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The Role of Coopetition in Fostering Innovation and Growth in New Technology-based Firms: A Game Theory Approach

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ABSTRACT

Objective: New technology-based firms (NTBFs) are key actors in creating value through innovation, but they face significant challenges in the rapidly changing and competitive technological environment. **Methods:** This research is a multi-method analysis aiming to present a model of relationships among drivers for collaboration and competition among technology-based companies and identify effective actions and policies to enhance coopetition (cooperation and competition) that can boost the ability of NTBFs to grow and commercialize innovations. The methodology of this study is exploratory in nature. Thus, it employs literature review method for gathering qualitative data, Fuzzy Delphi method for collecting data from experts, and DEMATEL-ISM method for modeling the relationships among drivers and demonstrating the impact of coopetition on the performance of NTBFs. **Results:** The research findings show that coopetition can improve growth, innovation, and commercialization in NTBFs by overcoming technological and competitive limitations. **Conclusions:** The study offers practical and social implications for managers, policy makers, and economic development by highlighting the role of coopetition in fostering innovation and prosperity.

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INTRODUCTION

The creation and success of new technology-based firms (NTBFs) are the basis of economic prosperity (Yazdanpanah et al., 2023) and one of the key drivers of innovation policies and strategies in developed and developing countries (Ferràs-Hernández et al., 2021). Technological innovation is associated with a set of knowledge and scientific methods and focuses on designing and implementing something bigger than what now exists, like launching new products, methods of production or redesigning organizational processes, etc. (Choi et al., 2020; Xiao & Su, 2022). Innovation in technology-based firms can be a source of long-term profit by creating new products and services and successfully introducing them to the market. This is because innovation helps them increase sales and competitive advantage, and improve their performance in the face of rapid technological changes (Ahn et al., 2022; Le et al., 2023; Ramos-Hidalgo et al., 2022; Tran et al., 2023).

New technology-based firms have technology as a strategic asset and contribute significantly to the production and diffusion of technological innovations in the industries they operate in (Arantes et al., 2019), and play a key role in productivity growth, wealth creation, employment opportunities, industries, promotion of innovations, and consequently, economic development and growth (Hemmert et al., 2022; Heydebreck et al., 2000; Lynskey, 2016; Storey & Tether, 1998). Generally, new technology-based firms are a group of small and medium-sized firms influenced by technological capacity that are pursuing innovation (Acosta-Prado, 2020). New technology-based firms can create value for their customers, target investors and achieve long-term and sustainable growth by offering new goods and services (Salamzadeh, Dana et al., 2022). They struggle to survive and reduce the likelihood of failure in different industries in the early years of their operation (Aspelund et al., 2005).

The findings of Löfsten (2016, 2022), while stating that many of these new firms have a low survival rate in their early years (Löfsten et al., 2022), explain how the behavior and competition of new technology-based firms may affect the firm's survival during the first few years of their operation (Löfsten, 2016). Competition between firms is divided into technological and non-technological competitive relationships and among these relations, technological competition is the most important (Wen et al., 2021). Competition between firms leads to their focus on improving innovative performance, but it weakens cooperation and leads to a rapid increase in research and development costs (Huang, 2023). Currently, with the change of policies of many firms, the goal of competition is not to destroy or drive out competitors from the market, but to create a win-win situation for all various participants in the market (Korolev et al., 2021). Therefore, in today's business environment with market complexity and uncertainty, rapid trend of technological change, and intense competition, coopetition (cooperation and competition) is important for the firm's growth potential (Chen & Yu, 2022) since it provides better access to external knowledge and resources (Tsai, 2002), shares the risk, saves costs of R&D activities, and reduces market uncertainty (Bagherzadeh et al., 2022).

In this framework, one can benefit from the applications of game theory for coopetition (Pujats et al., 2020) and adopt business planning strategy to improve business performance (Avotra et al., 2022). Game theory is a mathematical approach to model the decision-making process in cooperative or conflicting situations (Karabiyik et al., 2020; Lucas, 1972). It assumes that a competitor can be the best partner in a competitive market environment (Heiets et al., 2021). There are two types of game theory for decision-making: cooperative and non-cooperative games (Mirzaei-Nodoushan et al., 2022). The main distinction between the two is that non-cooperative game theory is chiefly about maximizing participant's interests through the optimization process of their decision and therefore does not have binding agreements between players (Huang & Li, 2022), while cooperative game theory is actually mainly based on agreements for the allocation of participatory benefits (Parrachino et al., 2006) and leads to the best performance (Boujnoui et al., 2022).

By reviewing the studies conducted in the past, it can be stated that there is a lack of studies on NTBFs that provide empirical evidence on the factors/drivers of coopetition in the context of technology-based companies, which creates a theoretical gap that needs to be filled with this empirical research. In this regard, we have the following research question: What are the effective drivers of collaboration and competition among technology-based companies, what relationships exist among them, and what is the resulting model of relationships among these drivers?

In order to fill this gap, the aim of this research is to present a model of relationships among drivers for collaboration and competition among NTBFs to determine the actions and policies that influence their coopetition in relation to technology, aiming to stimulate actions and policies with a view to the future. Managers should recognize the importance of supporting NTBFs in a coopetitive environment to ensure a sustainable and flourishing ecosystem. In this way, managers can develop targeted strategies and policies that enhance technological innovation and provide access to resources and guidance. Such support can help improve the competitive advantage and development of NTBFs and position them as key drivers of economic prosperity. However, there is a lack of studies that examine the factors/drivers of coopetition in the context of technology-based companies, and provide empirical evidence on the actions and policies that influence their coopetition in the face of technology. This research aims to fill this gap by using a mixed exploratory method and by determining the actions and policies that affect their coopetition in relation to technology.

THEORETICAL FOUNDATION

New technology-based firms (NTBFs)

The fourth industrial revolution has taken shape with manufacture and supply 'new technologies' (Dymitrowski & Mielcarek, 2021). In this framework, there is a group of firms influenced by new technologies that are pursuing innovation (Acosta-Prado, 2020). Some firms act as a tool for transferring technology from their parent organization to a new firm and as a means for acquiring and disseminating technology (Li et al., 2019). These firms are known as new technology-based firms (NTBFs) (Acosta-Prado, 2020). NTBFs use knowledge-based technologies, employing skilled and educated labor force (Borges et al., 2021). There is still no agreement on the key characteristics of NTBFs. This lack of consensus in the conceptualization of NTBFs prevents the adequate application of the concept or comparison between different existing studies (Cunha et al., 2013; Sońta-Drączkowska & Mrożewski, 2020;Salamzadeh, Mortazavi et al., 2023). Generally, NTBFs are defined as firms that: (1) are small (with less than 50 employees) or small and medium-sized (more than 50 and less than 250 employees); (2) have independent ownership in which an entrepreneur owns the majority of shares and independent investment from capital groups; (3) are less than 25 years old; (4) and operate in an advanced technology or knowledge-intensive industry (Cunha et al., 2013; Sońta-Drączkowska & Mrożewski, 2020; Fudickar & Hottenrott, 2019).

