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Seyedeh Khatereh Daneshjoovash , Parivash Jafari & Abbas Khamseh

To cite this article: Seyedeh Khatereh Daneshjoovash , Parivash Jafari & Abbas Khamseh (2020): Effective commercialization of high-technology entrepreneurial ideas: a meta-synthetic exploration of the literature, Journal of Small Business & Entrepreneurship, DOI: [10.1080/08276331.2020.1789825](https://doi.org/10.1080/08276331.2020.1789825)

To link to this article: <https://doi.org/10.1080/08276331.2020.1789825>



Published online: 11 Jul 2020.



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Effective commercialization of high-technology entrepreneurial ideas: a meta-synthetic exploration of the literature

Seyedeh Khatereh Daneshjoovash^a, Parivash Jafari^b and Abbas Khamseh^c

^aDepartment of Entrepreneurship Management, College of Management and Economics, Science and Research Branch, Islamic Azad University, Tehran, Iran; ^bDepartment of Educational Administration, College of Management and Economics, Science and Research Branch, Islamic Azad University, Tehran, Iran; ^cDepartment of Industrial Management, College of Management and Accounting, Karaj Branch, Islamic Azad University, Karaj, Iran

ABSTRACT

Commercialization of high-technology entrepreneurial ideas plays an important role in the success of high-technology companies and economic development. However, most of commercialization processes fail due to poor recognition of enabling and constraining factors at each stage of the process. Thus, this article aimed to identify the factors through the meta-synthesis method of Sandelowski and Barroso. A systematic review of 30 articles selected on the basis of inclusion criteria was carried out. The findings revealed that the key internal enabling factors were competitive capabilities of the high-tech company, qualified human resources, satisfying market needs, content marketing, application of high technology, innovative high-technology product, and sufficient financial resources; as well, the key external enabling factors were elite research universities, quadruple helix, intellectual property rights, and government support policies. Moreover, the findings showed that the key internal constraining factors were limited financial resources, uncertainty of high technology, traditional marketing, market uncertainty, limited companies' capabilities, unqualified human resources, and uncertainty of product, while the key external constraining factors were shortage of government support, absence of quadruple helix, lack of intellectual property rights, and weak research universities. Consequently, identifying the factors help high-technology firms to effectively commercialize high-technology entrepreneurial ideas.

RÉSUMÉ

La commercialisation des idées entrepreneuriales en matière de haute technologie joue un rôle important dans le succès des entreprises de haute technologie et le développement économique. Cependant, la plupart des processus de commercialisation échouent en raison d'une faible reconnaissance des facteurs habilitants et contraignants à chacune de leurs étapes. Aussi, cet article visait-il à identifier ces facteurs par la méthode de méta-synthèse de Sandelowski et Barroso. Un examen systématique de 30 articles sélectionnés sur la base des critères

ARTICLE HISTORY

Received 25 December 2019;
Accepted 24 June 2020

KEYWORDS

Commercialization; entrepreneurial ideas; high technology; enabling and constraining factors; internal and external factors; meta-synthesis

MOTS-CLÉS

Commercialisation; idées entrepreneuriales; haute technologie; facteurs habilitants et contraignants; méta-synthèse

d'inclusion a été réalisé. Les résultats révèlent que les principaux facteurs internes d'habilitation étaient les capacités concurrentielles de la firme de haute technologie, les ressources humaines qualifiées, la satisfaction des besoins du marché, le marketing de contenu, l'application de la haute technologie, un produit de haute technologie innovant et des ressources financières suffisantes ; de même, les principaux facteurs externes d'habilitation étaient les universités de recherche de grand renom, le modèle de la quadruple hélice, les droits de propriété intellectuelle et les politiques gouvernementales de soutien. En outre, les résultats montrent que les principaux facteurs internes contraignants étaient les ressources financières limitées, l'incertitude de la haute technologie, le marketing traditionnel, l'incertitude du marché, les capacités limitées des entreprises, les ressources humaines non-qualifiées et l'incertitude du produit, tandis que les facteurs externes contraignants étaient un faible soutien gouvernemental, l'absence de la quadruple hélice, l'absence de droits à la propriété intellectuelle et la faiblesse des universités de recherche. Par conséquent, l'identification de ces facteurs aide les entreprises de haute technologie à commercialiser efficacement les idées entrepreneuriales de haute technologie.

1. Introduction

In the technology-based century, high-technologies (high-tech) play an important role in the economic development of societies (Al Natsheh et al. 2015; Grilli 2013; Wang and Chen 2018; Daneshfaraz and Khamseh 2015). High-tech industries generate direct revenue for countries by exporting; they also contribute, indirectly, to the economic growth of countries by impacting the low and medium-sized industries (Wang and Chen 2018; Lovely and Huang 2018). High-tech new ventures are established when entrepreneurs recognize an opportunity and create a high-tech idea, but new ventures will succeed when the entrepreneurs commercialize high-tech entrepreneurial ideas (Hashai and Zander 2018; Guo 2019). The commercialization of high-tech entrepreneurial ideas is a multi-stage process that involves research and development, producing a new high-tech product, and deployment of the high-tech product. The components of the first stage consist of assessing customers' demands, recognizing an opportunity, creating an idea, choosing the primary market, confirmation and proof of the idea, feasibility of the idea, selecting a high-tech, evaluating the high-tech, and preparing a business model. The components of the second phase include producing a prototype, evaluating the high-tech for the second time, development of high-tech, evaluating market entry conditions, assessing the final features of high-tech products, and patenting. Finally, the components of the third step involve preparing a marketing plan, content marketing, high-tech product sales and distribution, value creation for customers, and evaluating periodic high-tech product performance (Gbadegeshin 2017; Khamseh and Daneshjoovash 2018; Nambisan and Sawhney 2007; Nerkar and Shane 2003). Therefore, the first significant component of the commercialization process is an entrepreneurial idea that influences the three phases of the process (Schaufeld 2015). Effective commercialization is deeply dependent on selecting the

entrepreneurial idea (Gbadegeshin 2017; Abdul Razak, Murray, and Roberts 2014) that results in valuable outcomes (Aslani et al. 2015) including the improvement in competitive advantage of the company and the economic growth of the country (Wang and Chen 2018; Hain and Jurowetzki 2018).

