Challenges and difficulties of technology commercialization – a mixed-methods study of an industrial development organization

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Abstract

Purpose – This paper aims to reveal the challenges and problems of technology commercialization in an industrial development organization in Iran.

Design/methodology/approach – To achieve the objective of this paper, a mixed-methods case study was used. Initially, 15 in-depth interviews with technology commercialization experts were conducted and 43 themes were extracted as problems of technology commercialization. The outcomes of the interviews informed the development of the questionnaire. Subsequently, a survey of 205 experts was performed to examine the responses obtained from the interviews. The main problems were identified through exploratory factor analysis and evaluated through confirmatory factor analysis.

Findings – Seven factors are identified as the main difficulties of technology commercialization, including weakness in the commercialization process, challenges of the business environment, weak organizational structure, inefficient project management, ineffective cooperation with non-governmental sectors, failure to collaborate with stakeholders and conflicting political behaviors.

Practical implications – The outcomes of this research inform the organization's managers of the poor conditions and barriers of the technology commercialization process. The findings also help managers to overcome the challenges that are under the control of the organization.

Originality/value – This paper contributes to the knowledge on technology commercialization by exploring the main factors that form barriers to and difficulties of technology commercialization in an industrial development organization and suggesting appropriate solutions.

Keywords Difficulties of technology commercialization, Industrial development organization, Mixed-methods approach

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1. Introduction

In recent decades, commercialization and transfer of technology have attracted the attention of governments, researchers and educational institutions. A broad understanding of the ways in which technological knowledge is created and applied can be a driving factor for successful economic development (Agrawal, 2001; Arvanitis *et al.*, 2008). Technology has always played a significant role in creating wealth in countries and influencing the standards of living and quality of life. It has also been the most important element and driving force of economic growth (Arvanitis *et al.*, 2008; Chiesa and Frattini, 2011). Similarly, Iran's national archives show that the primary goal of using technology is to achieve national wealth, economic growth, and profitability. The central question, then, is how to create this wealth and economic value and generate social welfare through technology.

Technology by itself cannot create national wealth; this can be achieved though effective and appropriate use of technological applications and technology commercialization. To implement technology, the full value chain, including research, development, innovation, product development, marketing and aftersales service, must possess the necessary robustness. Despite the various problems and challenges in the commercialization process, companies are increasingly aiming to apply knowledge and commercialize it (Lichtenthaler, 2005). Studies on commercialization of technology show that new and small businesses have been able to compete with large enterprises, and even pull ahead of them in the market, through technology commercialization (Carayannopoulos, 2009). Owing to the economic impact of technology commercialization, many developed countries are increasingly establishing research and development (R&D) institutes to help commercialize technology in companies and industries via consultation services and performing joint research projects (Klofsten and Jones-Evans, 2000).

Likewise, advanced technology has repeatedly been highlighted in the general policies of Iran's development plans, and technology commercialization was underlined in the country's most recent development plan (Law for the Fourth Development Plan of the Islamic Republic of Iran, 2004; Law for the Fifth Development Plan of the Islamic Republic of Iran, 2011). The importance of high-tech applications in Iran has been growing alongside the emerging role of development organizations in the country's socioeconomic growth. The development organization studied in this paper is a governmental and industrial organization, which is referred to as "the organization" in this paper. The organization is one of the largest development organizations in the field of commercialization in Iran, and it plays a crucial role in the country's economic growth and technical improvement in the international market. According to the general policies of Iran's constitution and the approaches of international development organizations, absorption, commercialization and technology offers are among the most important missions of the organization. However, worldwide evidence suggests that although a large number of projects on technology development have been technically successful, only a small percentage have achieved success in the commercialization domain, which reflects the complexity of the commercialization process (Bandarian, 2005). In Iran, regardless of the critical role of the organization in the development of the country and achievement of its 20-year vision, existing documents related to commercialization in this firm show that from 2003 to 2015, 61.4 per cent of the 95 projects conducted in high-tech industries did not achieve their goals and failed. The presented reports regarding the failures of these projects indicate difficulties and challenges in the commercialization process of the organization. These failures, unsuccessful projects and loss of investments have prevented the organization from accomplishing its missions in countries' development programs. Based on this weak performance, the current study explores the challenges and difficulties of technology

commercialization in the mentioned development organization by applying a mixed-methods approach, and suggests appropriate solutions for the difficulties identified.

2. Literature review

2.1 Commercialization of technology

Organizations are under increasing pressure to survive due to tough competition that exists in the global economy. Technology commercialization is a common strategy to remain competitive in the global market (Chen *et al.*, 2011). Commercialization refers to the moment of entering the market and the distribution of innovation (Story *et al.*, 2011). Farrukh *et al.* (2004) considered technology commercialization as an inclusive process, involving R&D, manufacturing and distributing a new product. "Technology commercialization refers to the translation of technological capabilities into beneficial products and services that increase profit and/or social welfare", and it "entails the sourcing of technologies, adding value to make them viable goods and services, and launching these offerings into the marketplace" (Krishnan, 2013, p. 1443). From a knowledge perspective, the technology commercialization approach requires collaborative efforts by several experts to accomplish complicated and challenging tasks (Grant, 1996; Kotha *et al.*, 2013), as it involves implementing the whole process of imaging, incubating, representing, marketing and sustaining (Jolly, 1997).

Commercialization of technology is an important part of the innovation process (Frattini *et al.*, 2012), which means that technologies and products cannot successfully enter the market without going through the commercialization process. Today, large companies are forced to introduce their new technologies through commercialization to achieve profitability and retain their market share (Datta *et al.*, 2015; Haeussler, 2011). Owing to the significant impact of technology commercialization on the growth and value of companies, many corporations appreciate its strategic importance and aim to develop novel technology products (Cho and Lee, 2013). However, success in this path is not easy (Datta *et al.*, 2015), as there are several constraints and difficulties pertaining to commercialization that lead to the failure of many commercialized products.

