cell and its reciprocal (j, i) are assigned the value 1.

d) If cell (i, j) in the SSIM matrix takes the symbol O, then both the corresponding cell and its reciprocal (j, i) are assigned the value 0.

After calculating the final reachability matrix, the levels of the model must be determined. Accordingly, the input and output sets for each factor are identified, and if the outputs and the calculated intersection set are identical, the factor belongs to that level. Otherwise, it is transferred to the next level. The results of the stratification of factors are presented below.

After calculating the final reachability matrix, the model levels must be identified. In this way, the input and output sets for each factor are specified. If the outputs and the intersection set match, the factor belongs to that level; otherwise, it is transferred to the next level. Based on the results obtained, three factors belong to the first level (the final level of influence). Accordingly, these three factors are removed from the calculations, and the remaining calculations continue without them. These three factors are: “production processes and product market, standardization and packaging quality, and product diversification and innovation.”

The results also showed that nine factors fall into the second level: “market developments and demand, conditions and infrastructure of the saffron industry, challenges, limitations and infrastructure, opportunities, market and sustainable development, production, processing and quality challenges, structural challenges, workforce and skills challenges, training, awareness and empowerment, and export development and international support.”

The only factor belonging to the third level is “sustainability and social responsibility.”

Three factors are classified at the fourth level of influence. These three factors are: “innovation and research and development, collaborations, networking and international growth, and social and ethical responsibility.”

The only factor related to the fifth level is “research, innovation and quality improvement.”

The remaining factors belong to the final two levels, six and seven. At level six, there are two factors: “branding and marketing challenges and economic challenges.” The only factor at level seven, which is the most influential, is “modern technologies and smart packaging.” Thus, all identified factors were placed across seven hierarchical levels.

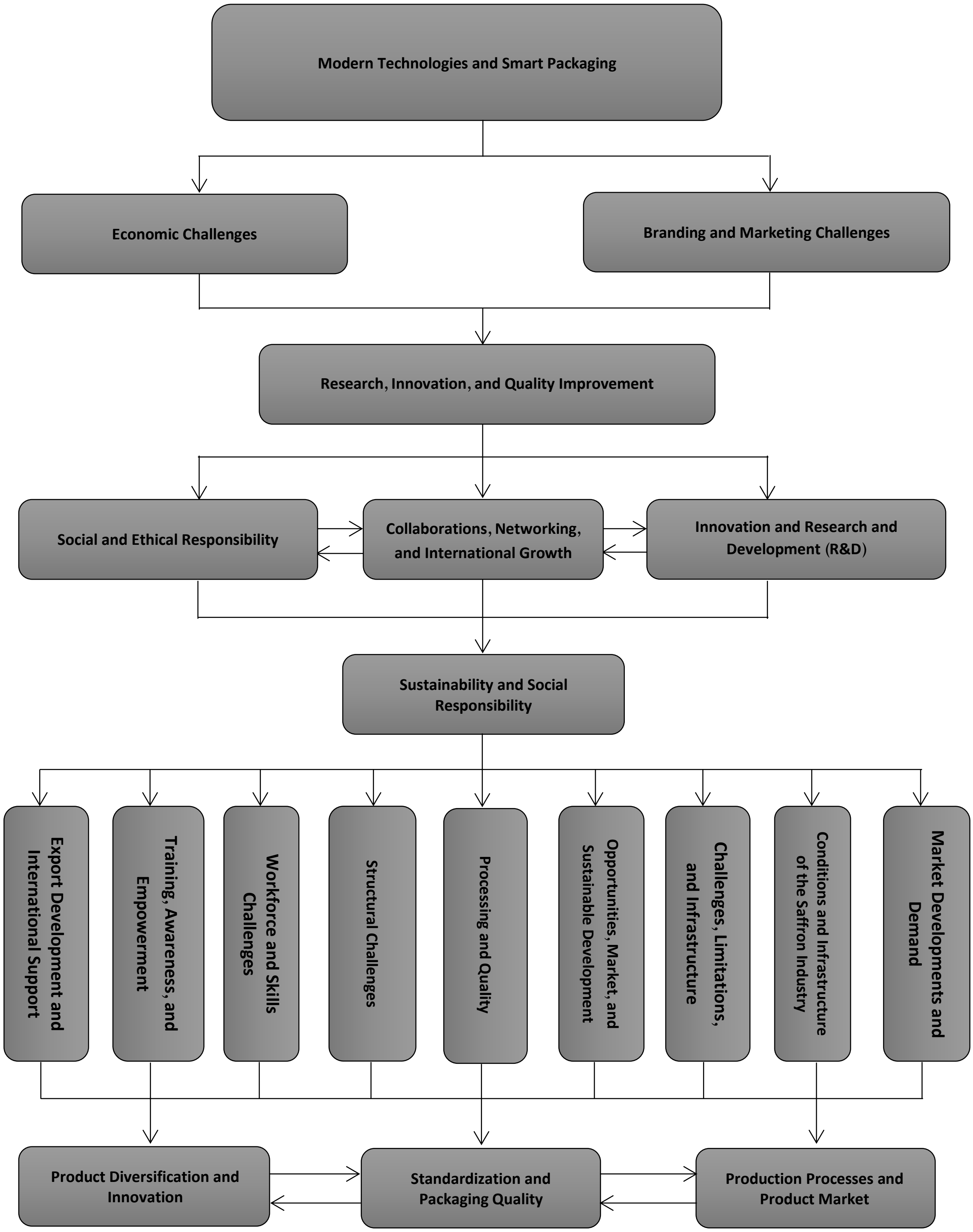
Table 1.