Despite the above benefits, numerous studies showed that entrepreneurs face many challenges during the process of commercialization (Hashai and Zander 2018) and fail to transform their entrepreneurial ideas into innovative high-tech products (Presbitero, Roxas, and Chadee 2017; Aslani et al. 2015; Kim et al. 2017; Li et al. 2017; Madzik 2019). According to Guo (2019), high-tech new firms have more challenges in the commercialization of entrepreneurial ideas compared to low and medium-tech firms. One of the high-tech new firms' challenges is producing a market-based product. The other challenges are a lack of relation between university researches and industry, a clear contribution of Science and Technology Parks, financial resources, accessing high-skilled staff, and forming effective networks (Henriques, Sobreiro, and Kimura 2018). To address these challenges, identifying enablers and barriers to the commercialization of high-technology entrepreneurial ideas is very important. Some studies have examined factors influencing commercialization (Sheth, Acharya, and Sareen 2019; Hameed, Von Staden, and Kwon 2018; Van Norman and Eisenkot 2017; Zhao, Xiang, and Yi 2017; Flammini et al. 2017), but the enabling and constraining factors at each stage of the commercialization are not specified. Moreover, effective commercialization of high-tech entrepreneurial ideas differs from commercialization of low or medium-tech ideas due to specific features of high-tech companies such as shortage of internal resources, complicated process of opportunity recognition, indefinite nature of competition, and limited management skill and knowledge (Hashai and Zander 2018; Al-Kwafi, Ahmed, and Yammout 2014; Al-Kwafi 2016). Thus, we know relatively little about the effective commercialization of high-tech entrepreneurial ideas (Madzik 2019; Cui, Kumar, and Gonçalves 2019; Kunte, Promsiri, and Kampanthong 2018) and we need more attention to identify enabling and constraining factors affecting the process. To fill the gap, this article focuses on identifying the enabling and constraining factors at each stage of the commercialization process through a meta-synthesis approach.

This article is organized as follows: Section 2 discusses the theoretical background of high-tech and commercialization of high-tech entrepreneurial ideas, while Section 3 describes the methodology employed through a meta-synthesis process. Then, Section 4 provides findings and analyzes their relation to previous works. Finally, Section 5 presents a conclusion of the research, contribution, recommendation, and limitations.

2. Literature review

2.1. High technology

High technology is one type of technology that is markedly different from the low or medium-tech. The difference is due to the need to apply high-qualified staff, a high rate of research and development, and complicated processes that result in specific high-tech products. Nevertheless, high-tech products have a short life-cycle as well as

require excellent specialists, high R&D costs, and being innovative (Khamseh and Daneshjoovash 2018; Hashai and Zander 2018; Al-Kwafi 2016). Moreover, the purchase of high-tech products makes a high level of uncertainty for customers during the decision-making process (Hashai and Zander 2018; Al-Kwafi, Ahmed, and Yammout 2014; Al-Kwafi 2016). Uncertainty of customers during the decision-making process creates difficulties in the marketing of high-tech products and makes uncertainty for the high-tech company (Mansour and Barandas 2017). The high-technology companies are established by entrepreneurs who believe they have recognized distinctive business opportunities by their tacit technological knowledge (Kaplan and Tripsas 2008; Hashai and Zander 2018). Thus, high-tech companies are formed on the basis of knowledge-seeking and knowledge-creating capabilities of the entrepreneurs (Hallam, Dorantes Dosamantes, and Zanella 2018). Therefore, companies' performance is intimately related to the social capital of the entrepreneurs (Stam, Arzlanian, and Elfring 2014; Ahearne, Lam, and Kraus 2014).

Accordingly, high-tech companies face more challenges in the commercialization of entrepreneurial ideas than the low or medium-tech companies due to high-tech companies' lack of internal resources, complicated process of opportunity recognition, the nature of competition, and limited management skill and knowledge (Guo 2019; Park and Tzabbar 2016; Siepel, Cowling, and Coad 2015). However, the companies generate high-tech ideas and commercialize them under high uncertainty and lack of an established market by employing high-qualified human capital and innovative marketing strategies (Mansour and Barandas 2017). Therefore, the high-tech industry produces high-tech products that satisfy the market needs (Motaharrad, Arasteh, and Jafari 2014; Al Natsheh et al. 2015; Hui, Li, and Li 2018) and facilitate the economic development of countries (Hallam, Dorantes Dosamantes, and Zanella 2018; Corsi and Prencipe 2017).

2.2. Commercialization of high-technology entrepreneurial ideas

The new solutions applied by the entrepreneurs of high-tech firms are called "high-tech entrepreneurial ideas." Entrepreneurs use these ideas to introduce innovative high-tech products and, consequently, grow their business (Lukes and Stephan 2017; Brorström 2015; Sandoval et al. 2018; Madzik 2019). Innovative high-tech products will result in the success of the company if they are commercialized (Al-Kwafi 2016; Aslani et al. 2015). Commercialization is the process of transforming entrepreneurial and innovative ideas into products and creating value for customers (Namdarian and Naimi-Sadigh 2018; Sheth, Acharya, and Sareen 2019; Hameed, Von Staden, and Kwon 2018; Sharp, Iyer, and Brush 2017). Previous literature has multiple perspectives on the concept of commercialization. Some scholars such as Nambisan and Sawhney (2007) and Nerkar and Shane (2003) believed that commercialization is a chain process from the creation of an idea to sell a product to customers. The second group assumed that commercialization is the transfer of knowledge or technology from research centers to industries, designating it "technology commercialization" (Yahyaei and Hassanzadeh 2018; Sheth, Acharya, and Sareen 2019; Liu et al. 2009). According to Vohora, Wright, and Lockett (2004) and Paul, Thangaraj, and Ma

(2015), the commercialization process of a university spin-off consists of four stages of research, opportunity recognition, pre-organization, and re-orientation. The most important components of these stages are opportunity recognition, proof of ideas, entrepreneurial commitment, credibility, and sustainability. They believed managing these stages, attracting investors, providing a business plan, budget availability, and quality management of research and development activities lead to effective commercialization. Finally, the third group supposed that commercialization is the last stage of the new product development cycle, dubbing it “product commercialization”; therefore, they did not consider entrepreneurial ideas as an essential factor in the commercialization process (Burgelman and Hitt 2007; Bandariyan, Heydari, and Pourebrahimi 2015). Accordingly, as Aarikka-Stenroos and Lehtimäki (2014) and Aarikka-Stenroos and Sandberg (2012) stated, commercialization is a dynamic process that consists of moving forward and backward between three key areas of strategic marketing decision-making, creation of market, and sales development.

Therefore, high-tech entrepreneurial ideas are commercialized through the chain process of research and development, producing a new high-tech product, and deployment of the high-tech product (Gbadegeshin 2017; Khamseh and Daneshjoovash 2018; Nambisan and Sawhney 2007; Nerkar and Shane 2003).