2.2 Barriers to commercialization

Success in innovation depends on integration of a company's capabilities, including accessing financial resources, understanding market needs, employing high-skilled forces and forming effective interactions with the other actors in the market (D'Este *et al.*, 2012). Previous studies link the ability to successfully commercialize innovations with a company's capabilities, human resource activities, top-managers' characteristics and the external environment (Datta *et al.*, 2013; Dougerty and Hardy, 1996; Howell and Higgins, 1990; Scott and Bruce, 1994; Wade and Hulland, 2004). Nevertheless, commercializing technical innovations has always been challenging (Datta *et al.*, 2015), which causes a high failure rate in the innovation process (Cooper, 2011). Many studies have addressed the challenges and obstacles of the innovation process; however, researchers tend to analyze this quite generally, and categorize the barriers in two broad classes, i.e. external barriers, which companies cannot influence and that may arise due to market, government or economic actors or system failures, and internal barriers, which companies have the ability to influence and are strongly associated with the management and organization itself (D'Este *et al.*, 2012; Hölzl and Janger, 2012; Madrid-Guijarro *et al.*, 2009; Sandberg and Aarikka-Stenroos, 2014). Although literature shows that most of the factors influencing the success of new products are in the control of management and the organization, many companies do not invest enough in this area and do not expend sufficient effort into the planning and management of commercialization (Aarikka-Stenroos and Lehtimäki, 2013),

resulting in the failure of commercialized products. The success of new product or service commercialization requires acceptance among the main actors in the market. New products will fail if they cannot attract the support of shareholders and stakeholders (Talke and Hultink, 2010). According to Chiesa and Frattini (2011), most products in the high-tech industry fail due to poor understanding of the commercialization process. Some researchers state that refusal to accept new technologies is one of the main reasons for such failure (Gourville, 2006).

In high-tech markets, the challenges of commercializing technological innovation that companies face are intensified by "the volatility, interconnectedness, and proliferation of new technologies that characterize such markets" (Chiesa and Frattini, 2011, p. 437). Kimura (2010) classified the factors contributing to the failure of technology transfer and commercialization into five groups: poor technology performance, poor economic performance, organizational changes, market changes and regulatory changes. Jung *et al.* (2015) studied the success and failure factors of technology commercialization regarding public R&D and explored its problems within different phases, including "technology acquisition, prototype testing, and product manufacturing stages" (p. 877). "Marketing capability" and "cooperation with developer" were the most significant factors for the success or failure of technology commercialization (p. 877). The authors indicated that "insufficiency of funds" and "lack of facility and equipment" were the primary barriers to technology acquisition; "deterioration of market condition" and "insufficiency of funds" were the topmost obstacles within prototype testing; and "insufficiency of marketing capability", as well as "deterioration of market condition", were the major barriers to product manufacturing (Jung *et al.*, 2015, p. 895). By reviewing existing studies and conducting interviews with experts, Tabatabaian *et al.* (2007) found lack of knowledge about consumers, lack of consumption culture, lack of technical expertise, weakness in intellectual property rights, business owners' lack of awareness about the business models, economic sanctions, lack of definite goals, poor central management of the projects, high risks of investment in the field of nanotechnology and lack of constructive interactions between researchers and business owners as the most significant deficiencies in the process of nanotechnology commercialization. Moghimi *et al.* (2010) considered the impact of environmental factors on commercialization of ideas and revealed that financial constraints, inefficient organizational bureaucracy, unclear corporate strategies, lack of interaction with research teams, lack of mass production, lack of assessment of research achievements and lack of product modification and optimization could negatively impact the commercialization of ideas.

Reviewing existing literature on entrepreneurship and commercialization at research institutions reveals that scholars have found similar reasons for the failure of institutions' research activities and universities' projects. Pourezzat *et al.* (2010) stated that bureaucracy and inflexibility of university management systems; weak communications and networking among investors, industry practitioners and academicians; culture differences between industry professionals and scholars; lack of strict regulations for protecting intellectual property at a national level; universities' dependence on public funds; lack of information about the needs and priorities of the business sectors; and lack of motivation for knowledge commercialization are barriers to entrepreneurship and commercialization at universities. In addition to these barriers and limitations, a number of scholars and university staff believe that being an entrepreneur may move them away from their primary missions as learners, researchers or lecturers (Williams, 2003). New companies established by scientists frequently suffer from a lack of technical resources, as well as of human and financial capital (Lockett *et al.*, 2005). One of the reasons scientists face problems in attracting investors

pertains to the limited industrial experience of their financial team (Moray and Clarysse, 2005). Studies show that the success or failure of commercialization is influenced by incentive structures; university entrepreneurs' characteristics; social, commercial and industrial networks; scientists' lack of business experience; and the structure of management and the senior management team (Vohora *et al.*, 2004). Mahmmoudpour *et al.* (2012) examined difficulties in the commercialization of research in educational administration from the researcher perspective. They showed that lack of scientific skills, lack of motivation, improper policymaking, pessimism toward commercialization and nature of research are barriers to commercialization. Based on knowledge spillover theory of entrepreneurship, commercialization of new knowledge through entrepreneurship happens when scientists identify new and personal interests for commercialization and recognize the business value of new knowledge, and the owners of sources, especially those who are familiar with the knowledge market, invest in new knowledge (Acs *et al.*, 2004). According to this theory, major reasons for the failure of university entrepreneurs in commercialization are:

- Academics are not aware of the benefits of product commercialization.
- Academics are not able to recognize the potential for commercialization of their products owing to a lack of information about the market.
- Organizations and bodies that have access to financial resources are not familiar with new knowledge and technologies (Acs *et al.*, 2004).

In general, previous research has shown that the main problems and challenges of the commercialization process are related to marketing, human resources, technical resources, financial resources, the business environment, and the planning and management of the commercialization process. However, what is missing from the existing discussions is research into the difficulties and challenges of commercialization in industrial development organizations. These organizations play an important role in the development and commercialization of technology in each country and many research companies, R&D organizations, and universities cooperate with them regarding commercialization projects. Despite the importance of these organizations, insufficient attention has been paid to them, especially with respect to the difficulties and challenges they face in their commercialization processes.

3. Research methodology

This research can be considered as empirical, as the main objective was to explore a phenomenon that was not well understood, namely, to develop a comprehensive understanding of the factors contributing to the failure of technology commercialization within an industrial development organization. To achieve the main objective of the research, the following question was developed: What are the main problems and challenges of technology commercialization in the organization?

To answer the question, an in-depth case study was conducted (Siggelkow, 2001; Siggelkow, 2002; Tripsas, and Gavetti, 2000). This method is appropriate when the emphasis is on a contemporary phenomenon within a real-life context (Yin, 2014) and it is a "necessary and sufficient method" for research problems in the social sciences (Flyvbjerg, 2006, p. 26). Another advantage of the case study method is that it can highlight many factors in a particular setting, depicting something unique while also providing insights that have "wider relevance" (Daymon and Holloway, 2002, p. 106). Because generalization from a case is analytical rather than statistical, and can be achieved through inductive work and

conceptualization (Johansson, 2003), this research used inductive reasoning rather than theory testing (Perry, 1998).