Final Levels of Research Variables

Level	Factors
Level 1	Production processes and product market — Standardization and packaging quality — Product diversification and innovation
Level 2	Market developments and demand — Conditions and infrastructure of the saffron industry — Challenges, limitations, and infrastructure — Opportunities, market, and sustainable development — Production, processing, and quality challenges — Structural challenges — Workforce and skills challenges — Training, awareness, and empowerment — Export development and international support
Level 3	Sustainability and social responsibility
Level 4	Innovation and research and development — Collaborations, networking and international growth — Social and ethical responsibility
Level 5	Research, innovation, and quality improvement
Level 6	Branding and marketing challenges — Economic challenges
Level 7	Modern technologies and smart packaging

Figure 2.

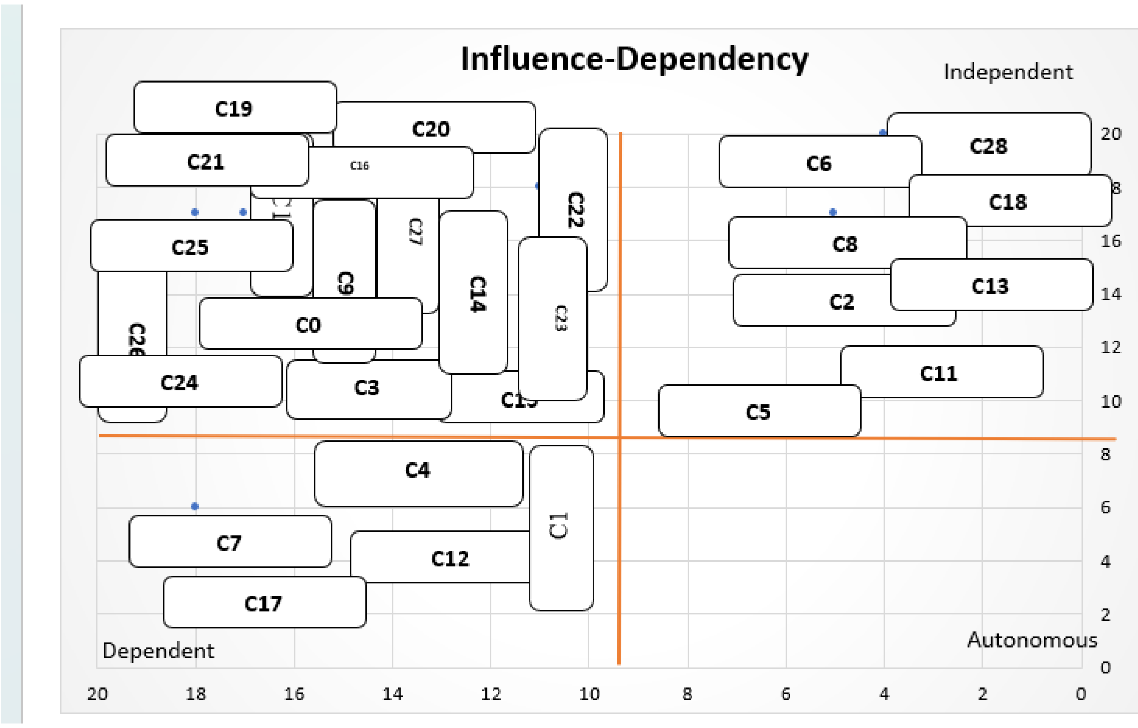
Final Model of Technological Foresight in Iran's Packaging Industry (Case Study: Saffron Packaging)