Technological advantage is the basic element of the fundamental strategies of NTBFs (Thomson, 2022). NTBFs tend to have higher financial performance levels and market value and a greater chance of survival in the dynamic market where they operate (Modolo et al., 2021). These firms, due to their entrepreneurial orientation and technological capabilities, will be more successful in benefiting from international opportunities (Salamzadeh, Hadizadeh, & Mortazavi, 2022).

NTBFs have attracted considerable interest from most transition economies, as they will be able to create more added value by using more knowledge in their organization (Farnoodi et al., 2020; Meysami et al., 2022). They are seen as an engine of technological changes that is an important source for intensifying market competition, accelerating industrial evolution (Ejermo & Xiao, 2014), new employment, product and service innovation, and ultimately economic growth (Almus & Nerlinger, 1999; Ganotakis, 2012).

Iran has been studied as an example within the framework of NTBFs, as Iran is undergoing a transition from a resource-based economy to a knowledge-based economy. Iran's goal is to move from a natural resource-based economy to a knowledge-based economy by following the long-term comprehensive national development plan, the roadmap known as Vision 2025 (Kanani & Goodarzi, 2017). As a result, many new technology-based firms have become new actors in the innovation ecosystems in Iran (Naghizadeh et al., 2021). These are emerging market firms in Iran (Dastkhan, 2022). Iranian NTBFs face various challenges such as financial challenges, human resource management, support actions and mechanisms, and lack of access to international markets due to sanctions (Salamzadeh et al., 2021). About 3% of the gross domestic product (GDP) of Iran belongs to the NTBFs established in the country (Yazdanpanah et al., 2023). They need development and they reflect on their management practices and organizational learning processes and the capabilities they need to develop to achieve competitive advantage (Acosta-Prado et al., 2021). However, developing NTBFs is not a simple process. They require an effort and investment in research and development (Vargas et al., 2020), and incur significant costs, while uncertainty about technology life cycle may limit available capital (Pary & Witmeur, 2019). Therefore, the approach of NTBFs for success and growth must move in the right and optimal direction to achieve national economic growth through innovation, entrepreneurship and increasing their share in gross domestic product.

Coopetition among new technology-based firms

Technology strategy is one of the most important factors in the financial performance and also in the general and internal performance of NTBFs (García-Cabrera et al., 2019), which can be defined by considering the emerging technologies, changes in the strategies and structures of other businesses, as well as changes in the competitive nature of businesses (Montiel Campos et al., 2009). One of the most important factors that encourage firms to use more advanced technologies is competition. However, what is optimal competition, and do firms always have to beat their competitors? The answers to these questions have initiated a review trend in the competition among NTBFs (Korolev et al., 2021; Salamzadeh, Hadizadeh, Rastgoo et al., 2022). Nowadays, firms success requires that they pursue both competition and cooperation strategies simultaneously (coopetition), playing an important role in their performance improvement and providing innovative products by creating a balance between both strategies (Czachon & Mucha-Kuś, 2014; Quintana-García & Benavides-Velasco, 2004; Rastgoo et al., 2021), but we usually do not want to consider that a firm can be in a coopetition position with our firm (Luo et al., 2006; Quintana-García & Benavides-Velasco, 2004). The competitive market and a dynamic business environment make coopetition a dynamic strategy for many firms, especially those that lack the resources to cope with innovation challenges and take advantage of environmental opportunities (Devece et al., 2019). Coopetition acts as 'an important domain for industrial performance' and has become increasingly popular for firms in recent years. Multinational corporations create synergy through coopetition where local units cooperate to achieve the objectives of their parent company while competing for resources provided by that company (Pant & Yu, 2018). According to Bengtsson and Kock's (2014) coopetition is defined as: "A paradoxical relationship between two or more actors, regardless of whether they are in horizontal or vertical relationships, who are simultaneously involved in cooperative and competitive interactions" (p. 180). Coopetition does not refer to cases where cooperation occurs in one period and competition in another. Based on coopetition, competitors cooperate in some areas while competing in others (Luo, 2007). Coopetition as a paradoxical concept (Dagnino, 2009; Raza-Ullah et al., 2014) is an essential element for achieving competitive advantage, efficiency achievements, performance improvement in economics, finance, market, and innovation, especially when competitors attain inter-firm learning (Bengtsson & Raza-Ullah, 2016; Burström et al., 2022; Fredrich et al., 2019; Mierzejewska et al., 2023; Molling et al., 2023).

Coopetition strategy is a cooperation and competition between competitors to capture value for them by accessing to external resources and capabilities especially in the areas of R&D and market (Bouncken et al., 2020; Dagnino, 2009; Rai et al., 2023; Riquelme-Medina et al., 2022). The best and most complex inter-firm relationships today can be between firms in the same industry, i.e., competitors (Bengtsson & Kock, 2000; Bouncken et al., 2020). Therefore, they are influenced by exchanges between sharing costs and control, and collaboration versus competition (Corbo et al., 2023). Examples include pharmaceutical companies working together to produce vaccines, charities forming alliances for a common goal, and large technology-oriented companies collaborating for greater benefits (Crick & Crick, 2020; Salamzadeh, Mortazavi et al., 2022). Also, using the phenomenon of coopetition in a wide range of global industries and firms such as the automotive industry demonstrate the increasing importance of this phenomenon (Brandenburger & Nalebuff, 2021; Luo, 2007; Ritala & Hurmelinna-Laukkanen, 2009; Ritala et al., 2014)

Coopetition can be considered as a key strategy for NTBFs in developing economies (Feela, 2020). The innovative activities associated to research and development in NTBFs involve many risks and costs and coopetition strategy is one of the key drivers that can be used in this situation (Molling et al., 2023; Salamzadeh, Hadizadeh, Rastgoo et al., 2022). Coopetition is important for improving the innovative performance of SMEs (Devece et al., 2019). The results have shown that firms cooperating with their competitors are likely to perform better than firms that do not use the resources and knowledge of their competitors (Avotra et al., 2022). These coopetitions involve improving existing solutions or creating new services, products, and processes and both firms share the risks and costs of innovative actions (Corbo et al., 2023). This strategy enhances the ability of NTBFs to develop innovative and effective technologies (Gnyawali & Park, 2009; Salamzadeh, Rezaei et al., 2023) and improves their survival rate (Feela, 2020). Such an action provides learning opportunities for firms, whereas coopetition can create challenges (Morris et al., 2007) and increase the risk of proprietary knowledge misuse that needs to be addressed (Ritala & Hurmelinna-Laukkanen, 2013; Runge et al., 2022. Therefore, NTBFs should be careful about the competitors they cooperate with, as it can have detrimental effects on their performance (Crick & Crick, 2020).