Moreover, the case study method was applied, as it provides flexibility in the use of different data collection methods (Beeton, 2005). A mixed-methods approach can provide stronger implications and offer a deeper insight of the phenomenon being studied, which might be overlooked when only a single method is applied (Johnson and Onwuegbuzie, 2004). This research thus triangulated the data by using both quantitative and qualitative methods to comprehend different data sources and to improve the validity and credibility of the outcomes (Creswell and Plano Clark, 2007; Greene *et al.*, 2005). A qualitative approach is a suitable technique for the first step of this research, as there is no clear idea or broad understanding of the reasons for technology commercialization failure within industrial development organizations, and qualitative research offers profound insights into the research problem (Malhotra, 2008). Hence, in-depth interviews with experts were conducted to obtain enough information and insight into the research problems (Rowley, 2012; Siggelkow, 2001). A thematic analysis was then performed to help design the questionnaire for the subsequent quantitative study. Consequently, based on the knowledge obtained from the qualitative phase, a more accurate and detailed picture of the phenomenon was achieved by conducting a cross-sectional survey (Agyemang and Ansong, 2016).

3.1 Stage one: qualitative study

In qualitative research, the goal is to comprehend a phenomenon according to the participants' views. Furthermore, as the case study approach is appropriate for inductively building a rich understanding of a new phenomenon (Christie *et al.*, 2000), the first stage of this research is based on an in-depth, inductive case study of the industrial development organization. The logic behind using this method is to deepen understanding of the phenomenon under study and use the results to design the subsequent quantitative study. To conduct the qualitative case study, a four-step method, adapted from Yin (2014), was used:

3.1.1 Problem definition and case selection. A single industrial development organization was selected as the case, given that a deep understanding of one case can provide universal information and insights that study of numerous cases cannot (Easton, 2010). Focusing on one case allows researchers to go back, study and review the case several times. Then, after exploration and reflection, they can examine their understanding of what they are studying (Easton, 2010). Flyvbjerg (2006) clarified that in conducting in-depth research on a topic, it is acceptable to study only one case, and the results can then be generalized. Strategic selection of the case can significantly increase the study's generalizability (Flyvbjerg, 2006). Accordingly, the organization in this research was not chosen randomly. It was intended to select a specific organization so as to obtain certain understandings that other organizations would not be able to offer. As a result, to gain a deep understanding of the difficulties of technology commercialization in industrial development organizations, a leading development organization in the field of commercialization in Iran that has so far not performed well in technology commercialization was selected. To identify the main challenges of technology commercialization in the organization, and the reasons for failure in most commercial projects, the experts involved in technology commercialization of the examined organization were selected for interviews.

3.1.2 Literature review and planning for field operations. After reviewing the existing literature, some commercialization challenges were found and used in the interviews to increase the interviewed experts' awareness.

3.1.3 Data gathering and analyzing case study evidence. The sample included senior experts from the organization who had been involved in technology commercialization

projects from 2003, when the firm entered high-tech industries, to 2015. As the qualitative study was exploratory and required the participation of certain people with expertise in the area of study, purposive sampling was applied to choose interviewees from the experts. The criteria for selecting the interviewees included their level of involvement in the commercialization process, related education, interest in the topic and involvement in at least three technology commercialization projects, as well as having more than 10 years' experience in commercialization in the main organization or in its affiliated companies. Semi-structured interviews were conducted, and the saturation point was reached after 15 interviews had been conducted. Table I shows the demographic characteristics of the interviewees. Test–retest reliability and intra-subject agreement indices were calculated to assess the reliability of the interviews. As can be seen in Tables II and III, the values of the test–retest reliability and inter-rater reliability were all above 60 per cent, which confirmed the reliability of the coding (Kvale, 1996, p. 237). Thematic analysis was then performed for interpretation of the interviews.

3.1.4 Compiling reports. A detailed report of the findings of the case study was compiled and presented.

3.2 Stage two: quantitative study

The results of the qualitative analysis were converted into inputs for the quantitative study and became the basis for designing the questionnaire. The questionnaire covered 43

Demographic variables	Measurement item	Frequency	(%)
Gender	Male	4	27
	Female	11	73
Age	Under 30	–	–
	31-40	5	33
	41-50	7	47
	51 or above	3	20
Years of work experience	11-15	12	80
	15 or above	3	20

Table I. Demographics of interviewees

Title of interviewee	No. of total codes	No. of agreements	No. of disagreements	Test–retest reliability (%)
Interviewee 1	20	8	4	80
Interviewee 2	13	6	1	92
Interviewee 4	16	6	4	75
Total	49	20	9	82

Table II. Test–retest reliability

Title of interviewee	No. of total codes	No. of agreements	No. of disagreements	Intra-subject agreement for two coders (%)
Interviewee 1	19	8	3	84
Interviewee 2	11	5	1	91
Interviewee 4	17	7	3	82
Total	47	20	7	85

Table III. Inter-rater reliability (for two coders)

questions on five-point Likert scales from 1 (strongly disagree) to 5 (strongly agree), and examined the factors influencing technology commercialization in the oganization.

3.2.1 Reliability. A pilot study was conducted on a sample of 40 participants to test the reliability of the questionnaire. The reliability of the questionnaire was confirmed using Cronbach's alpha, parallel, strictly parallel, Guttman and split-half tests, as shown in Table IV. As can be seen, all reliability criteria were acceptable.

3.2.2 Validity. To check the validity of the study, face, content and construct validity tests were used. The face validity of the questionnaire was examined by asking the opinions of 12 academicians and experts regarding the vocabulary, the logical sequence of statements and the grammatical structure of the questionnaire (Alumran *et al.*, 2012). To test content validity, the content validity index (CVI) and content validity ratio (CVR) were calculated. For the CVI, 12 experts reviewed the questions and confirmed the relevance, clarity and simplicity of each item on a four-point scale. In this study, the accepted threshold for CVI was 0.79 for each item (Waltz *et al.*, 2005). Based on the opinions of experts, the CVR of each item was examined on a four-point scale according to whether the item was essential to the domain. In this study, the accepted threshold for CVR was 0.56 for each item (Lawshe, 1975). According to these two indices, all questions were approved. The construct validity of this study was also tested based on convergent and discriminant (divergent) validity (Campbell and Fiske, 1959), as presented in the Results section.