The purpose of MICMAC analysis is to identify and examine the influence and dependency power among factors. In this analysis, factors are classified into four categories based on their degree of influence and dependency. The first category includes autonomous variables, which have weak influence and weak dependency. These factors are relatively disconnected from the system and have few and weak relationships with it. Dependent factors form the second category, characterized by low influence but high dependency. The third category comprises linkage factors, which have high influence and high dependency. These factors are unstable, as any change in them can impact the system, and, in turn, system feedback can alter them again. The fourth category includes independent factors, which have strong influence but weak dependency. After the multi-level model was determined, the influence–dependency diagram was drawn as follows:

Figure 3.

MICMAC Diagram



In the independent quadrant (upper-right), factors with high driving power but low dependency are positioned. These represent the key drivers of the system, largely independent of other variables, and thus act as strategic levers in shaping the direction of technological foresight. Examples include C6, 28, 18, C8, C22, C13, and C11. In the ISM framework, such factors are typically located in levels 7 or 6, functioning as critical enablers for the rest of the system. The appropriate managerial response is to focus policy-making, allocate investments, and set implementation priorities around these drivers, as they are the most influential in guiding future trajectories.

In the linkage quadrant (upper-left), factors demonstrate both high driving power and high dependency, meaning they are simultaneously highly influential and highly sensitive to changes in other variables. This interdependence makes them particularly unstable and critical, as any shift in these factors creates a domino effect that reverberates throughout the system, while they themselves are also strongly shaped by the dynamics of other elements. Examples include a substantial group of C factors such as C16, C21, C20, and C25. Given their dual role, interventions in this zone must be carefully designed with simultaneous coordination and robust risk management, as mismanagement could amplify systemic vulnerabilities.

The dependent quadrant (lower-left) contains factors with low driving power but high dependency, positioning them as outcomes or results of the broader system. These factors are usually located in the lower levels of ISM (levels 1 or 2), reflecting their role as consequences rather than initiators of change. Examples include C7, C17, C12, and others. While these elements do not independently drive systemic transformation, they are crucial as evaluative indicators of the effectiveness and success of upstream strategies. Monitoring their performance enables managers to assess whether high-level interventions are producing the intended results and to recalibrate strategies where necessary.

Finally, the autonomous quadrant (lower-right) represents factors with both low driving power and low dependency. These elements are largely isolated from the system and exert minimal influence while also being minimally affected by other variables. In this study's model, it is noteworthy that no factors fell into this quadrant. This absence suggests that all identified factors have meaningful systemic relevance, either as drivers, linkages, or dependent outcomes. The lack of autonomous variables strengthens the model by confirming that each identified factor contributes directly or indirectly to the technological foresight structure in the saffron packaging industry.

Discussion and Conclusion

The findings of this study revealed a multi-layered framework of factors influencing technological foresight in the Iranian saffron packaging industry. Using thematic analysis and interpretive structural modeling (ISM), the results demonstrated that the identified variables could be structured across seven hierarchical levels, ranging from operational factors such as production processes and packaging quality to strategic drivers such as modern technologies and smart packaging. This hierarchy not only confirms the systemic complexity of technological foresight but also underscores the critical role of advanced technologies in shaping the future trajectory of the saffron packaging industry. The placement of "modern technologies and smart packaging" at the highest level of influence reflects the global transition toward innovation-driven packaging and the importance of adopting intelligent solutions for product quality, sustainability, and market competitiveness.