Technology-based coopetition and game theory

Game theory was created to fill the gap of understanding a person's decisions in economics, where one person's decision affects the decision of others (Ozkan-Canbolat et al., 2016). When all businesses are assumed to be rational in a competitive market and each one is trying to predict the actions and possible reactions of their competitors, it focuses on optimal decision-making (Brickley et al., 2000). The concept of coopetition as a key strategy of inter-firm relationship in the market place was developed in the work done in game theory by Nalebuff and Brandenburger (1996). The traditional approach in competitive market that was based on the 'win-lose' scenarios led to the loss of countless opportunities. However, in the mid-1990s, the trend of moving from inter-firm competition and cooperation separately toward coopetition as a 'win-win' scenario was created (Bouncken et al., 2015; Dana, Salamzadeh, Hadizadeh et al., 2022; Nalebuff & Brandenburger, 1996; Padula & Dagnino, 2007; Walley, 2007). Coopetition has always been associated with game theory and has also been addressed in various studies (Gelei & Dobos, 2023; Rodrigues et al., 2011). Coopetition studies describe it from a game theory perspective and consider it as balanced win-win relationships (Klimas et al., 2023; Galkina & Henriksson, 2017; Salamzadeh, Hadizadeh, Rastgoo et al., 2022). Game theory can explain the behavior of firms in relation to each other in the competitive environment (Okura & Carfi, 2014). Eventually, game theory takes an optimistic view to coopetition. Therefore, simultaneous cooperation and competition with competitors is a better strategy in various aspects (Le Roy et al., 2018). Game theory assumes that the best partner of a business in today's market is a competitor. It implies that coopetition with such a partner provides an appropriate strategy and is a beneficial tool for decision-making processes (Heiets et al., 2021). Based on this theory, coopetition involves logical reasoning that cooperate based on inter-firm partnerships to create total value and then compete for its division (Luo, 2005; Ritala, 2012). According to this theory, in coopetition as a game, the preferences and interests of the firms that are providing coopetition strategy are developed to some extent (Heiets et al., 2021). Coopetition in game theory is based on the 'tit for tat' strategy in solving prisoner's dilemma, in order to limit opportunistic behavior in the coopetitive relations. This also applies to the sustainable growth (Cygler et al., 2018;Dana, Salamzadeh, Mortazavi et al., 2022; Nayeri et al., 2022).

The benefits of using game theory for coopetition studies have been well investigated in previous studies. The first benefit is that game theory is a very suitable method for analyzing market structures and conditions in relationships among firms. This is because it can clarify situations where a firm's decision directly affects the returns of their competitors. The second benefit is that game theory can easily analyze inter-firm complex relationships by aspects of coopetition stage by stage. The third benefit is that results from game theory are very rigorous and generalizable and provide solutions to solve complex problems (Okura & Carfi, 2014)

Recent literature

Several studies have examined the phenomenon of coopetition from different perspectives and contexts. For example, Chin et al. (2008) conducted a study to identify the key success factors for coopetition strategy in the Hong Kong industry. They used a Fuzzy Delphi method to collect and analyze data from experts in various sectors. The results show that management leadership and trust development are the most important factors for coopetition strategy. Based on the identified factors, the authors propose a hierarchical model for managing coopetition strategy that consists of four levels: strategic level, tactical level, operational level, and control level. The model can facilitate the formulation of action plans for better coopetition management.

In our examination of recent literature on coopetition, we aim to draw a cohesive thread through studies that, while diverse in focus and sector, collectively illuminate the nuanced impact of coopetition on innovation and growth. Recognizing the variation in the recency and objectives of these studies, we categorize them into thematic groups that reflect their relevance to our investigation. This organization allows us to highlight the multifaceted nature of coopetition and its varied effects across different industries. We specifically focus on studies that, regardless of their sectoral focus — from technology startups to established manufacturing firms —, provide insights into the strategic utilization of coopetition for overcoming common challenges in innovation and market positioning. For instance, Corbo et al. (2023) in the technology sector and Zgarni (2019) in the manufacturing industry both illustrate how coopetition fosters innovation through shared knowledge and resources, despite their differing contexts. This comparative analysis not only bridges the sectoral divides but also underscores the universal applicability and benefits of coopetition strategies, thus directly supporting our study's premise on the role of coopetition in driving innovation and growth within new technology-based firms.

Gnyawali and Park (2009) conducted a study to develop a multilevel conceptual model for coopetition in small and medium-sized enterprises (SMEs). They argue that coopetition can help SMEs enhance their ability to pursue effective technological innovations by providing them with access to external knowledge, resources, and markets, as well as stimulating internal learning and creativity. They propose that the decision and outcome of coopetition in SMEs are influenced by three levels of factors: individual level, firm level, and network level. They also suggest that the outcome of coopetition in SMEs can be measured by three dimensions: innovation performance, financial performance, and relational performance.

Cohen and Zhang (2022) conducted a study to examine the impact of coopetition between two-sided platforms, that is, the business strategy of cooperation and competition to offer a new joint service. They analyzed a setting where two competing platforms participate in a profit-sharing contract and showed that a coopetition can be beneficial for both platforms in the market, especially when they face intense competition on the demand side. They also demonstrate that the optimal profit-sharing contract depends on several factors, such as the degree of demand-side competition, the degree of supply-side differentiation, the marginal costs of the platforms, and the demand elasticity of the joint service.

These studies illustrate some of the aspects and implications of coopetition in different settings and industries. However, there is still a need for more research on coopetition to address some of the gaps and limitations in the existing literature. For instance, more empirical studies are needed to test and validate the theoretical models and propositions of coopetition. Moreover, more comparative studies are needed to explore the similarities and differences of coopetition across different regions, cultures, and institutional environments. NTBFs operate in a dynamic technology-based environment and their activity requirements are based on software capabilities rather than logistics structure, they require a faster response to new values and needs for developing their capabilities, which can be realized through coopetition. Furthermore, more longitudinal studies are needed to examine the dynamic and evolutionary nature of coopetition over time.