3.2.3 Data collection. The sample for this study included all technology commercialization experts who worked in 2015 in the organization or in other corporations that work under the organization's supervision. A total of 245 commercialization experts were in the organization and its partner companies, 215 of whom agreed to participate in this study. In total, 205 questionnaires were suitable to be used for analysis. The demographic characteristics of the respondents are shown in Table V.

Table IV.
Reliability of the questionnaire

	Split-half	Guttman	Strictly parallel	Parallel	Cronbach's alpha
Standard value	Spearman–Brown coefficient > 0.7	Lowest lambda > 0.7	Error < 0. 05 and reliability ≥ 0.7	Error < 0. 05 and reliability ≥ 0.7	Reliability ≥ 0.7
Obtained value	0.78	0.76	0.00 and 0.90	0.00 and 0.90	0.90

Table V.
Demographic characteristics of the respondents in the quantitative study

Demographic variables	Chosen items	Frequency	(%)
Gender	Male	161	78.5
	Female	44	21.5
Age	Under 30	16	8
	31-40	73	35.5
	41-50	75	36.5
	51 or above	41	20
Years of work experience	Less than 1	–	–
	1-5	53	26
	6-10	77	37
	11-15	47	23
	15 or above	28	14

3.2.4 Data analysis. To extract the factors, exploratory factor analysis was employed using SPSS, and to examine the results of the exploratory factor analysis, confirmatory factor analysis was employed in LISREL.

4. Results

The findings of this study consist of two parts: the first is related to the qualitative study and the second to the quantitative study.

4.1 Qualitative study

The primary objective of the qualitative study was to find the general problems and challenges of technology commercialization in the inspected organization. The data gathered through interviews were used for the data-driven thematic analysis (Rowley, 2012). In total, 98 codes were found; these were grouped into 43 different themes based on their similarities. The outcomes of the thematic analysis (shown in Table VI) helped to develop the questionnaire for the quantitative study.

4.2 Quantitative study

The data collected through the survey were analyzed through exploratory factor analysis to extract the main factors and through confirmatory factor analysis to assess the results of the exploratory factor analysis.

4.2.1 Exploratory factor analysis. Factor analysis was conducted on 43 items. Kaiser–Meyer–Olkin (KMO), a measure of sampling adequacy, and Bartlett's test of sphericity were conducted to ascertain whether exploratory factor analysis could be carried out on the data (Table VII). The KMO index = 0.88 > 0.5, and the significant Bartlett's test of sphericity result ($p < 0.05$) justified the use of exploratory factor analysis (Tabachnick and Fidell, 2014). As demonstrated in Table VIII, the initial value of the communality is 1, and the values in the extraction column, indicating the proportion of each variable's variance that can be explained by the principal components, are above 0.5. Consequently, all items met the required conditions for continuing the analysis (Tabachnick and Fidell, 2014). Finally, seven main factors were extracted that explained about 68.26 per cent of the variance of 43 items related to the challenges of technology commercialization (Table IX). Table X shows the correlation matrix between the items and the factors after rotation. In this table, the items were classified in line with their correlations and biggest factor loadings.

Extracted factors: Seven factors were identified according to Tables IX and X:

(1) The first factor explained 16.04 per cent of the total variance and included 12 items, referring to the failure of finance and investment in the project; abandoning established companies after mass production; lack of the required abilities to produce a prototype; inability of the organization to mass-produce and prepare a marketing plan; failure in the pilot implementation and operationalization; executives' lack of access to information resources; improper legal and intellectual property regulations in commercialization projects; lack of complete guidelines and accurate documentations for implementation of commercialization; passivity in absorbing new ideas; defining technical know-how without considering the needs of the industry, market and end users; lack of appropriate mechanisms to identify the necessary knowledge; and inability of the organization to move from knowledge to technology. These items were under the supervision of the organization and occurred during the process of commercialization. This factor was titled "weakness in the commercialization process".

Theme no.	Theme
1	Incapability of the supervision systems to control commercialization projects
2	Lack of qualified experts
3	Inappropriate project assessment by executives
4	Lack of suitable criteria for the projects' evaluation
5	Lack of capability and knowledge in mass production and marketing
6	Lack of attention to the interactions among executives, investors and end users
7	Inaccurate identification of the stakeholders and inability to attract them
8	Organization's engagement in lobbying activities
9	Incapability of the consulting team to implement the project
10	Organization's inability to move from knowledge to technology
11	Limited market research for assessment and screening of the commercialization plans
12	Lack of classifications of the target industries' needs
13	Existence of politicians in the organization
14	Time-consuming and disorganized procedures for obtaining facilities and loans from banks
15	Inflation
16	Sanctions
17	Exchange rate fluctuations
18	High costs and lack of easy access to domestic- and foreign-currency loans
19	Complicated and time-consuming procedures for obtaining licenses and facilities from governmental organizations
20	Incapability of the private sector to provide suitable guarantees to obtain necessary loans
21	Private sector's lack of attention to regulatory policies of the governmental divisions
22	Private sector's failure to comply with and adhere to financial commitments
23	Lack of suitable and systematic cooperation among the internal divisions, such as the financial, investment and legal sectors
24	Lack of attention to the role of experts in the projects' implementation
25	Lack of proper time management and inaccurate estimation of the projects' completion time
26	Unrealistic estimation of the projects' costs
27	Inefficient legal model for partnerships with the private sector
28	Passivity in absorbing new ideas
29	Lack of effective communication between industries and universities
30	Unethical behaviors of executives in accepting project proposals
31	Lack of supervision of companies after commercialization and mass production
32	Lack of skills in tentative production of samples
33	Lack of complete and documented guidelines for commercialization
34	Defining technical know-how regardless of the needs and concerns of the industry, the market, and end users
35	Lack of proper mechanism for identifying technical know-how
36	Inability of the organization in the pilot implementation and operationalization
37	Investment weakness
38	Weakness in the financial system and payment policies
39	Executive team's lack of access to information resources
40	Executive team's lack of required abilities and skills
41	Excessive bureaucracy, guidelines, and regulations
42	Improper legal and intellectual property regulations in projects' commercialization
43	Lack of trust culture

Table VI.
Results of thematic analysis

(2) The second factor explained 11.45 per cent of the total variance and covered seven items, i.e. time-consuming and disorganized procedures for obtaining facilities and loans from banks; inflation; sanctions; exchange rate fluctuations; complicated and time-consuming process of obtaining licenses and facilities from governmental

organizations; high costs and lack of easy access to domestic- and foreign-currency loans; and lack of trust culture. These challenges were beyond the control of the organization and were related to the business environment and situation in the country. They were not unique to the commercialization issues, but might result in failure or obstruction of the commercialization process. This factor was named "challenges of the business environment".