These results resonate with international studies that highlight the role of advanced materials and nanotechnology in driving innovation within the packaging sector. Research on carboxymethyl chitosan-based films, for instance, demonstrates how functional developments in packaging materials can transform industry practices by enhancing shelf life, improving safety, and promoting environmental sustainability [7]. Similarly, nanotechnology has been identified as a major driver of sustainable packaging systems, providing competitive advantage to firms that can integrate it into production and logistics chains [9]. The growing body of work on nanocellulose-based packaging further illustrates how technical innovation in material science can reshape market expectations and consumer perceptions [8]. These global insights are directly applicable to the Iranian saffron packaging industry, where market expansion depends not only on preserving product quality but also on aligning with international environmental and safety standards.

The study also showed that intermediate-level factors—such as market developments, infrastructural conditions, and training and empowerment—play a bridging role between strategic drivers and operational outcomes. These factors correspond to the "linkage" category in the MICMAC analysis, where elements are both highly influential and highly dependent. Such findings align with previous research emphasizing the interdependence of policy, industry conditions, and human capital in shaping catch-up processes. For example, work on technological upgrading in emerging economies has stressed that knowledge flows, institutional frameworks, and human resources collectively condition the pace of catch-up [4]. In the case of solar technologies, patent metadata analyses confirm that knowledge diffusion across national systems is crucial for enabling latecomer countries to absorb and deploy new technologies [18]. This reinforces the need for Iran's saffron packaging industry to focus not only on technological investment but also on strengthening educational and institutional infrastructure to support the effective adoption of advanced packaging technologies.

Another important outcome of this study is the identification of dependent factors—such as branding and marketing challenges, workforce skills, and economic barriers—that reflect the systemic consequences of weaknesses in higher-level drivers. These dependent factors are often used as outcome indicators for the success of policy and industry-level interventions. Prior literature similarly points out that catch-up success cannot be measured only by technical adoption but must also account for branding, market positioning, and workforce capacity. For instance, in the software industry, the role of technological capability was shown to directly influence branding and competitiveness in global markets [27]. Furthermore, the Iranian steel industry's catch-up experience highlights how structural and marketing challenges limit the capacity of firms to translate technical improvements into sustainable international competitiveness [11]. These parallels suggest that for saffron packaging, overcoming downstream challenges in branding, market access, and workforce training is as critical as adopting advanced technologies.

The centrality of innovation and research and development (R&D) in the model is consistent with prior scholarship on catch-up strategies. Research on latecomer economies emphasizes that firms and industries can move from lagging positions to leadership by strategically leveraging "windows of opportunity" created by shifts in global industries [5]. Empirical evidence from CNC machine tools in China shows how collaborative networks and industrial value chains foster collective innovation and strengthen R&D capacities [22]. Likewise, the role of product architecture in green industries demonstrates that innovation is not only about resource investment but also about how firms design and integrate modular systems to achieve flexibility and competitiveness [21]. These insights support the study's finding that innovation-driven strategies, including collaborations and international networking, are pivotal for the Iranian saffron packaging sector to maintain competitiveness and achieve long-term sustainability.

From a broader perspective, the results also confirm that technological foresight in saffron packaging cannot be understood in isolation but must be contextualized within global value chains and governance structures. Studies on the coffee industry, for instance, reveal that governance asymmetries in global value chains shape opportunities for latecomer economies to achieve upgrading [16]. Similarly, international technology transfer research indicates that traditional North-South models are insufficient and that more adaptive frameworks are needed for countries seeking to catch up [19]. For Iran, this implies that achieving foresight in saffron packaging requires engagement with global standards and partnerships, while simultaneously building domestic capacities to mitigate dependency risks.