3. Research methodology

The meta-synthesis approach based on the guidelines of Sandelowski and Barroso (2002, 2003, 2007) was applied in this study. This approach is a systematic review of qualitative research findings to create a new interpretation through a logical and consistent seven-step process. The meta-synthesis process includes defining the research questions and goals, organized reviewing of the literature, searching and choosing related studies, extracting textual information, analyzing and synthesizing qualitative findings, controlling the quality, and, finally, providing the findings. Therefore, this study has explored the following research question:

RQ. What are the internal and external enabling and constraining factors at each stage of the commercialization process of high-technology entrepreneurial ideas?

3.1. Data collection and sample

A systematic review of qualitative research findings was performed by employing the keywords including commercialization, commercialization of entrepreneurial ideas, entrepreneurial ideas, commercialization of high technology, and high technology in titles, abstracts, and keywords of published articles. The inclusion criteria consist of qualitative research articles related to the research question, published via Emerald, Elsevier, IEEE, Sage Publications, Taylor and Francis, Wiley, Springer, or found via Google Scholar, and indexed by Scopus, ISI-Listed, or ISI-WOS during 2010–2019. The process of inclusion and exclusion resulted in the exclusion of 288 articles and the inclusion of 30 bibliographic samples shown in Figure 1.

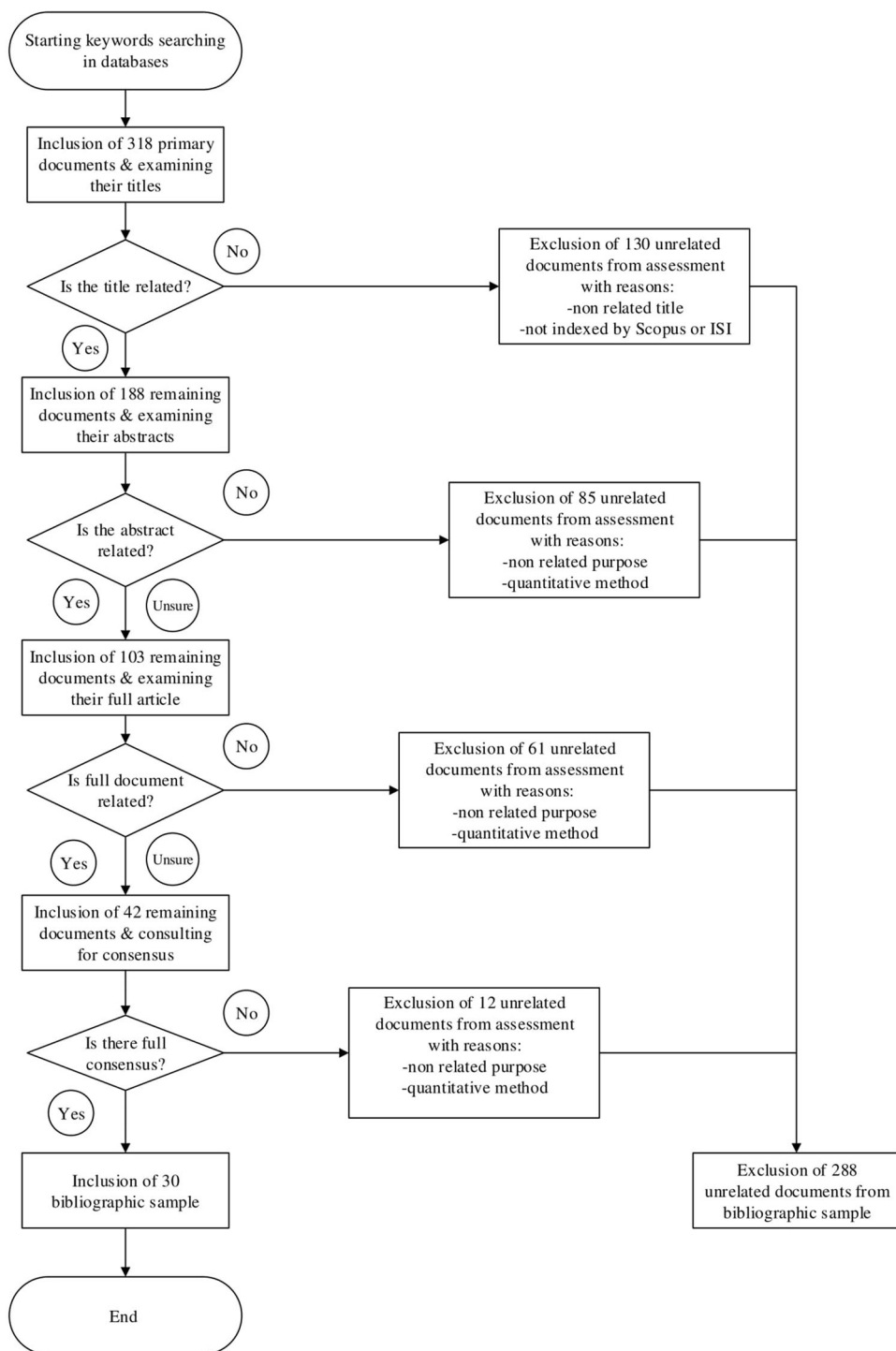


Figure 1. Process of selecting the bibliographic samples.

3.2. *Validity and reliability*

The validity of the study resting on the guidelines of Sandelowski and Barroso (2007) was approved during the research via applying various mechanisms. At first, the researchers used the inclusion criteria to set the boundaries for the systematic review, held monthly sessions to offer the report of searching articles, and used Endnote software to save and assess articles to improve the descriptive validity. Second, they held monthly sessions and appraised the team statement to increase the interpretative validity. Third, the researchers used a specialized person to improve theoretical validity. Finally, they assessed the entire route to accomplish theoretical consensus by all the researchers and the expert to enrich practical validity. The reliability of the study was also assessed by the comparative appraisal method via the parameters such as the article's title, purpose, methodology, analysis, findings, year of publication, the first author's organizational affiliation, and the journal's index (Sandelowski and Barroso 2007). Accordingly, Critical Appraisal Skills Programme (2018) was applied to assess the quality, accuracy, validity, relevance, and importance of the final articles through 10 questions focusing on the following criteria: (1) clarity of the research objectives, (2) methodology logic (qualitative), (3) adaptability of the research design to achieve goals, (4) adaptability of the sampling method to achieve goals, (5) consistency of data collection with the research subject, (6) the quality of the relationship between the researcher and the participants, (7) the quality of ethical considerations, (8) the accuracy of data analysis, (9) the clear expression of the findings, and (10) the value of the research. Due to the large volume of the final articles, only two of them were listed in Table 1 to provide an example of how the scoring of papers was applied.