Table VII. KMO and Bartlett's test

KMO measure of sampling adequacy		0.88
Bartlett's test of sphericity	Approximate χ^2	6297.17
	df	903
	Significance	0.00

Table VIII. Communalities

Question	Initial	Extraction	Question	Initial	Extraction	Question	Initial	Extraction
Q1	1	0.55	Q16	1	0.69	Q31	1	0.74
Q2	1	0.57	Q17	1	0.69	Q32	1	0.86
Q3	1	0.68	Q18	1	0.65	Q33	1	0.65
Q4	1	0.53	Q19	1	0.59	Q34	1	0.68
Q5	1	0.63	Q20	1	0.57	Q35	1	0.63
Q6	1	0.71	Q21	1	0.52	Q36	1	0.82
Q7	1	0.81	Q22	1	0.76	Q37	1	0.65
Q8	1	0.71	Q23	1	0.75	Q38	1	0.79
Q9	1	0.58	Q24	1	0.77	Q39	1	0.76
Q10	1	0.56	Q25	1	0.64	Q40	1	0.77
Q11	1	0.54	Q26	1	0.70	Q41	1	0.66
Q12	1	0.60	Q27	1	0.70	Q42	1	0.77
Q13	1	0.72	Q28	1	0.69	Q43	1	0.77
Q14	1	0.74	Q29	1	0.74			
Q15	1	0.72	Q30	1	0.63			

Table IX. Total variance explaining the challenges of technology commercialization

	Initial eigenvalues			Extraction sums of squared loadings			Rotation sums of squared loadings		
Components	Cumulative (%)	Variance (%)	Total	Cumulative (%)	Variance (%)	Total	Cumulative (%)	Variance (%)	Total
1	27.96	27.96	12.02	27.96	27.96	12.02	16.05	16.05	6.90
2	37.65	9.69	4.17	37.65	9.69	4.17	27.50	11.45	4.92
3	45.79	8.14	3.50	45.79	8.14	3.50	37.46	9.96	4.28
4	53.36	7.57	3.25	53.36	7.57	3.25	46.98	9.52	4.09
5	59.20	5.84	2.51	59.20	5.84	2.51	56.02	9.04	3.89
6	64.47	5.27	2.27	64.47	5.27	2.27	62.72	6.70	2.88
7	68.26	3.79	1.63	68.26	3.79	1.63	1.63	5.54	2.38
8	70.50	2.27	0.96						
9	72.67	2.18	0.94						
10	74.45	1.78	0.76						

Questions	Factors 1	2	3	4	5	6	7
Q1	*0.656*	0.233	0.133	0.146	0.113	0.119	−0.068
Q2	0.235	0.275	0.308	*0.580*	0.095	−0.003	0.014
Q3	0.205	0.161	0.339	*0.680*	0.112	0.117	0.071
Q4	*0.686*	0.147	0.171	0.072	0.068	0.007	−0.048
Q5	*0.769*	0.105	0.151	0.065	0.027	0.059	0.027
Q6	0.192	0.011	*0.778*	0.220	0.025	0.146	−0.013
Q7	0.123	0.111	0.110	*0.879*	0.048	0.058	0.001
Q8	0.143	0.086	0.165	−0.006	0.091	*0.802*	0.079
Q9	*0.716*	0.153	0.122	0.132	0.043	0.104	0.051
Q10	*0.711*	0.031	0.096	0.071	0.190	−0.090	0.012
Q11	*0.712*	0.001	0.005	0.123	0.107	0.010	−0.074
Q12	*0.720*	0.162	0.191	0.119	0.043	0.067	0.003
Q13	0.148	0.163	0.160	*0.796*	0.076	0.035	0.037
Q14	0.122	0.008	*0.817*	0.154	0.092	0.122	0.122
Q15	0.244	0.024	0.203	*0.784*	0.081	0.018	0.050
Q16	*0.802*	0.099	0.149	0.060	−0.001	0.078	0.071
Q17	0.154	*0.787*	0.098	0.076	0.038	0.167	0.004
Q18	0.209	0.090	0.755	0.043	0.147	−0.030	−0.043
Q19	*0.734*	0.127	0.103	0.023	0.133	0.093	0.030
Q20	*0.695*	0.243	−0.018	0.147	0.006	0.059	0.074
Q21	*0.651*	0.239	0.066	0.088	0.120	0.090	0.054
Q22	0.132	0.064	*0.831*	0.120	0.094	0.121	0.107
Q23	0.064	0.147	0.076	0.013	0.034	*0.843*	0.091
Q24	0.151	0.100	0.134	*0.844*	0.082	0.036	0.030
Q25	*0.731*	0.128	−0.015	0.254	0.126	0.078	−0.083
Q26	0.190	*0.787*	0.032	0.136	−0.012	0.112	0.097
Q27	0.173	*0.769*	0.079	0.236	0.034	0.090	0.086
Q28	0.129	0.034	*0.767*	0.243	0.102	0.076	−0.086
Q29	0.225	*0.818*	0.030	0.142	0.035	−0.008	0.015
Q30	0.074	0.157	*0.721*	0.240	0.139	0.087	−0.007
Q31	0.124	*0.832*	0.069	0.031	−0.028	0.139	−0.101
Q32	0.037	0.043	0.053	0.045	0.058	0.165	*0.908*
Q33	−0.060	−0.025	0.002	0.013	0.135	0.063	*0.793*
Q34	0.138	0.218	0.117	0.109	0.028	*0.747*	0.160
Q35	0.224	*0.753*	0.044	0.014	0.042	−0.010	−0.082
Q36	0.143	0.018	0.176	0.057	*0.859*	0.167	−0.008
Q37	0.172	*0.763*	0.038	0.091	0.068	0.144	0.065
Q38	0.162	0.065	0.177	0.095	*0.829*	0.152	0.074
Q39	0.038	0.031	0.006	0.076	0.099	0.158	*0.850*
Q40	0.129	0.071	0.082	0.126	*0.848*	−0.044	0.071
Q41	0.063	0.090	0.078	0.086	0.130	*0.780*	0.094
Q42	0.118	0.013	0.009	0.085	*0.854*	0.067	0.140
Q43	0.149	−0.007	0.136	0.043	*0.848*	0.002	0.070

Table X.
Rotated component matrix

(3) The third factor explained 9.96 per cent of the total of variance and covered six items, i.e. failure of regulatory systems to control commercialization projects; bureaucratic process, as well as excessive regulations and guidelines; lack of suitable and systematic cooperation among internal sections, such as finance, legal and investment in high-tech industries; failures in financial system and payment policies; lack of skilled forces; and denial of the role of experts in the projects' implementation. These challenges were under the control of the organization and related to

organizational systems such as control, finance, human resources and leadership. They were also associated with the whole organization's process, and thus occurred not only throughout the commercialization process, but also in other activities. The factor including these items was named "weak organizational structure".