The results also highlight the importance of social responsibility and sustainability as intermediate factors. The presence of "sustainability and social responsibility" as a distinct level in the ISM model underscores its mediating role between technological drivers and operational outcomes. Prior studies similarly argue that technological catch-up is increasingly inseparable from environmental and social considerations. For example, sustainability-driven transitions have been analyzed as key to understanding long-term industrial upgrading [25]. Moreover, research in polysaccharide-based packaging highlights how social and ecological imperatives shape the direction of innovation [10]. This reflects the necessity for Iranian saffron packaging firms to embed sustainability principles not only as compliance measures but as central strategic objectives for competitive differentiation in international markets.

The dependent role of institutional and policy frameworks is another theme reinforced by this study. Historical evidence from Korea's capital goods industry demonstrates that sectoral innovation systems provide the necessary institutional structure for sustained catch-up [1]. Studies on China's offshore oil and gas equipment industry confirm the enabling role of government policies in supporting supply chain integration and fostering innovation [17]. Similarly, Iranian research on petrochemicals and nuclear technologies highlights the importance of coherent policies and capability-building models in overcoming systemic challenges [12, 13]. For saffron packaging, policy intervention will be critical in providing incentives for innovation, facilitating export-oriented standards, and mitigating the risks associated with global competition.

Furthermore, the identification of economic and branding challenges at level six of the ISM model reflects the downstream vulnerabilities of the saffron packaging industry. These findings are consistent with research on the maritime and defense industries, which highlights that without addressing structural and market-facing challenges, technological investments alone are insufficient for long-term catch-up [14]. Similarly, research on Chinese enterprises illustrates that institutional-led markets play a critical role in ensuring that technological improvements translate into competitive performance [6]. Therefore, policy and industry leaders in Iran must prioritize strategies that integrate marketing innovation and economic resilience alongside technological upgrading.

Finally, the position of "modern technologies and smart packaging" at the top of the hierarchy validates the transformative role of digitalization, smart materials, and intelligent systems in shaping the future of packaging industries. Studies on innovation performance in China show that forward and reverse engineering both contribute to catch-up outcomes [23]. Moreover, an asymmetry-based view emphasizes that technological catch-up often involves navigating global imbalances while strategically leveraging strengths [3]. These perspectives reinforce the conclusion that for Iran's saffron packaging industry, technological foresight will hinge on the ability to integrate cutting-edge smart technologies with local capabilities and institutional support.

This study is subject to several limitations that must be acknowledged. First, the qualitative phase relied on interviews with a relatively small sample of experts and managers in the saffron packaging industry. Although theoretical saturation was reached, the sample size may limit the generalizability of the findings to other industries or broader national contexts. Second, the study employed ISM and MICMAC methodologies, which, while robust, are inherently dependent on expert judgment in structuring relationships among factors. This reliance introduces the potential for bias and subjectivity in the stratification of variables. Third, the focus on saffron packaging in Iran provides valuable contextual insights but may not fully capture the dynamics of other export-driven industries or different packaging sectors. Lastly, data collection was constrained by access limitations, particularly given the sensitivity of industrial and policy-related information in Iran, which may have restricted the depth of analysis in certain areas.

Future studies should consider expanding the scope of research by incorporating larger and more diverse samples, including stakeholders from international markets, policymakers, and consumers, to triangulate findings more effectively. Comparative studies across industries—such as petrochemicals, pharmaceuticals, and food processing—could also provide a broader understanding of technological foresight mechanisms. Methodologically, future research could employ hybrid approaches that integrate ISM with quantitative modeling techniques, such as structural equation modeling (SEM) or system dynamics, to validate and expand upon the hierarchical structures identified in this study. Additionally, longitudinal studies that track changes in technological foresight over time would be valuable in capturing the dynamic nature of innovation, market developments, and policy interventions. Finally, greater attention should be paid to the role of digitalization, artificial intelligence, and blockchain technologies in shaping the future of packaging and supply chain systems, offering a forward-looking perspective on the industry's evolution.

From a practical standpoint, industry leaders in the saffron packaging sector should prioritize investments in modern technologies and smart packaging, recognizing their central role as identified in this study. Policymakers should focus on creating an enabling environment through supportive regulations, financial incentives, and international cooperation mechanisms to facilitate innovation and export competitiveness. Capacity-building initiatives, including workforce training and managerial development, are necessary to ensure that technological advances are effectively adopted and utilized. Moreover, firms should embrace sustainability and social responsibility as integral components of their competitive strategy, aligning with global market expectations and consumer demands. Finally, strengthening branding, marketing innovation, and economic resilience will be critical to translating technological investments into long-term competitive advantage in both domestic and international markets.