According to Critical Appraisal Skills Programme (2018), the frequency of final articles with an excellent score was 81.25% and the very good score was 12.50%, which indicated the quality of the sample.

4. *Analyzing and synthesizing qualitative findings*

In line with the guidelines of Sandelowski and Barroso (2007), the final qualitative research findings were analyzed and synthesized by conducting the taxonomic analysis consists of inductive analysis through open, axial, and selective coding. Table 2 shows the main themes that were identified via open coding and were classified into internal and external enabling and constraining factors via axial coding. Moreover, Table 2 reveals the effect of each theme on the different phases of the commercialization process as well as the references and frequencies of the themes.

Based on Table 2, 102 themes were identified. The themes were analyzed, synthesized, and classified into internal and external enabling and constraining factors at each stage of the commercialization process of high-technology entrepreneurial ideas. The internal and external enabling factors positively affect the process, while the internal and external constraining factors negatively influence it. Internal enabling and constraining factors were classified as those that acted under company's control such as companies' capabilities, high-tech product, marketing, human resources, financial resources, high technology, and market; as well, external enabling and constraining factors were classified as those that did not act under company's control or

Table 1. Evaluation of the final articles.

Reference and affiliation	Topic and journal's index	Purpose, method, and analysis	Findings	Score
Sheth, Acharya, and Sareen (2019) Affiliation: Research associate at the center for policy research in science and technology entrepreneurship development institute of India	Policy implications for the improvement of technology transfer and commercialization process in the Indian context Journal's index: Scopus	Providing a list of different technologies for commercialization, paying attention to political gaps and proposing acceptable solutions to improve the technology transfer and commercialization process in India. Method: Multiple case studies Analysis: Inductive descriptive analysis	Technology transfer and commercialization result in improving startup ecosystems and economic growth; consequently, the policies of providing infrastructure by government; intellectual property rights, technology commercialization process, and financing in India need to be rebuilt.	43
Flammini et al. (2017) Affiliation: Research associate at the University of Cambridge	Business model configuration and dynamics for technology commercialization in mature markets Journal's index: ISI, Scopus, and Master Journal List	Providing a framework for business model development in the process of commercializing emerging technologies related to strategies, collaborative business models, and innovative business models. Method: Grounded theory Analysis: Induction and content analysis	It is needed more than one parallel business model when a new technology is considered to be commercialized in a company. Moreover, to face market uncertainty, it is necessary to adopt temporal collaborative strategies to identify the ideal strategy.	45

Table 2. Open and axial coding of the extracted data.

Categories	Factors	Phases	Themes	References	Frequencies
Internal enabling factors	Competitive capabilities of a high-tech company	First phase	Developing flexible organizational structures, rich business model	(Simmons, Palmer, and Truong 2013; Datta, Mukherjee, and Jessup 2015; Faghni et al. 2018; Flammini et al. 2017; Henttonen and Lehtimäki 2017; Boehm and Hogan 2013; Ettlie and Rosenthal 2012; Mesny, Pinget, and Mailhot 2016; Golcic and Sebastiao 2011; Wonglimpiyarat 2010; Sheth, Acharya, and Sareen 2019; Wonglimpiyarat 2014; Leisyrte 2011; McAdam, Miller, and McAdam 2018; Nassiri-Koopaei et al. 2014; Öberg and Shih 2014; Suvinen, Konttinen, and Nieminen 2010; Mansour and Barandas 2017)	21 themes 18 references
		Third phase	Brand, distribution resources		
		Three phases	Strategic leadership, making strategic decisions, creating a vision of the future, coordinating key competencies, supporting effective organizational culture, social capital, entrepreneurial culture, responsiveness to changes, networking, open innovation, make trust with innovation actors, a knowledge-sharing attitude, optimum resources (both tangible and intangible), organizational context, nature of capabilities, skills, and applied knowledge, managers' attitudes and behaviors toward entrepreneurship, complementary assets		
	Innovative High-tech product	Second phase	Configuration of the whole product based on customers' need, high-tech features of a product	(Golcic and Sebastiao 2011; Sargent and Matthews 2014; Aarikka-Stenroos and Sandberg 2012; Chiesa and Frattini 2011; Lovely and Huang 2018; Stenard, Thursby, and Fuller 2016)	4 themes 6 references
		Third phase	Frugality, customer's acceptance		
		Third phase	Type of message conveyed through advertising and by the internet, pull marketing through SEO and social media, content marketing in the earlier stage of a high-tech product life cycle, more visible future for technology makes easier entry into the market, more diverse suppliers and a higher level of consumer involvement in purchase decisions, strategic marketing, marketing through open innovation		8 themes 9 references
	Content marketing	Third phase	Type of message conveyed through advertising and by the internet, pull marketing through SEO and social media, content marketing in the earlier stage of a high-tech product life cycle, more visible future for technology makes easier entry into the market, more diverse suppliers and a higher level of consumer involvement in purchase decisions, strategic marketing, marketing through open innovation	(Simmons, Palmer, and Truong 2013; Aarikka-Stenroos and Lehtimäki 2014; Datta, Reed, and Jessup 2013; Henttonen and Lehtimäki 2017; Boehm and Hogan 2013; Golcic and Sebastiao 2011; Aarikka-Stenroos and Sandberg 2012; Chiesa and Frattini 2011; Mansour and Barandas 2017)	8 themes 9 references
		Third phase	Type of message conveyed through advertising and by the internet, pull marketing through SEO and social media, content marketing in the earlier stage of a high-tech product life cycle, more visible future for technology makes easier entry into the market, more diverse suppliers and a higher level of consumer involvement in purchase decisions, strategic marketing, marketing through open innovation		
		Third phase	Type of message conveyed through advertising and by the internet, pull marketing through SEO and social media, content marketing in the earlier stage of a high-tech product life cycle, more visible future for technology makes easier entry into the market, more diverse suppliers and a higher level of consumer involvement in purchase decisions, strategic marketing, marketing through open innovation		

(continued)

Table 2. Continued.