(4) The fourth factor explained 9.52 per cent of the total of variance and comprised six items, referring to improper evaluation of projects; insufficient market research for evaluating and screening commercialization plans; lack of appropriate criteria for project evaluation; lack of clarification of the target industries' needs; lack of proper estimation of the project completion time; and unrealistic estimation of project costs. The items within this factor were under the control of the organization and were related to the commercialization process. These problems usually occurred before or at the beginning of implementing commercialization, and all referred to the assessment process. As a result, the factor encompassing these items was named "inappropriate evaluation of the plan and inefficient project management".

(5) The fifth factor explained 9.04 per cent of the total of variance and encompassed five items, i.e. inability of the private sector to provide timely loan guarantees; lack of attention of the private sector to the public sector's rules and processes; lack of adherence to the financial commitments in the private sector; consulting team's inability to help with project implementation; and executive team's lack of required abilities to accomplish the project. These challenges were not under the absolute control of the organization and did not occur during the commercialization process. The factor including these challenges was named "ineffective cooperation with non-governmental sectors".

(6) The sixth factor explained 6.70 per cent of the total of variance and comprised four items, referring to an inappropriate legal model for collaboration with the private sector in the commercialization process; ineffective communications between industry and universities in the commercialization process and intermediary role of the organization; lack of attention to interactions among executives, investors and end users; and improper identification of stakeholders and inability to attract them to the project. These challenges were under the organization's control, occurred within the commercialization process and referred to the inappropriate policies and models of partnership between the organization and groups involved in the project. The factor covering these items was named "inappropriate model of attracting and collaborating with stakeholders of the project".

(7) The seventh factor explained 5.54 per cent of the total of variance and consisted of three items, referring to lobbying in the organization; conflicting political behavior of project executives in accepting project plans; and existence of politicians in the organization. These items were not fully under the control of the organization and were linked to biased and negative behaviors in governmental organizations that were mainly due to the presence of politicians. These negative behaviors happened during the commercialization process and gave rise to a kind of organizational culture. The factor covering these items was named "conflicting political behaviors".

The abovementioned factors were identified as challenges and difficulties of technology commercialization in the organization. Confirmatory factor analysis was then used to verify these factors.

4.2.2 Confirmatory factor analysis. Before conducting confirmatory factor analysis, the normality of the data was examined. To indicate a normal distribution, kurtosis and skewness values should be close to zero, but can lie between −1 and +1 (Mertler and Vannatta, 2005). As can be seen in Table XI, the values for skewness and kurtosis for all factors are in the acceptable range, indicating normally distributed data. To further examine the normality of the data, the Kolmogorov–Smirnov (K-S) test of normality (Thode, 2002) was conducted, and the results are presented in Table XII. The *p*-values were >0.05 for all factors, showing that the assumption of normality is not violated. The results of the confirmatory factor analysis are presented in Table XIII. The questions had good explanatory power, as all factor loadings were in the acceptable range (>0.5; Hair *et al.*, 2010). The absolute values of all *t*-values were higher than 1.96, showing significant parameters of the model (Diamantoppoulos and Siguaw, 2000). As the results indicate, all Cronbach's alpha values were above 0.7, indicating good internal consistency (Hair *et al.*, 2010). Furthermore, all average variance extracted (AVE) values were above 0.5, and composite reliability (CR) values for all latent variables were higher than the AVE values, signifying good convergent validity of constructs (Hair *et al.*, 2010). Moreover, to have acceptable divergent validity, we need maximum shared variance (MSV) < AVE, and average shared variance (ASV) < AVE (Hair *et al.*, 2010). Table XIV shows that the MSV values for all factors are lower than the AVE values (presented in italic at the intersection of the same variables), and Table XV indicates that the ASV values for all factors are lower than the AVE values, confirming the divergent validity of the constructs. Figure 1, which shows the output of the confirmatory factor analysis, displays the factor loadings and *t*-values of the measurement model. In this measurement model, $\chi^2/df = 1.81$ (between 1 and 3), root mean square error of approximation (RMSEA) = 0.06 (above 0.08) and both the comparative fit index (CFI) and incremental fit index (IFI) were above 0.9. The model was therefore accepted and shown to have excellent fit (Diamantoppoulos and Siguaw, 2000).

5. Discussion and conclusions

Regardless of the need to recognize how to successfully commercialize technology in industrial development organizations, the literature has not yet identified the important factors related to this. Accordingly, through an in-depth case study of an industrial development organization, we expand upon the technology commercialization literature by exploring the difficulties of the process of technology commercialization in the mentioned organization. The studied organization is a convincing example, as the experts of the main organization and its affiliated companies could be interviewed. Moreover, it is one of the largest development organizations in the field of commercialization in Iran, while it has so

Table XI. Skewness and kurtosis values

	Factor 1	Factor 2	Factor 3	Factor 4	Factor 5	Factor 6	Factor 7
Skewness	−0.13	0.12	−0.13	−0.09	−0.05	0.15	0.36
Kurtosis	−0.18	−0.61	−0.68	−0.29	−0.70	−0.61	−0.39

Table XII. K-S test of normality

	Factor 1	Factor 2	Factor 3	Factor 4	Factor 5	Factor 6	Factor 7
K-S Z	*1.07*	11.0	*1.01*	*1.12*	*1.28*	31.1	1.32
p-values	*0.20*	*0.26*	*0.25*	*0.16*	0.08	0.16	0.05