METHODOLOGY

The present study is applied in terms of purpose, as it aims to identify and analyze the relationships between exploratory drivers and in terms of orientation, since it applies the results to NTBFs. The methodology of this study is mixed exploratory due to the goal of this study that is identifying the drivers of coopetition in NTBFs, analyzing the relationships between them and obtaining a conceptual model of them; in the first section, we collect qualitative data, and after organizing these data in the second section, we collect and analyze quantitative data. According to that, we identified the drivers of coopetition in NTBFs in the first step using literature review. In the second step of the research, since the identified drivers were not specific to NTBFs, they needed expert confirmation and screening. Using the Fuzzy Delphi method, these drivers were screened and confirmed (Dong et al., 2019; Yao et al., 2022). The Fuzzy Delphi method was developed to improve the traditional Delphi method. This hybrid method uses fuzzy set theory to reduce possible uncertainties (Barghi & Sikari, 2020; Lin et al., 2020). Therefore, the impact of each of the drivers is determined by the experts as qualitative options (Esmaelnezhad et al., 2023). One of the advantages of the Fuzzy Delphi method is that it can be done in one round, it is efficient and takes less time (Kumar et al., 2023; Petrudi et al., 2022; Yao et al., 2022). In the third step, the DEMATEL-ISM method was used. The DEMATEL method was first used to obtain the relationships between the drivers. This method, in addition to showing the cause and effect relationships (Du & Shen, 2023; Šmidovnik & Grošelj, 2023), helps to improve the ISM method. In the fourth step, the ISM method was used for structural-interpretive modeling. This improved method (DEMATEL-ISM) has been applied in many researches for modeling the relationships between drivers. In this method, the results of the DEMATEL method is used for ISM (Alqahtani & Makki, 2023; Chauhan et al., 2018). In the fifth step, we applied the MICMAC method to analyze the results of the conceptual model of ISM properly. This step can help us in better analysis by classifying the drivers into four categories including independent, autonomous, dependent, and linkage (Chen & Huang, 2022; Trivedi et al., 2021). As a result, we went through five steps of literature review, Fuzzy Delphi, DEMATEL, structural-interpretive modeling, and MICMAC analysis to achieve the research goal. For this purpose, the theoretical community going through the mentioned steps, academic experts and managers of NTBFs, are aware of the topics of the present research, including the concepts of coopetition and game theory. The selection of participants is based on several factors, including their knowledge of the subject regarding the role of coopetition in fostering innovation and growth in new technology based firms: a game theory approach, having enough motivation to participate in different steps of the research, having a PhD degree for academic experts, having at least a master's degree for NTBF managers and having at least four years of relevant work experience that indicates their expertise in this field. Finally, 20 experts were selected based on the mentioned characteristics through purposive sampling. In addition, according to the Fuzzy Delphi and DEMATEL-ISM methods in the present research, expert questionnaire was used for screening and standard pairwise comparison questionnaire for DEMATEL-ISM. The criteria of this questionnaire are formed by the drivers obtained from the previous steps that have been confirmed by the experts. The reliability and validity of the mentioned questionnaires are confirmed.

RESULTS

In the second stage of the present research, data were collected from 20 experts using the Fuzzy Delphi process and an expert questionnaire. The experts were asked to select the level of influence of each factor and driver from a set of predefined qualitative options. After defuzzification, factors with defuzzification values less than 0.7 were eliminated, while those with values higher than 0.7 were retained (Habibi et al., 2015). The drivers with values higher than 0.7 were considered to have a significant impact, while the remaining factors were excluded from the analysis due to their lower defuzzification values (Table 1).

Table 1. The average of experts' opinions and the result of defuzzification.

No.	Index	Drivers	Fuzzy numbers a_3	a_2	a_1	Defuzzification	Result
1	A1	Technological innovation	0.925	0.725	0.475	713	Accepted
2	A2	Rapid changes in technology and market	0.9	0.75	0.5	0.725	Accepted
3	A3	Facilitating access to financial resources and investment	0.938	0.813	0.563	0.781	Accepted
4	A4	Creating new products and services	0.95	0.825	0.575	0.794	Accepted
5	A5	Response to needs and emergencies	0.925	0.775	0.525	0.75	Accepted
6		Provision of human resources	0.9	0.688	0.438	0.678	Not accepted
7	A6	Facilitating the commercialization of innovations	0.938	0.8	0.55	0.722	Accepted
8	A7	Sustainable development and economic growth	0.925	0.813	0.563	0.778	Accepted
9	A8	Access to complementary resources and knowledge	0.925	0.763	0.513	0.741	Accepted
10		Development of communication networks and new collaborations	0.875	0.688	0.438	0.672	Not accepted
11	A9	Reducing market uncertainty	0.925	0.75	0.5	0.731	Accepted
12	A10	Sharing the costs and risks of innovation	0.975	0.838	0.588	0.809	Accepted
13	A11	Development of innovative products and services	0.95	0.813	0.563	0.784	Accepted
14	A12	Realization of long-term competitive advantage	0.963	0.85	0.6	0.816	Accepted
15		Increasing the role of government and academic companies	0.888	0.7	0.45	0.684	Not accepted
16	A13	Ability to anticipate and adapt to future changes	0.95	0.825	0.575	0.794	Accepted
17	A14	Strengthening the innovation and technology ecosystem	1	0.838	0.588	0.816	Accepted
18	A15	Extensive competition and competitive pressure	0.938	0.775	0.525	0.753	Accepted
19	A16	Creating value for customers and investors	0.938	0.8	0.55	0.772	Accepted
20		The increase of companies based on new technology	0.875	0.663	0.413	0.653	Not accepted

In the third stage of the research, the remaining drivers were represented by symbols A1 to A16 (Table 2). These drivers were given to the relevant experts through a standard pairwise comparison questionnaire, and then the data was analyzed to obtain a complete relationship matrix according to the Dematel process. The matrices obtained were aggregated using the arithmetic mean method, and then the data was normalized using the linear method. Finally, to obtain the complete normal relationship matrix, the normal direct relationship matrix was multiplied by the inverse difference matrix of the identity matrix (I). Therefore, the Dematel method is performed according to the following process:

(1) First, the normal direct relationship matrix is calculated based on the following relationships.

$$N = K * M$$

$$k = \min\left[\frac{1}{\max \sum_{j=1}^{n} |aij|}, \frac{1}{\max \sum_{i=1}^{n} |aij|}\right] = 0.023 \quad (1)$$

(2) To calculate the complete correlation matrix, we multiply the normal matrix by the inverse matrix according to the following equation. First, we subtract the normal matrix from the identity matrix, and then we take the inverse of the resulting matrix.

$$T = N * (I-N)^{-1}$$

Table 2. Normal matrix of complete relationships.