Categories	Factors	Phases	Themes	References	Frequencies
Qualified human resources	Three phases	Well-trained, qualified,	knowledge, motivated, skilled, and creative human resources, self-confidence, team-work behavior, and a strong work ethic of human resources, top management commitment	(Henttonen and Lehtimäki 2017; Marx and Hsu 2015; Boehm and Hogan 2013; Ettlie and Rosenthal 2012; Golcic and Sebastiao 2011; Powell 2010; Sheth, Acharya, and Sareen 2019; Wonglimpiyarat 2014; Flammini et al. 2017; McAdam, Miller, and McAdam 2018; Nassiri-Koopaei et al. 2014; Suvinen, Konttinen, and Nieminen 2010)	10 themes 12 references
Sufficient financial resources	First phase	Available financial resources for R&D	(Hameed, Von Staden, and Kwon 2018; Aarikka-Stenroos and Lehtimäki 2014; Boehm and Hogan 2013; Ettlie and Rosenthal 2012; Wonglimpiyarat 2010; Powell 2010; Sheth, Acharya, and Sareen 2019; Wonglimpiyarat 2014; Leisyte 2011; Wu 2010; Flammini et al. 2017; Nassiri-Koopaei et al. 2014; Suvinen, Konttinen, and Nieminen 2010)	3 themes 13 references	development,
	Second phase	Available financial resources for prototype			
	Third phase	Available financial resources for			international investment and attracting an investor
Application of high-tech	First phase	Value of	technology suitability, considering each technology separately	(Hameed, Von Staden, and Kwon 2018; Paul, Thangaraj, and Ma 2015; Mesny, Pinget, and Mailhot 2016; Ettlie and Rosenthal 2012; Wonglimpiyarat 2010; Sargent and Matthews 2014; Flammini et al. 2017; McAdam, Miller, and McAdam 2018; Suvinen, Konttinen, and Nieminen 2010)	4 themes 9 references
	Second phase	Technology evaluation and	development, resources to adapt to new technologies		

(continued)

Table 2. Continued.

Categories	Factors	Phases	Themes	References	Frequencies
Satisfying market needs	First phase	Availability of potential market, idea generation	(Aarikka-Stenroos and Lehtimäki 2014; Datta, Mukherjee, and Jessup 2015; Datta, Reed, and Jessup 2013; Chiesa and Frattoni 2011; Yu et al. 2013; Khademi et al. 2015; Stenard, Thursby, and Fuller 2016; Sargent and Matthews 2014)	8 themes 9 references	
	Third phase	Resources to adapt to market demands, market			knowledge, timing of innovation's launch, customer acceptance, customer satisfaction, global scope, customer loyalty
External enabling factors	Government support policies	Three phases	Cultivation of entrepreneurship culture and providing infrastructure through technology clusters of Science Parks	Hameed, Von Staden, and Kwon 2018; Aarikka-Stenroos and Lehtimäki 2014; Marx and Hsu 2015; Boehm and Hogan 2013; Golcic and Sebastiao 2011; Öberg and Shih 2014; Datta, Mukherjee, and Jessup 2015; Powell 2010; Wonglimpiyarat 2014)	1 theme 9 references
	Intellectual property rights	Three phases	Intellectual property rights and regulations, frequency of patent filing	(Hameed, Von Staden, and Kwon 2018; Paul, Thangaraj, and Ma 2015; Aarikka-Stenroos and Lehtimäki 2014; Datta, Mukherjee, and Jessup 2015; Marx and Hsu 2015; Boehm and Hogan 2013; Ettlie and Rosenthal 2012; Wonglimpiyarat 2014)	2 themes 8 references
	Relationship of quadruple helix	First phase Second phase Three phases	University research and key ideas come from a relationship with the private sector and industry, accessing knowledge Accelerating entry to a market Collaboration between companies and investors, linking talented faculty with students, building an innovation ecosystem, development of scientific competence	(Datta, Reed, and Jessup 2013; Marx and Hsu 2015; Boehm and Hogan 2013; Ettlie and Rosenthal 2012; Golcic and Sebastiao 2011; Leisyte 2011; McAdam, Miller, and McAdam 2018; Nassiri-Koopaei et al. 2014; Sørheim et al. 2011)	7 themes 9 references

(continued)

Table 2. Continued.

Categories	Factors	Phases	Themes	References	Frequencies
Internal constraining factors	Elite research universities	First phase	Incubators, facilitating of knowledge transfer, awarding to research projects, providing developed technology, providing qualitative, industry-based research, and cost-effective project, funding research	(Paul, Thangaraj, and Ma 2015; Mesny, Pinget, and Mailhot 2016; Aarikka-Stenroos and Lehtimäki 2014; Datta, Reed, and Jessup 2013; Boehm and Hogan 2013; Ettlie and Rosenthal 2012; Golcic and Sebastiao 2011; Powell 2010; Wonglimpiyarat 2014; Öberg and Shih 2014; Datta, Mukherjee, and Jessup 2015)	8 themes 11 references
		Three phases	cultivation of entrepreneurship, team-working, and research, providing services of training, counseling and mentoring		
	Limited companies' capabilities		Three phases	Lack of support from innovation's network or has unreliable networks	(Simmons, Palmer, and Truong 2013; Datta, Mukherjee, and Jessup 2015; Faghih et al. 2018; Flammini et al. 2017; Henttonen and Lehtimäki 2017; Boehm and Hogan 2013; Ettlie and Rosenthal 2012; Mesny, Pinget, and Mailhot 2016; Golcic and Sebastiao 2011; Wonglimpiyarat 2010; Sheth, Acharya, and Sareen 2019; Wonglimpiyarat 2014; Leisyte 2011; McAdam, Miller, and McAdam 2018; Nassiri-Koopaei et al. 2014; Öberg and Shih 2014; Suvinen, Konttinen, and Nieminen 2010;

(continued)

Table 2. Continued.

Categories	Factors	Phases	Themes	References	Frequencies
	1 theme 18 references Uncertainty of high-tech product	Third phase	Radical high-tech products have greater uncertainty of customers' acceptance rather than incremental ones	(Golcic and Sebastiao 2011; Sargent and Matthews 2014; Aarikka-Stenroos and Sandberg 2012; Chiesa and Frattini 2011; Lovely and Huang 2018; Stenard, Thursby, and Fuller 2016)	1 theme 6 references
	Traditional marketing	Third phase	Traditional marketing strategies, weak marketing programs	(Simmons, Palmer, and Truong 2013; Aarikka-Stenroos and Lehtimäki 2014; Datta, Reed, and Jessup 2013; Henttonen and Lehtimäki 2017; Boehm and Hogan 2013; Golcic and Sebastiao 2011; Aarikka-Stenroos and Sandberg 2012; Chiesa and Frattini 2011; Mansour and Barandas 2017)	2 themes 9 references
	Unqualified human resources	Three phases	Lack of skilled, motivated, knowledgeable, and experienced human resource	(Henttonen and Lehtimäki 2017; Marx and Hsu 2015; Boehm and Hogan 2013; Ettlie and Rosenthal 2012; Golcic and Sebastiao 2011; Powell 2010; Sheth, Acharya, and Sareen 2019; Wonglimpiyarat 2014; Flammini et al. 2017; McAdam, Miller, and McAdam 2018; Nassiri-Koopaei et al. 2014; Suvinen, Konttinen, and Nieminen 2010)	1 theme 12 references
	Limited financial resources	First phase	lack of R&D investment	(Hameed, Von Staden, and Kwon 2018; Aarikka-Stenroos and Lehtimäki 2014; Boehm and Hogan 2013; Ettlie and Rosenthal 2012; Wonglimpiyarat 2010; Powell 2010; Sheth, Acharya, and Sareen 2019;	5 themes 13 references
		Third phase	Increased cost results in failure in the market		
		Three phases	Limited financial resources, the uncertainty of investor, increased cost of investment for investors,		

(continued)

Table 2. Continued.