Factor	Item	Factor loading	*t*-value	Cronbach's alpha	CR	AVE
Weakness in the commercialization process	Failure of finance and investment in the project	0.71	11.43	0.93	0.93	0.53
	Abandoning established companies after mass production	0.77	12.79			
	Lack of ability to produce a prototype	0.69	11.08			
	Inability of the organization to mass-produce and prepare a marketing plan	0.74	12.10			
	Failure in the pilot implementation and operationalization	0.68	10.70			
	Executives' lack of access to information resources	0.67	10.48			
	Improper legal and intellectual property regulations in commercialization projects	0.75	12.32			
	Lack of complete guidelines and accurate documentation for implementation of commercialization	0.80	13.44			
	Passivity in absorbing new ideas	0.73	11.88			
	Defining technical know-how without considering the needs of the industry, market, and end user	0.71	11.33			
	Lack of appropriate mechanisms to recognize the necessary knowledge	0.69	10.92			
	Inability of the organization to move from knowledge to technology	0.75	12.38			
Challenges of the business environment	Time-consuming and disorganized procedure for obtaining facilities and loans from banks	0.80	13.45	0.92	0.92	0.63
	Inflation	0.80	13.52			
	Sanctions	0.79	13.34			
	Exchange rate fluctuations	0.82	14.07			
	Complicated and time-consuming process of obtaining licenses and facilities from governmental organizations	0.82	13.96			
	High costs and lack of easy access to domestic- and foreign-currency loans	0.73	11.87			
	Lack of trust culture	0.76	12.58			
Weak organizational structure	Failure of regulatory systems to control commercialization projects	0.80	13.65	0.91	0.91	0.60
	Bureaucratic process, as well as excessive regulations and guidelines	0.90	16.37			
	Lack of suitable and systematic cooperation among internal sections	0.65	10.18			
	Failures in financial system and payment policies	0.91	16.52			
	Lack of skilled forces	0.70	11.21			
	Denial of the role of experts in the projects' implementation	0.66	10.45			

(*continued*)

Table XIII. Results of the confirmatory factor analysis

Factor	Item	Factor loading	*t*-value	Cronbach's alpha	CR	AVE
Inappropriate evaluation of the plan and inefficient project management	Improper evaluation of projects	0.67	10.54	0.91	0.91	0.64
	Insufficient market research for evaluating and screening commercialization plans	0.75	12.31			
	Lack of appropriate criteria for project evaluation	0.88	15.58			
	Lack of clarification of the target industries' needs	0.81	13.61			
	Lack of proper estimation of the project completion time	0.80	13.38			
	Unrealistic estimation of the project costs	0.86	15.00			
Ineffective cooperation with non-governmental sectors	Inability of the private sector to provide timely loan guarantees	0.90	16.27	0.92	0.91	0.71
	Lack of attention of the private sector to the public sector's rules and processes	0.88	15.33			
	Lack of adherence to the financial commitments in the private sector	0.80	13.82			
	Consulting team's inability to help with project implementation	0.80	13.61			
	Executive team's lack of required abilities to accomplish the project	0.82	14.05			
Inappropriate model of attracting and collaborating with stakeholders	Inappropriate legal model for collaboration with the private sector in the commercialization process	0.77	12.28	0.85	0.87	0.60
	Ineffective communications between industry and universities in the commercialization process and intermediary role of the organization	0.82	13.30			
	Lack of attention to the interactions among executives, investors, and end-users	0.76	12.01			
	Improper identification of stakeholders, and inability to attract them to the project	0.74	11.50			
Conflicting political behaviors	Lobbying in the organization	0.99	17.40	8.44	0.84	0.68
	Conflicting political behavior of project executives in accepting project plans	0.63	9.60			
	Existence of politicians in the organization	0.82	13.41			

Notes: χ^2 = 15.11; RMSEA = 0.06; χ^2/df = 1.81; CFI = 0.96; IFI = 0.96; relative fit index (RFI) = 0.90; normed fit index (NFI) = 0.91; standardized root mean square residual (SRMR) = 0.06

Table XIII.

	Factor 1	Factor 2	Factor 3	Factor 4	Factor 5	Factor 6	Factor 7
Factor 1	*0.53*						
Factor 2	0.20	*0.63*					
Factor 3	0.13	0.04	*0.60*				
Factor 4	0.18	0.12	0.21	*0.64*			
Factor 5	0.10	0.02	0.10	0.07	*0.71*		
Factor 6	0.08	0.12	0.10	0.04	0.07	*0.60*	
Factor 7	0.06	0.01	0.02	0.01	0.03	0.10	*0.68*

Table XIV.
Divergent validity based on MSV and AVE values

far not performed well in technology commercialization. In line with analytical reports, technology commercialization projects of the studied industrial development organization have had a high rate of failure since 2003. Hence, this study aimed to identify the significant challenges and difficulties of the process of technology commercialization in the organization to help improve this process.

To accomplish this objective, both qualitative and quantitative approaches were employed. Based on the results of the qualitative study, 43 themes were identified as difficulties and challenges of technology commercialization. Some themes were related to the organization and were under its control, while others were related to the external

Table XV. Divergent validity based on ASV and AVE values

	Factor 1	Factor 2	Factor 3	Factor 4	Factor 5	Factor 6	Factor 7
AVE	0.53	0.63	0.60	0.64	0.71	0.60	0.68
ASV	0.11	0.08	0.10	0.11	0.06	0.07	0.03