Acknowledgments

We would like to express our appreciation and gratitude to all those who cooperated in carrying out this study.

Authors' Contributions

All authors equally contributed to this study.

Declaration of Interest

The authors of this article declared no conflict of interest.

Ethical Considerations

The study protocol adhered to the principles outlined in the Helsinki Declaration, which provides guidelines for ethical research involving human participants. Written consent was obtained from all participants in the study.

Transparency of Data

In accordance with the principles of transparency and open research, we declare that all data and materials used in this study are available upon request.

Funding

This research was carried out independently with personal funding and without the financial support of any governmental or private institution or organization.

References

[1] Y. Z. Kim and K. Lee, "Sectoral innovation system and a technological catch-up: the case of the capital goods industry in Korea," *Global economic review,* vol. 37, no. 2, pp. 135-155, 2008, doi: 10.1080/12265080802021151.

[2] K. Lee and F. Malerba, "Changes in Industry Leadership and Catch-up by the Latecomers: Toward a theory of catch-up cycles," ed, 2014.

[3] J. Wei, D. Wang, and Y. Liu, "Towards an asymmetry-based view of Chinese firms' technological catch-up," *Frontiers of Business Research in China,* vol. 12, pp. 1-13, 2018, doi: 10.1186/s11782-018-0041-y.

[4] J. D. Lee, S. Radosevic, D. Meissner, and N. Vonortas, "Technology Upgrading and Economic Catch-Up," in *The challenges of technology and economic catch-up in emerging economies*, 2021, pp. 1-34.

[5] Y. Li, Y. Teng, D. Wu, and X. Wu, "From lagging behind to going beyond: windows of opportunity and latecomers' catch-up strategies," *European Journal of Innovation Management,* vol. 28, no. 3, pp. 978-1009, 2025, doi: 10.1108/EJIM-04-2023-0300.

[6] J. Wei, C. Sun, Q. Wang, and Q. Pan, "The critical role of the institution-led market in the technological catch-up of emerging market enterprises: evidence from Chinese enterprises," *R&d Management,* vol. 50, no. 4, pp. 478-493, 2020, doi: 10.1111/radm.12399.

[7] J. Su, W. Zhang, Z. Moradi, M. Rouhi, E. Parandi, and F. Garavand, "Recent functionality developments of carboxymethyl chitosan as an active food packaging film material," *Food chemistry,* vol. 463, p. 141356, 2025, doi: 10.1016/j.foodchem.2024.141356.

[8] X. Wang *et al.*, "Research progress of nanocellulose-based food packaging," *Trends in Food Science & Technology,* vol. 143, p. 104289, 2024, doi: 10.1016/j.tifs.2023.104289.

[9] S. Ghosh, R. K. Mandal, A. Mukherjee, and S. Roy, "Nanotechnology in the manufacturing of sustainable food packaging: a review," *Discover Nano,* vol. 20, no. 1, p. 36, 2025, doi: 10.1186/s11671-025-04213-x.

[10] Q. B. Yao *et al.*, "Polysaccharide-based food packaging and intelligent packaging applications: A comprehensive review," *Trends in Food Science & Technology,* vol. 147, p. 104390, 2024, doi: 10.1016/j.tifs.2024.104390.

[11] J. Soltanzadeh, S. Rahmani, and M. Majidpour, "Technological catch-up in the Iranian steel industry: Integrating regime-based and complex product systems approaches," *Resources Policy,* vol. 89, p. 104601, 2024, doi: 10.1016/j.resourpol.2023.104601.

[12] J. f. Jafari Tuyeh and M. Norouzi, "Identifying and Prioritizing Policies to Counter Technological Catch-up Failures in Iran's Petrochemical Industry," *Iranian Journal of Public Administration Studies,* 2024, doi: 10.22034/jipas.2024.392404.1581.