Categories	Factors	Phases	Themes	References	Frequencies
Uncertainty of market	Uncertainty of technology	First phase Second phase	lack of technology assessment Risk of technology development, lack of a unique model for each technology commercialization	Wonglimpiyarat 2014; Leisyte 2011; Wu 2010; Flammini et al. 2017; Nassiri-Koopaei et al. 2014; Suvinen, Konttinen, and Nieminen 2010) (Hameed, Von Staden, and Kwon 2018; Paul, Thangaraj, and Ma 2015; Mesny, Pinget, and Mailhot 2016; Ettlie and Rosenthal 2012; Wonglimpiyarat 2010; Sargent and Matthews 2014; Flammini et al. 2017; McAdam, Miller, and McAdam 2018; Suvinen, Konttinen, and Nieminen 2010)	3 themes 9 references
	Third phase	Uncertainty of customer, a negative post-purchase attitude of early adopters	(Aarikka-Stenroos and Lehtimäki 2014; Datta, Mukherjee, and Jessup 2015; Datta, Reed, and Jessup 2013; Chiesa and Frattini 2011; Yu et al. 2013; Khademi et al. 2015; Stenard, Thursby, and Fuller 2016; Sargent and Matthews 2014)	2 themes 8 references	
	External constraining factors	Shortage of government support	Favoritism, lack of providing required infrastructure, lack of high-speed information and communication technology, energy supply, transport, standards, regulations, and intellectual property rights, lack of policies to support spin-offs	(Hameed, Von Staden, and Kwon 2018; Aarikka-Stenroos and Lehtimäki 2014; Marx and Hsu 2015; Boehm and Hogan 2013; Golcic and Sebastiao 2011; Öberg and Shih 2014; Datta, Mukherjee, and Jessup 2015; Powell 2010; Wonglimpiyarat 2014)	4 themes 9 references
Lack of intellectual property rights	Lack of intellectual property rights	Second phase	Lack of suitable rights and regulation, the difficulty of obtaining intellectual property, infringement of intellectual property rights	(Hameed, Von Staden, and Kwon 2018; Paul, Thangaraj, and Ma 2015; Aarikka-Stenroos and Lehtimäki 2014; Datta, Mukherjee, and Jessup 2015; Marx and Hsu 2015; Boehm and	3 themes 8 references

(continued)

Table 2. Continued.

Categories	Factors	Phases	Themes	References	Frequencies
	Absence of quadruple helix	First phase	Wittingly or unwittingly bias of university to knowledge transfer	Hogan 2013; Ettlie and Rosenthal 2012; Wonglimpiyarat 2014)	2 themes 9 references
		Three phases	Lack of constant collaboration between university, industry, and companies	(Datta, Reed, and Jessup 2013; Marx and Hsu 2015; Boehm and Hogan 2013; Ettlie and Rosenthal 2012; Golcic and Sebastiao 2011; Leisyte 2011; McAdam, Miller, and McAdam 2018; Nassiri-Koopaei et al. 2014; Sorheim et al. 2011)	
	Weak research universities	First phase	Lack of support from research universities for transferring developed knowledge	(Paul, Thangaraj, and Ma 2015; Mesny, Pinget, and Mailhot 2016; Aarikka-Stenroos and Lehtimäki 2014; Datta, Reed, and Jessup 2013; Boehm and Hogan 2013; Ettlie and Rosenthal 2012; Golcic and Sebastiao 2011; Powell 2010; Wonglimpiyarat 2014; Öberg and Shih 2014; Datta, Mukherjee, and Jessup 2015)	1 theme 11 references

the company had little control over them such as government policies, intellectual property rights, quadruple helix, and research universities.

According to the findings, of internal enabling factors, the competitive capabilities of the high-tech company have the highest rank based on 21 themes cited in 18 references; thus, they have the most positive effect on the effective commercialization process. On the opposite, sufficient financial resources have the lowest rank based on three themes cited in 13 references; therefore, they have the least positive effect on the effective commercialization process. As a result, competitive capabilities of the high-tech company, qualified human resources, satisfying market needs, content marketing, application of high technology, innovative high-technology products, and sufficient financial resources are the most important internal enabling factors in the effective commercialization of high-technology entrepreneurial ideas in the order of importance.

The findings showed that competitive capabilities of high-tech company such as flexible organizational structures and the rich business model have a positive effect on the first phase of the commercialization process, brand and distribution resources have a positive effect on the third step; last but not least, strategic leadership, making strategic decisions, creating a vision of the future, coordinating key competencies and capabilities, supporting effective organizational culture, social capital, entrepreneurial culture, responsiveness to changes, networking, open innovation, make trust with innovation actors, a knowledge-sharing attitude, both tangible and intangible optimum resources, organizational context, nature of applied knowledge, managers' attitudes and behaviors toward entrepreneurship, and complementary assets have a positive effect on all three stages of the commercialization process. The second internal enabling factor is qualified human resources. As the findings revealed and Nassiri-Koopaei et al. (2014) indicated, human resources act in the company as research and development specialists, producer, marketer, and distributor of high-tech products; they, therefore, positively affect the whole process via their high work ethics, motivation, and creative behavior. The third internal enabling factor is known as satisfying market needs. As the findings suggest and Aarikka-Stenroos and Lehtimäki (2014) stated, while the availability of potential market and idea generation based on market needs have positive influences on the first stage of the commercialization process, the other elements – such as capacities or resources to adapt to market demands, customer knowledge, the timing of innovation's launch on the market, customer acceptance, customer satisfaction, global scope of the market, and customer loyalty – positively affect the third stage. Furthermore, content marketing as the fourth internal enabling factor positively influences the third phase via the type of message conveyed by advertising and pull marketing. Thus, the findings supported the research results of Mansour and Barandas (2017). The fifth factor is the application of high technology that positively affects the first phase when it is selected based on its suitability for customers, and positively influences the second phase when it is developed. The findings confirm the research results of Paul, Thangaraj, and Ma (2015) and Wonglimpiyarat (2010). Besides, the innovative high-tech product is the sixth factor. As the findings reveal and Al-Kwafi (2016) and Al-Kwafi, Ahmed, and Yammout (2014) indicated, a configuration of the whole high-tech product and its