	A_1	A_2	A_3	A_4	A_5	A_6	A_7	A_8	A_9	A_{10}	A_{11}	A_{12}	A_{13}	A_{14}	A_{15}	A_{16}
A_1	0.863	0.951	0.970	0.988	0.981	0.940	0.947	0.931	0.998	0.932	0.957	0.967	1.016	0.958	0.919	0.929
A_2	0.946	0.912	1.000	1.009	1.006	0.968	0.962	0.949	1.014	0.974	0.981	1.005	1.026	0.988	0.946	0.964
A_3	0.951	0.978	0.943	1.018	1.015	0.972	0.990	0.967	1.032	0.958	1.008	1.005	1.047	1.009	0.957	0.976
A_4	0.912	0.980	0.988	0.948	1.002	0.968	0.979	0.964	1.009	0.963	0.999	0.999	1.041	1.000	0.960	0.972
A_5	0.964	0.985	1.007	1.033	0.960	0.963	0.996	0.974	1.035	0.977	1.021	1.025	1.056	1.022	0.979	0.996
A_6	0.995	1.015	1.044	1.053	1.045	0.947	1.034	0.984	1.064	1.014	1.045	1.048	1.088	1.047	0.992	1.020
A_7	1.017	1.033	1.064	1.076	1.061	1.031	0.984	1.027	1.076	1.027	1.065	1.067	1.110	1.070	1.016	1.040
A_8	0.936	0.949	0.982	0.989	0.987	0.946	0.949	0.880	0.998	0.955	0.962	0.969	1.024	0.974	0.936	0.945
A_9	0.950	0.984	0.997	1.024	1.006	0.954	0.993	0.964	0.962	0.970	1.010	1.000	1.044	1.014	0.963	0.982
A_{10}	0.950	0.980	0.990	1.010	0.982	0.949	0.985	0.954	1.018	0.905	0.984	1.006	1.038	0.998	0.948	0.968
A_{11}	0.907	0.929	0.958	0.986	0.967	0.918	0.940	0.926	0.967	0.931	0.902	0.977	0.999	0.972	0.919	0.935
A_{12}	0.968	1.006	1.034	1.034	1.038	0.991	1.009	0.991	1.036	0.992	1.031	0.970	1.071	1.021	0.980	0.993
A_{13}	0.922	0.929	0.947	0.972	0.979	0.937	0.954	0.902	0.986	0.923	0.972	0.978	0.947	0.974	0.930	0.946
A_{14}	0.961	0.995	1.006	1.018	1.028	0.986	0.999	0.982	1.029	0.980	1.007	1.016	1.061	0.956	0.959	0.980
A_{15}	0.956	0.982	1.009	1.003	0.999	0.977	0.987	0.957	1.029	0.973	1.006	1.006	1.048	1.011	0.903	0.984
A_{16}	1.002	1.027	1.046	1.068	1.052	1.016	1.041	1.010	1.065	1.025	1.047	1.060	1.097	1.058	1.005	0.964

Finally, the pattern of relationships between research drivers is obtained according to Table 3. The sum of the criteria in each row (D) indicates the degree of influence of that criterion on other system criteria. Therefore, the driver (A7) has the greatest impact on the system. In addition, the sum of the criteria in each column (R) indicates the degree of influence of that criterion on other system criteria. Based on this, the driver (A13) has the highest susceptibility to other criteria in the system.

Table 3. Influence values and susceptibility of drivers.

D-R	D+R	R	D	Drivers
0.045	30.444	15.200	15.245	A_1
0.013	31.286	15.637	15.650	A_2
-0.159	31.810	15.984	15.825	A_3
-0.547	31.911	16.229	15.682	A_4
-0.113	32.097	16.105	15.992	A_5
0.972	31.896	15.462	16.434	A_6
1.017	32.515	15.749	16.766	A_7
0.019	30.743	15.362	15.381	A_8
-0.501	32.134	16.318	15.817	A_9
0.163	31.164	15.500	15.664	A_{10}
-0.865	31.131	15.998	15.133	A_{11}
0.068	32.262	16.097	16.165	A_{12}
-1.514	31.911	16.713	15.198	A_{13}
-0.107	32.037	16.072	15.965	A_{14}
0.517	31.143	15.313	15.830	A_{15}
0.991	32.177	15.593	16.584	A_{16}

According to the Cartesian coordinate diagram of Dematel (Figure 1), the sum of the horizontal vector (D+R) for each of the system's constituent criteria shows the interaction of that criterion in the system, such that the criterion has a greater influence and susceptibility to other system criteria. Therefore, the driver (A7) has the most interaction with other factors in the system. Furthermore, the difference (D-R) in the vertical vector for each of the system's constituent criteria shows the definite susceptibility or influence of that criterion in the system. If (D-R) is positive, the factor is considered a causal variable, and if it is negative, it is considered an effect variable. Therefore, drivers (A1, A2, A6, A7, A8, A10, A12, A15, A16) are causal and influential variables, and drivers (A3, A4, A5, A9, A11, A13, A14) are definite and effect variables (Table 4).

A threshold was introduced to eliminate weak relationships between agents and extra information in the system, which could simplify the structure of the system and obtain clear hierarchies. However, excessive simplification may lead to neglect of indirect or nonlinear interactions between agents in the system. Therefore, the key to creating an access matrix is to determine the threshold. In this research, the threshold is obtained by calculating the average values of the complete relationship matrix (Ni et al., 2022). As a result of this calculation (threshold = 0.990), if any of the values in the complete relationship matrix is less than the threshold value, we consider it as zero, and if it is greater than the threshold value, we consider it as one (Chen & Huang, 2022).

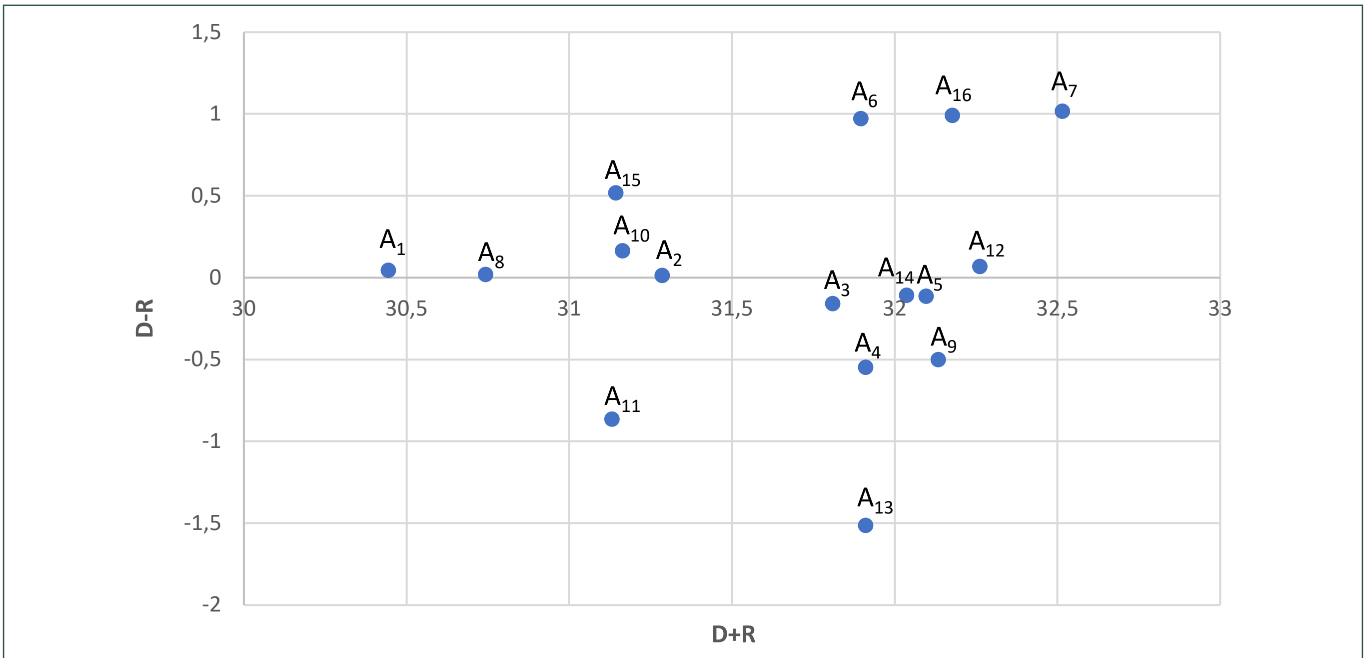

Figure 1. Cartesian coordinate diagram of drivers.