[13] M. Fakhimi and F. Saqafi, "Challenges of Technological Catch-up in the Nuclear Industry and the Development of a Capability-Building Model in This Industry," *Science and Technology Policy,* vol. 15, no. 2, pp. 1-20, 2022, doi: 10.22034/jstp.2022.1393.

[14] A. Maleki Karam Abad, Manteghi, Abdi, and Behnam, "Conceptualizing Technological Catch-up in the Maritime Industries of the Defense Sector," *Military Management Quarterly,* vol. 19, no. 76, pp. 69-102, 2019.

[15] S. Habiba and E. Kalantari, "Investigating the Role of Intellectual Property Rights Policy in the Technological Catch-up of Developing Countries," *Public Policy Quarterly,* vol. 3, no. 2, pp. 135-152, 2017.

[16] U. M. Lima and K. Lee, "Governance and asymmetry in global value chains of the coffee industry: Possibility for catch-up by emerging economies," *Seoul Journal of Economics,* vol. 36, no. 1, 2023.

[17] Y. Li, H. Li, and J. Tan, "Technological catch-up and innovations of China's offshore oil and gas equipment-manufacturing industry: The role of the supply chain and government policy," *Journal of Cleaner Production,* vol. 365, p. 132681, 2022, doi: 10.1016/j.jclepro.2022.132681.

[18] M. Nouri Zadeh and A. Maleki, "Modeling the Flow of Knowledge in Countries' Catch-up in Solar Technologies Using Patent Metadata," *Journal of Technology Development Management,* vol. 9, no. 3, pp. 137-167, 2021.

[19] A. Ponomarev and T. Gareev, "International technology transfer: In search of a new model for catching-up countries," *Terra Economicus,* vol. 23, no. 2, pp. 6-20, 2025, doi: 10.18522/2073-6606-2025-23-2-6-20.

[20] M. Safdari Ranjbar, "Conceptualizing Technological Authority from the Perspective of Technological Catch-up: Indicators, Requirements, and Policy Solutions," *Rahyaft,* vol. 32, no. 4, pp. 65-84, 2022, doi: 10.22034/rahyaft.2023.11416.1427.

[21] T. Matsuo, A. Malhotra, and T. S. Schmidt, "Catching-up in green industries: the role of product architecture," *Innovation and Development,* vol. 14, no. 1, pp. 135-164, 2024, doi: 10.1080/2157930X.2022.2115192.

[22] W. Liu, D. Guo, and J. Rogers, "Catch-up of CoPs in GIS and IVC: evidence from Chinese CNC machine tools," *Science and Public Policy,* p. scae086, 2025, doi: 10.1093/scipol/scae086.

[23] G. Zhang and J. Zhou, "The effects of forward and reverse engineering on firm innovation performance in the stages of technology catch-up: An empirical study of China," *Technological forecasting and social change,* vol. 104, pp. 212-222, 2016, doi: 10.1016/j.techfore.2016.01.010.

[24] F. Saqafi, A. Mohaghegh, M. Kashihan, and N. Dastranj, "Designing a Conceptual Model for Post-Catch-up Technology (Case Study: Oil Turbo Compressor Company Under Sanctions)," *Rahbord (Strategy),* vol. 29, no. 95, pp. 53-81, 2020.

[25] S. Rahmani, M. Alizadeh Sani, M. Majidpour, and M. Valipour Khatir, "A Look at Technological Studies from the Perspective of Sustainable Transitions: A Meta-synthesis Approach," *Science and Technology Policy,* vol. 12, no. 1, pp. 73-90, 2020.

[26] A. Daghayeqi, A. Jafarnejad Choghoushi, and N. Bagheri Moghadam, "The Formation of Technological Capabilities for Catch-up in Complex Products: (A Study of Equipment for Deviated Oil and Gas Well Drilling)," *Journal of Technology Development Management,* vol. 9, no. 2, pp. 13-45, 2021.

[27] M. A. Sharifeh and A. Bonyadi Naeini, "Investigating the Effective Factors on the Success of the Technological Catch-up Process in Iran's Software Industry with Emphasis on the Role of Technological Capability," 2016.