high-tech features based on customers' needs positively affect the second phase. Also, frugality of high-tech product and customer's acceptance positively influence the third step. Finally, sufficient financial resources as the last internal enabling factor positively influence the whole process. When the high-tech company has available financial resources for R&D, this factor has a positive effect on the first step, but when the company has available financial resources for prototype development, the factor positively affects the second phase. Also, if the company has available financial resources for international investment and attracting investors, the factor positively has an effect on the third stage. Therefore, the competitive capabilities of the company as the findings revealed and Simmons, Palmer, and Truong (2013), Datta, Mukherjee, and Jessup (2015), and Golicic and Sebastiao (2011) stated, are the main internal enabling factors that differentiate the company's commercialization process from the competitors' and make a competitive advantage for the company. Thus, the competitive advantage of the companies' capabilities, qualified human resources, satisfying the market needs, content marketing strategies, application of high technology, and innovativeness of high-tech products are more important than sufficient financial resources. As Tobiassen and Pettersen (2018), Al-Kwafi (2016), and Hashai and Zander (2018) asserted, high-tech companies have limited financial resources, but they can achieve sufficient financial resources by open innovation. Based on the findings, open innovation is one of the high-tech companies' capabilities; therefore, sufficient financial resources are dependent on the companies' capabilities.

Moreover, according to the findings, despite the lowest positive effect of sufficient financial resources among internal enabling factors, limited financial resources have the most negative effect and highest rank with six themes cited in 13 references among internal constraining factors on the effective commercialization process. Therefore, as mentioned earlier, high-tech companies can attract investors to eliminate the negative effect and increase the positive effect of financial resources. On the opposite, uncertainty of high-tech products has the lowest rank with one theme cited in six references. Thus, as Al-Kwafi, Ahmed, and Yammout (2014) and Al-Kwafi (2016) stated, producing an innovative high-tech product based on customers' needs results in decreasing the uncertainty of customers. Besides, the findings showed if the company has limited financial resources, if it does not receive support from innovation's network or it has unreliable networks, and if there is lack of skilled, motivated, knowledgeable, and experienced human resource, the three phases of commercialization process will be negatively affected. As well, if the company faces the uncertainty of high-tech products from the customer's acceptance and conducts traditional marketing strategies, the third stage will be negatively influenced. Finally, if the company does not eliminate the uncertainty of high technology, the first and second steps will be negatively affected. Accordingly, limited financial resources, the uncertainty of high technology, traditional marketing, the uncertainty of the market, limited companies' capabilities, unqualified human resources, and uncertainty of product are the most internal constraining factors in the commercialization process in the order of importance.

The findings also revealed that elite research universities among external enabling factors have the highest rank with 15 themes cited in 12 references; therefore, they

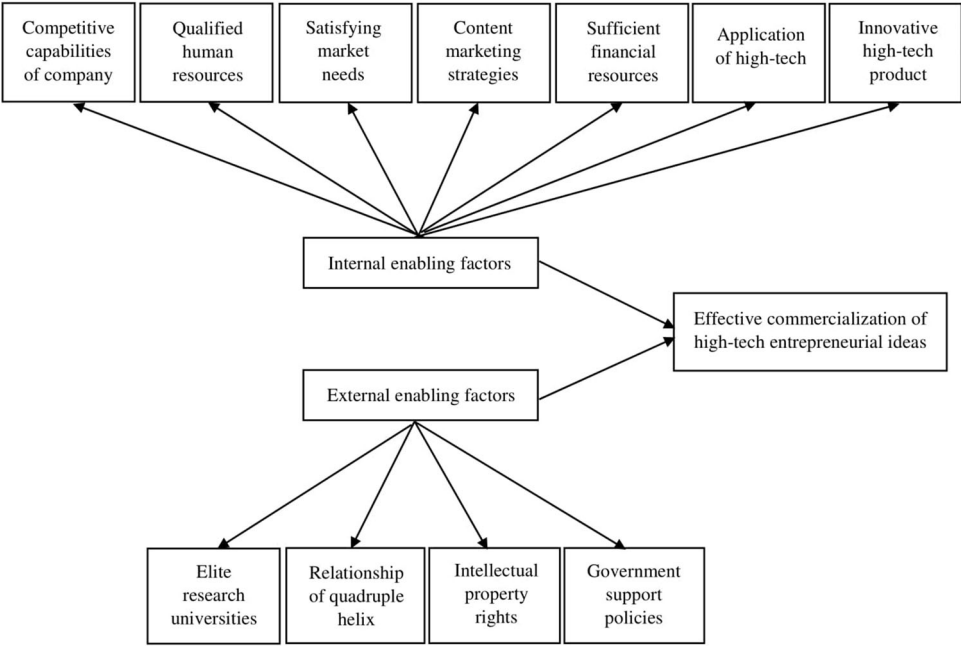


Figure 2. Effective commercialization of high-technology entrepreneurial ideas.

have the most positive effect on the effective commercialization process. On the opposite, intellectual property rights have the lowest rank with two themes cited in nine references; thus, they have the least positive effect on the process. Accordingly, elite research universities, quadruple helix, intellectual property rights, and government support policies are the most important external enabling factors in the effective commercialization of high-technology entrepreneurial ideas in the order of importance.

According to the findings, elite research universities positively affect the first stage of the commercialization process by supplying developed knowledge and high technology, providing incubators as well as qualitative, industry-based, and cost-effective research projects, facilitating knowledge transfer, awarding research projects, and funding the research project. They also influence the whole process positively by the cultivation of entrepreneurship, team-working, and research culture, and by providing services for training, counseling, and mentoring. Thus, the findings confirm the research results of Gbadegeshin (2017), Leisyte (2011), and Mesny, Pinget, and Mailhot (2016). The relationship of the quadruple helix as the second external enabling factor has a positive effect on the first phase by communicating with the private sector and industry to contribute high-tech firms to access the developed knowledge of universities. They also have a positive effect on the second step by accelerating entry into the market. Finally, they influence all three phases of the commercialization process by making collaboration between companies and investors, linking elite universities with students, building an innovation ecosystem, and developing scientific competence relevant to the market. Therefore, the findings supported the research results of Henttonen and Lehtimäki (2017) and McAdam, Miller, and McAdam

(2018). Besides, intellectual property rights and regulations positively affect the second phase as Stenard, Thursby, and Fuller (2016) and Sheth, Acharya, and Sareen (2019) mentioned. Finally, government support policies are the fourth factor that can enable the whole process by the cultivation of entrepreneurship culture and providing infrastructure through technology clusters of Science Parks. So, the findings confirm the research results of Sheth, Acharya, and Sareen (2019), Wonglimpiyarat (2014), and Suvinen, Konttinen, and Nieminen (2010).