Table 4. The initial access matrix.

	A_1	A_2	A_3	A_4	A_5	A_6	A_7	A_8	A_9	A_{10}	A_{11}	A_{12}	A_{13}	A_{14}	A_{15}	A_{16}
A_1	1	0	0	0	0	0	0	0	1	0	0	0	1	0	0	0
A_2	0	1	1	1	1	0	0	0	1	0	0	1	1	0	0	0
A_3	0	0	1	1	1	0	1	0	1	0	1	1	1	1	0	0
A_4	0	0	0	1	1	0	0	0	1	0	1	1	1	1	0	0
A_5	0	0	1	1	1	0	1	0	1	0	1	1	1	1	0	1
A_6	1	1	1	1	1	1	1	0	1	1	1	1	1	1	1	1
A_7	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
A_8	0	0	0	0	0	0	0	1	1	0	0	0	1	0	0	0
A_9	0	0	1	1	1	0	1	0	1	0	1	1	1	1	0	0
A_{10}	0	0	1	1	0	0	0	0	1	1	0	1	1	1	0	0
A_{11}	0	0	0	0	0	0	0	0	0	0	1	0	1	0	0	0
A_{12}	0	1	1	1	1	1	1	1	1	1	1	1	1	1	0	1
A_{13}	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0
A_{14}	0	1	1	1	1	0	1	0	1	0	1	1	1	1	0	0
A_{15}	0	0	1	1	1	0	0	0	1	0	1	1	1	1	1	0
A_{16}	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1

The final reachability matrix is developed based on the internal consistency check. The transitivity or internal consistency check implies that if variable A is related to variable B and variable B is related to variable C, then variable A is necessarily related to variable C. Table 5 shows the final reachability matrix with the stabilization of the initial reachability matrix. Through this matrix, the influence power and influencedness power of each factor are calculated by summing up all ones in the rows and all ones in the columns.

The reachability set of factor i is the set of factors with values '1' and '1*' in row i of the final reachability matrix and the antecedent set of factor i is the set of factors with values '1' and '1*' in column i of the final reachability matrix. According to Table 6, the reachability set, the antecedent set, and the intersection set of all factors have been found. A factor with the same reachability set and intersection set is considered as a high-level factor in the hierarchy of the interpretive structural modeling. Thus, in this study, we identified six levels of factors.

The formation of the ISM-based model can be depicted graphically as shown in Figure 2 in the sixth step of the present study.

Figure 2 illustrates the position of each factor in a hierarchical structure. Thus, each of the factors positioned at higher levels of this structure influences the factors placed at lower levels.

Top of Form

Out of the 16 factors identified by experts, (A13) and (A11) are positioned at the top level of the model. Factors (A3), (A4), (A5), (A7), (A8), (A9), (A12), and (A14) are also located at the third level of the model. (A1) and (A10) are positioned at the fourth level of the model. (A2), (A6), and (A16) are at the fifth level of the model. Finally, (A15) is at the sixth level of the model. To categorize these 16 factors, a MICMAC analysis has been conducted.

Table 5. The final access matrix.

	A_1	A_2	A_3	A_4	A_5	A_6	A_7	A_8	A_9	A_{10}	A_{11}	A_{12}	A_{13}	A_{14}	A_{15}	A_{16}	Influence
A_1	1	0	1*	1*	1*	0	1*	0	1	0	1*	1*	1	1*	0	0	10
A_2	0	1	1	1	1	1*	1*	1*	1	1*	1*	1	1	1*	0	1*	14
A_3	1*	1*	1	1	1	1*	1	1*	1	1*	1	1	1	1	1*	1*	16
A_4	0	1*	1*	1	1	1*	1*	1*	1	1*	1	1	1	1	0	1*	14
A_5	1*	1*	1	1	1	1*	1	1*	1	1*	1	1	1	1	1*	1	16
A_6	1	1	1	1	1	1	1	1*	1	1	1	1	1	1	1	1	16
A_7	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	16
A_8	0	0	1*	1*	1*	0	1*	1	1	0	1*	1*	1	1*	0	0	10
A_9	1*	1*	1	1	1	1*	1	1*	1	1*	1	1	1	1	1*	1*	16
A_{10}	0	1*	1	1	1*	1*	1*	1*	1	1	1*	1	1	1	0	1*	14
A_{11}	0	0	0	0	0	0	0	0	0	0	1	0	1	0	0	0	2
A_{12}	1*	1	1	1	1	1	1	1	1	1	1	1	1	1	1*	1	16
A_{13}	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	1
A_{14}	1*	1	1	1	1	1*	1	1*	1	1*	1	1	1	1	1*	1*	16
A_{15}	0	1*	1	1	1	1*	1*	1*	1	1*	1	1	1	1	1	1*	15
A_{16}	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	16
Dependence	9	12	14	14	14	12	14	13	14	12	15	14	16	14	9	12	208

Table 6. Segmentation of levels.

Factors	Access Set	Preliminary Set	Common Set	Level
A1	1	1, 3, 5, 6, 7, 9, 12, 14, 16	1	Fourth
A2	2, 6, 16	2, 3, 4, 5, 6, 7, 9, 12, 14, 16	2, 6, 16	Fifth
A3	1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 12, 14, 15, 16	1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 12, 14, 15, 16	1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 12, 14, 15, 16	Third
A4	2, 3, 4, 5, 6, 7, 8, 9, 10, 12, 14, 16	1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 12, 14, 15, 16	2, 3, 4, 5, 6, 7, 8, 9, 10, 12, 14, 16	Third
A5	1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 12, 14, 15, 16	1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 12, 14, 15, 16	1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 12, 14, 15, 16	Third
A6	2, 6, 15, 16	2, 3, 4, 5, 6, 7, 9, 10, 12, 14, 15, 16	2, 6, 15, 16	Fifth
A7	1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 12, 14, 15, 16	1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 12, 14, 15, 16	1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 12, 14, 15, 16	Third
A8	3, 4, 5, 6, 7, 8, 9, 12, 14	2, 3, 4, 5, 6, 7, 8, 9, 10, 12, 14, 15, 16	3, 4, 5, 6, 7, 8, 9, 12, 14	Third
A9	1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 12, 14, 15, 16	1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 12, 14, 15, 16	1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 12, 14, 15, 16	Third
A10	2, 6, 10, 16	2, 3, 4, 5, 6, 7, 9, 10, 12, 14, 15, 16	2, 6, 10, 16	Fourth
A11	11	1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 14, 15, 16	11	Second
A12	1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 12, 14, 15, 16	1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 12, 14, 15, 16	1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 12, 14, 15, 16	Third
A13	13	1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13, 14, 15, 16	13	First
A14	1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 12, 14, 15, 16	1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 12, 14, 15, 16	1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 12, 14, 15, 16	Third
A15	15	3, 5, 6, 7, 9, 12, 14, 15, 16	15	Sixth
A16	2, 6, 15, 16	2, 3, 4, 5, 6, 7, 9, 10, 12, 14, 15, 16	2, 6, 15, 16	Fifth