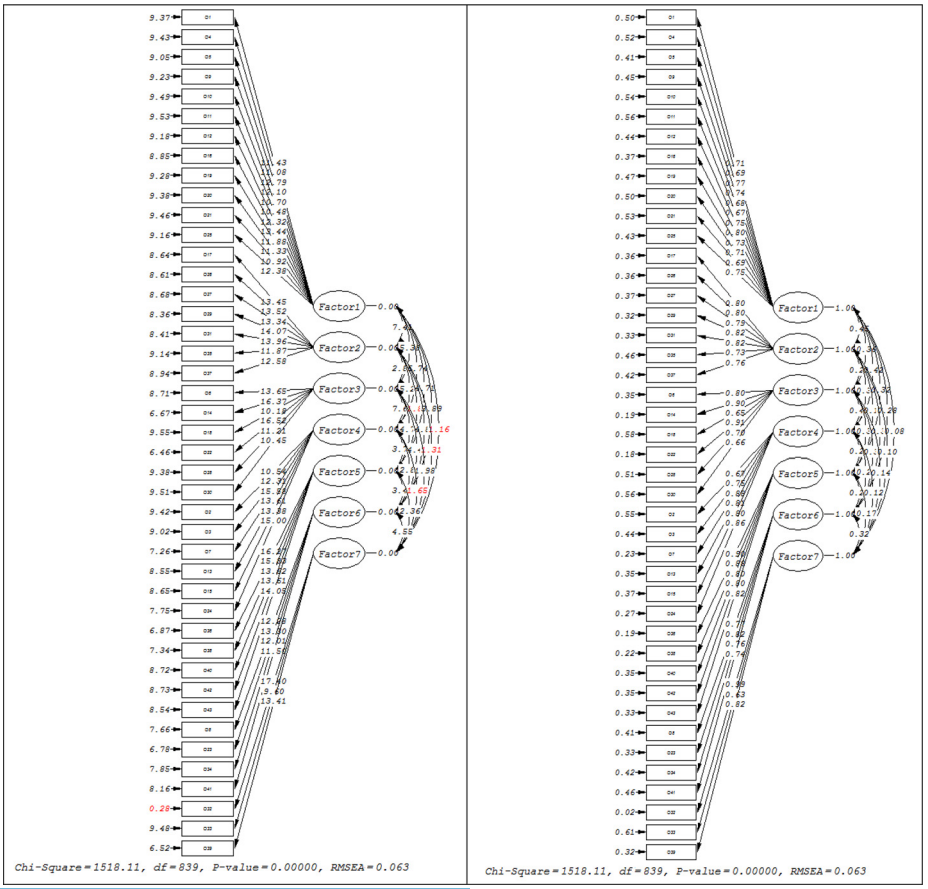

Figure 1. Factor loadings and *t*-values obtained from confirmatory factor analysis

environment, meaning that the organization had little or no control over them. The findings of the qualitative study guided the design of the questionnaire for the quantitative study. Exploratory factor analysis was conducted in SPSS to analyze the collected data, and seven factors were extracted as the main challenges of technology commercialization. The first factor included 12 items, which had two distinct features, i.e. they were under the control of the organization, and they occurred during the process of commercialization. These items were entitled "weakness in commercialization processes". The second factor incorporated seven items, which were not under the control of the organization and were related to the external business environment. This factor was named "challenges of the business environment". The third factor encompassed six items that were under the control of the organization and were related to the organizational systems, including control, finance, human resources and management. This factor was called "weak organizational structure". The fourth factor included six items that were under the control of the organization and were associated with evaluations and estimations before and during commercialization implementation. Accordingly, this factor was named "inappropriate assessment of the plan and inefficient project management". The fifth factor covered five items, which were connected to the financial issues of cooperation with private sectors and non-governmental organizations. The factor was thus named "ineffective collaboration with non-governmental sectors". The sixth factor encompassed four items that were related to the groups involved in the commercialization process and the collaboration between them. This factor was titled "inappropriate model of attracting and collaborating with stakeholders of the project". The last factor comprised three items that were linked to the opposing behaviors of the politicians in the organization. The factor was named "conflicting political behaviors". Confirmatory factor analysis then evaluated the outcomes of the exploratory factor analysis and confirmed that the factors could be measured using the explored items.

The identified challenges and difficulties were related to technology commercialization of the examined organization and its affiliated companies. However, several factors identified in this research as challenges of commercialization are consistent with the findings of earlier studies, namely, bureaucracy; lack of communication networks among investors, industry practitioners and academicians; unstrict regulations to protect intellectual properties at the national level (Pourezzat *et al.*, 2010); weakness of scientific knowledge and policymaking; lack of interest among researchers; negative attitudes toward commercialization and the nature of research (Mahmmoudpour *et al.*, 2012); financial constraints and organizational bureaucratic inefficiency; lack of mass production; changes in the market; poor economic performance; modifications in business strategies (Kimura, 2010); strict supervisions, regulations and time limits (Williams, 2003); lack of information about consumers; weak intellectual property rights; economic sanctions; lack of central project management; lack of proper interactions between researchers and investors (Tabatabaian *et al.*, 2007); organizational barriers; and lack of awareness of the commercialization process (Bandarian and Ghabezi, 2009).

6. Research implications

The outcomes of this research can increase managers' awareness regarding the inappropriate and unsatisfactory conditions of the technology commercialization process in their organization. These findings can also guide managers to overcome challenges and solve problems that are under the control of the organization. Because inductive reasoning, rather than theory testing, was used in this study and the identified themes were strongly linked to the data (Patton, 1990), several suggestions can also be offered in line with the outcomes of the research. All recommendations, which are generally derived from the

identified themes and codes regarding the challenges of technology commercialization, can be used to improve the performance of development organizations. However, clarifying the details of each proposal requires a separate, expert-driven study to identify appropriate and exact strategies to improve the conditions. Consequently, based on the results of the research, several general suggestions can be made to improve technology commercialization in industrial development organizations.

Organizations should:

- Embrace technology commercialization activities in the primary strategies and policies of the organization.
- Identify the priorities of technology commercialization.
- Determine criteria and standards for evaluating the project.
- Determine the competent institutions and laboratories from which to obtain the required licenses and approvals for technology commercialization.
- Hire experienced employees in line with the priorities of the organization.
- Implement a division to train staff, and to clarify the project management and commercialization process for the executive team.
- Form a negotiating team, whose members possess negotiation skills, to negotiate with stakeholders and attract them to the project.
- Involve all internal stakeholders in the process of drafting and setting the regulations and guidelines related to technology commercialization.
- Evaluate the external stakeholders and their roles in the different stages of the commercialization process, and develop suitable strategies based on their behaviors.
- Shape an active commercialization team to start collaborations with the executive team from the beginning of commercialization and facilitate smooth completion.
- Reform the regulations and guidelines that act as barriers to the commercialization process.

7. Limitations and suggestions for future study

This study also has some limitations. While the findings make valuable contributions to technology commercialization research, a main limitation of this study is that it was based on a single case. This research was conducted in a single industrial development organization, and with the participation of the experts from that organization alone, so generalizations should be made with caution. Another limitation of this study pertains to the non-participation of several experts in the qualitative stage due to the political atmosphere in the organization. Consequently, future research should focus on exploring the difficulties of technology commercialization in several industrial development organizations, or even in different countries, and comparing the outcomes.

Future studies should also aim to develop organizational structures that are tailored to the technology commercialization process in industrial development organizations, and to develop a business model for technology commercialization in these organizations according to their internal and external environments. Working on these issues can provide valuable information for managers to increase the success rate of their technology commercialization projects.

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