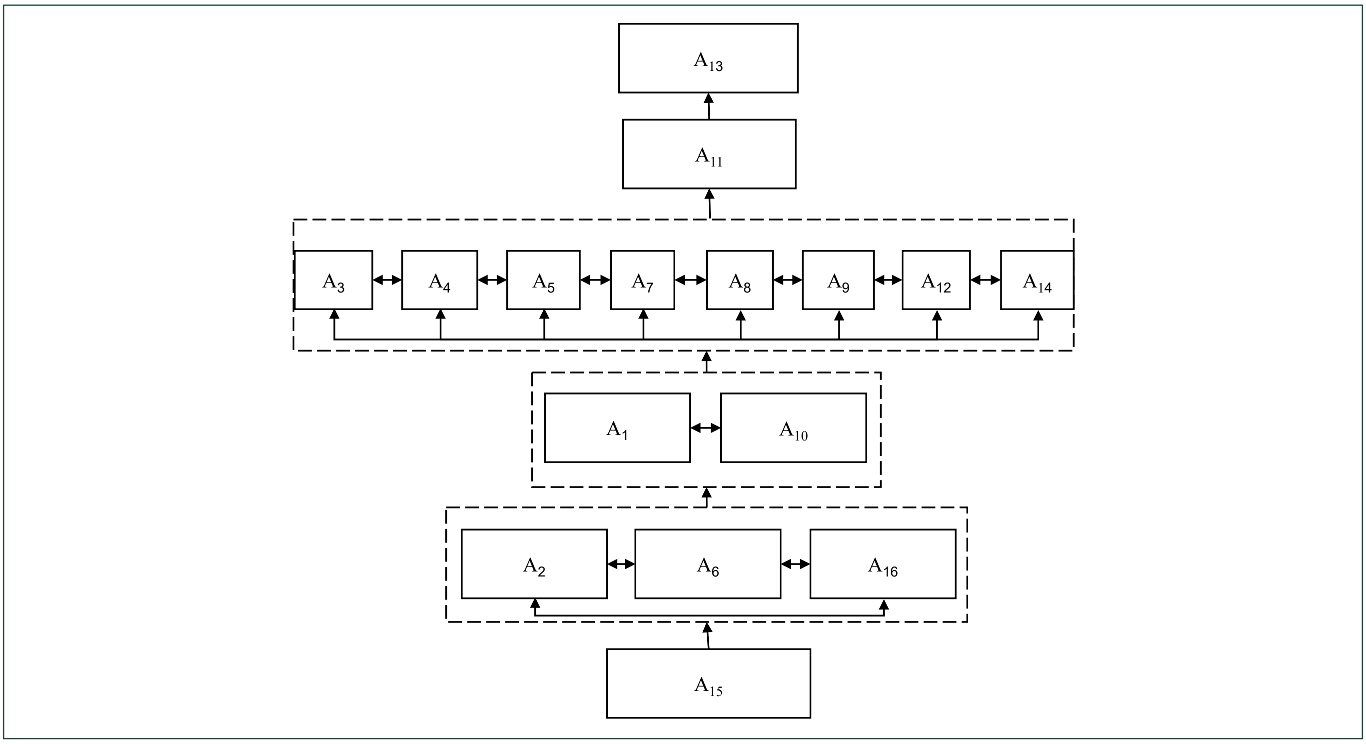

Figure 2. Conceptual model of research extracted from ISM method.

MICMAC

MICMAC analysis is an approach to graphical classification of the factors of a complex situation based on their penetration power and dependency power. Based on penetration power and dependency, factors are classified into four autonomous, independent, linked, and dependent categories. Independent variables have high penetration power and low dependency. Linked variables not only have high penetration power but also have high dependency power. Dependent variables have low penetration power and high dependency power (Mohammadhosseini et al., 2021). Autonomous variables also have low penetration power and dependency power, but they are still essential parts of the system (Mohammadhosseini et al., 2022; Salamzadeh et al., 2021).

Figure 2 shows the result of the MICMAC analysis of the factors based on their penetration power and dependency power.

According to Figure 3, research variables can be explained in the following four categories:

1. Linkage variables: these variables have relatively high penetration power and dependency power. Changing these variables can affect other variables in the system due to their penetration power and dependency power. Variables A2, A3, A4, A5, A6, A7, A8, A9, A10, A12, A14, and A16 fall into this category.

2. Independent variables: these variables have high penetration power and low dependency power. They are the main cause of other factors in the system. In this study, variables A15 and A1 fall into this category.

3. Dependent variables: these variables have low penetration power and high dependency power. They are influenced by the linkage and independent variables. In this study, variables A13 and A11 fall into this category.

4. Autonomous variables: these variables have less penetration power and dependency power than other variables. None of the variables in this study fall into this category, indicating that the identification of variables for achieving the goal of this study has been done accurately, and the identified variables have a significant impact on the overall decision-making process of the system.

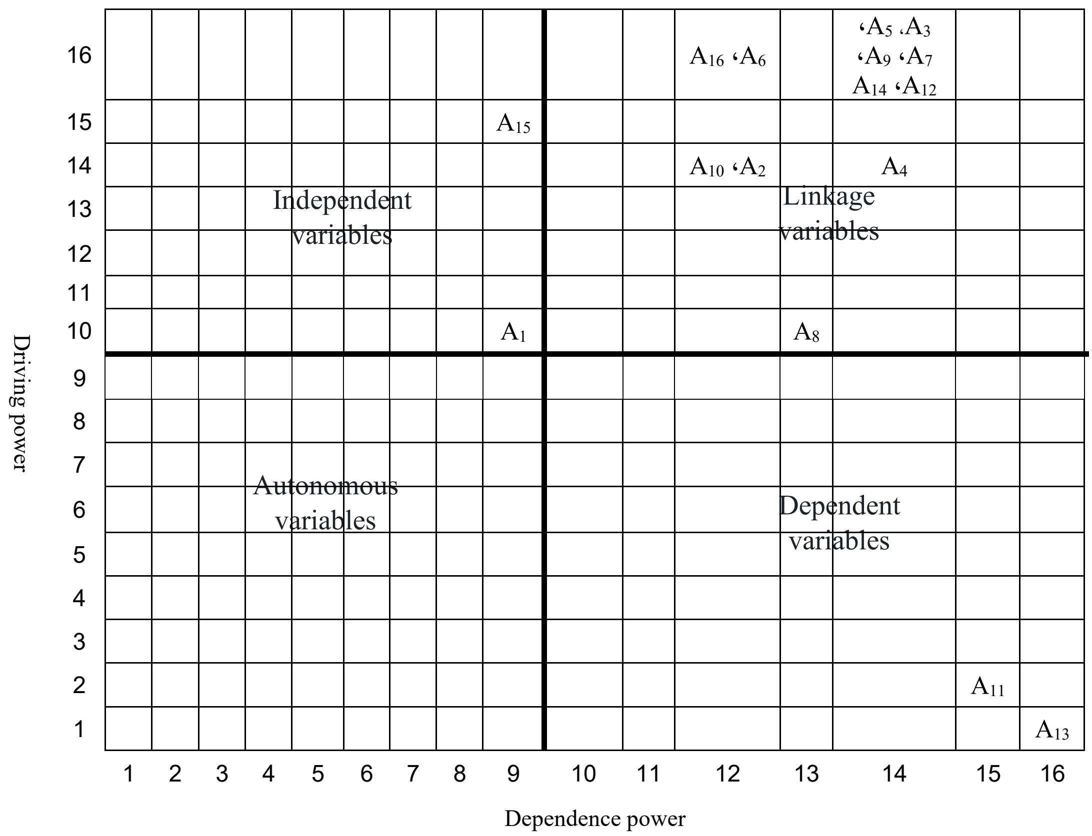

Figure 3. MICMAC analysis.

Figure 2 categorizes the factors, while Figure 3 illustrates the degree of power and dependence of the factors, aiding in a better analysis of the results. For instance, as evident from these two figures, variables A15 and A1 are categorized under the independent variables. However, it is noticeable that variable A15 has a greater influencing power compared to variable A1. Therefore, while both variables are necessary for fostering coopetition among NTBFs, variable A15 plays a more significant primary role.

Furthermore, based on these two figures, it can be discerned that factors A3, A5, A7, A9, A12, and A14 are vital actions influencing competition within NTBFs. Due to their high influencing power and their capacity to induce changes at higher levels of the system, coupled with their high susceptibility, these factors are pivotal elements capable of being influenced and improved upon. Consequently, they are regarded as key elements of interest.

DISCUSSION AND CONCLUSION

We rigorously analyze the impact of coopetition on innovation and growth within new technology-based firms (NTBFs), directly linking our findings to existing literature. Through our analysis, we provide evidence that NTBFs can harness coopetition as a strategic tool to generate innovative opportunities and navigate technological and competitive challenges. These findings underscore the significance of adopting flexible strategies in strategic management and highlight their pivotal role in facilitating sustainable growth and continuous innovation.

Following an in-depth analysis of the presented data and the application of scientific expertise, our study underscores the formidable challenges confronting new technology-based firms (NTBFs) in an era characterized by rapid technological transformations and intense competition. Central to the growth and successful commercialization of innovations for these firms is the pivotal role played by innovation itself.

Within this dynamic landscape, game theory posits that competition, including cooperation and competition, is integral to the expansion and commercial success of NTBFs. Coopetition emerges as a potent strategy capable of enhancing company performance and contributing to both economic prosperity and societal development. When amalgamated with other drivers such as fierce competition, the development of innovative products and services, and adeptness in anticipating and adapting to future changes, NTBFs can fortify their competitive prowess, flexibility, and sustainability.

The success of NTBFs in achieving growth and effectively commercializing innovations hinges on the implementation of strategic management approaches. Such strategies encompass active research and development, establishing collaborative networks with other entities, facilitating access to financial resources, reinforcing managerial capabilities, and leveraging new tools. Through the execution of these strategies, companies can carve out competitive advantages and adeptly navigate shifting market conditions, laying the groundwork for sustained growth.

Looking forward, future research endeavors should concentrate on the analysis and prediction of market and technology changes, the recognition and adaptation to emerging trends, identification of new market opportunities, comprehension of customer and competitor behaviors, and anticipation of the impacts stemming from forthcoming technological and economic shifts. A nuanced understanding of these factors will empower companies to not only adapt to future conditions but also contribute substantially to their long-term success.

In essence, this research underscores the indispensable role of innovation in the triumph of NTBFs, underscoring the significance of effective management strategies and proactive engagement with future trends for sustainable growth and community development. By conscientiously considering these factors, NTBFs can navigate challenges adeptly and flourish within a rapidly changing and competitive environment.

Continuing our exploration, it is evident that the symbiotic relationship between coopetition and innovation serves as a catalyst for the evolution and resilience of NTBFs. The strategic interplay between competitive and cooperative dynamics provides a framework for these firms to not only survive but also thrive amid the complexities of the contemporary business landscape.

As we delve into the realm of effective management strategies, our findings stress the multifaceted nature of success for NTBFs. Active investment in research and development becomes a cornerstone, allowing companies to stay at the forefront of technological advancements and maintain a competitive edge. Collaborative networks, formed with both industry peers and institutions, offer avenues for shared knowledge, resource pooling, and collective problem solving, fostering an environment conducive to innovation and growth.

Financial considerations play a pivotal role, and facilitating access to resources becomes imperative for NTBFs. Whether through strategic partnerships, venture capital, or governmental support, securing financial backing enables these firms to execute ambitious plans, undertake market expansion, and navigate the inherent uncertainties of the business landscape.

Furthermore, the emphasis on strengthening managerial capabilities underscores the importance of leadership in guiding NTBFs through the intricacies of their operations. Effective management involves not only astute decision-making but also the cultivation of a corporate culture that fosters creativity, adaptability, and a proactive approach to change.

In the context of adapting to future trends, the anticipation of market and technological shifts emerges as a cornerstone for NTBFs. Understanding customer and competitor behaviors, coupled with a foresight into the impacts of forthcoming changes, positions these firms to proactively shape their strategies, ensuring alignment with evolving market dynamics.

In conclusion, this research contends that the success of NTBFs is an intricate dance between innovation, coopetition, and effective management strategies. Navigating the challenges posed by a rapidly changing and competitive environment necessitates a holistic approach, incorporating a commitment to innovation, strategic partnerships, financial acumen, adept management, and a foresightful adaptation to emerging trends. By embracing these principles, NTBFs can not only overcome obstacles but also emerge as drivers of sustainable growth and contributors to broader societal development.

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