Moreover, according to the findings, government support policies have the highest rank in external constraining factors with eight themes cited in 10 references; thus, they have the most negative effect on the commercialization process. On the opposite, research universities have the lowest rank with one theme cited in 12 references; thus, they have the least negative effect on the commercialization process. Accordingly, shortage of government support, absence of quadruple helix, lack of intellectual property rights, and weak research universities are the most external constraining factors in the commercialization process in the order of importance.

The findings showed if governments do not support spin-offs or do not provide required infrastructure as high-speed information and communication technology, transport, standards, and intellectual property rights, as well as if the quadruple helix does not communicate, all the three phases of commercialization will be negatively affected. Also, lack of suitable intellectual property rights and regulation, the difficulty of obtaining intellectual property, or infringement of intellectual property rights negatively influence the first stage. Finally, if research universities do not facilitate the process of knowledge transfer, the first stage will be negatively affected. Therefore, the findings confirm the research results of Henttonen and Lehtimäki (2017), Gbadegeshin (2017), Mesny, Pinget, and Mailhot (2016), and Leisyte (2011).

Thus, identifying the internal and external enabling and constraining factors at each stage of the commercialization process, as well as making a balance between them by improving the positive effect of the enabling factors and reducing the negative effect of constraining factors, will result in the effective commercialization of high-tech entrepreneurial ideas. The effective commercialization of high-technology entrepreneurial ideas resting on the positive influence of enabling factors and eliminating the negative effect of constraining factors is depicted in Figure 2.

5. Conclusion

The effective commercialization of high-technology entrepreneurial ideas plays a significant role in the success of high-tech companies and the economic growth of countries in the competitive economies (Sheth, Acharya, and Sareen 2019; Khamseh and Daneshjoovash 2018; Hameed, Von Staden, and Kwon 2018). Nevertheless, some high-tech companies face many challenges during the stages of the commercialization process (Hashai and Zander 2018) and, consequently, do not succeed in transforming the entrepreneurial ideas into innovative high-tech products. The failure is due to poor recognition of the enabling and constraining factors at each stage of commercialization process (Presbitero, Roxas, and Chadee 2017; Aslani et al. 2015; Kim et al. 2017; Li et al. 2017; Madzik 2019; Chiesa and Frattini 2011; Aarikka-Stenroos and

Lehtimäki 2014; Aarikka-Stenroos and Sandberg 2012). Thus, the purpose of the study was to identify the factors at each stage of the commercialization process of high-tech entrepreneurial ideas.

According to Table 2, effective commercialization of high-tech entrepreneurial ideas is achieved through applying seven internal enabling factors, namely, competitive capabilities of the high-tech company, qualified human resources, satisfying market needs, content marketing strategies, sufficient financial resources, application of high technology, and innovative high-tech product as well as the existence of four external enabling factors, namely, elite research universities, the quadruple helix, intellectual property rights, and government support policies. According to the findings, competitive capabilities of the high-tech company has the most positive effect among internal enabling factors; also, elite research universities have the most positive influence among external enabling factors on the effective commercialization of high-tech entrepreneurial ideas.

As Figure 2 indicates, eliminating the effect of constraining factors and improving the positive influence of enabling factors result in the effective commercialization of high-tech entrepreneurial ideas. As a consequence, effective commercialization of high-tech entrepreneurial ideas means the process of idea generation based on market demands, producing an innovative high-tech product resting on the application of high technology and its suitability for customers, patenting, and presenting the innovative high-tech product in the market via content marketing strategies. The process will be improved by applying the competitive capabilities of the high-tech company, qualified human resources, and sufficient financial resources as well as the support of the government, elite research universities, and quadruple helix. Thus, as the results showed and Hashai and Zander (2018), Al-Kwafi (2016), and Al-Kwafi, Ahmed, and Yammout (2014) stated, effective commercialization of high-tech entrepreneurial ideas differs from the low or medium-tech ideas.

As a result, identifying the internal and external enabling and constraining factors at each stage of the commercialization process will help high-tech firms to reduce the commercialization challenges and improve the successful transforming entrepreneurial ideas into innovative high-tech products. Thus, high-tech firms should identify the factors and manage them by eliminating the effect of constraining factors and improving the effect of enabling factors at each stage of the commercialization process. Modeling effective commercialization of high-technology entrepreneurial ideas could help high-tech firms effectively commercialize high-technology entrepreneurial ideas.

Given the points made above, at first, it is suggested that high-tech firms (1) create open innovation to improve their core capabilities, recognize market demands, identify the value of technology, conduct content marketing, and reduce the company's financial constraints, (2) employ qualified and motivated human resources with teamwork behavior and high work ethics to achieve sustainable competitive advantage, and (3) prepare a professional business plan emphasizing their core capabilities to attract investors. Second, it is recommended that elite research universities communicate strongly with high-tech firms to provide market-based research projects and transfer developed knowledge. Third, it is proposed that governments allocate

resources to high-tech firms to improve the enabling factors, reduce constraints such as favoritism and lack of intellectual property rights, and prepare the required infrastructure for the commercialization process. Fourth, due to the significance of entrepreneurship education in gaining competitive capabilities (Leisyte 2011; Wonglimpiyarat 2014; Daneshjoovash and Hosseini 2019), it is suggested that policy-makers offer entrepreneurship education programs for high-tech entrepreneurs to learn and develop capacity for writing a rich business plan, recognizing markets' demands, and conducting content marketing. Fifth, since most of the final articles have been written by management or technology researchers in developed countries, it is advised that both management and technology researchers concentrate more on examining the prioritization of enabling and constraining factors in developing countries. Sixth, as Sheth, Acharya, and Sareen (2019) and Li et al. (2017) stated, each high-tech entrepreneurial idea needs a particular route to be commercialized, it is suggested that researchers examine enabling and constraining factors at each stage of commercialization process for each specific type of high technology such as information and communication technology, nanotechnology, aerospace technology, renewable energy, and so forth. Finally, due to the fact that the study analyzed and synthesized only the published articles by Elsevier, Emerald, IEEE, Sage Publications, Taylor and Francis, Wiley, and Springer or the articles found via Google Scholar (i.e. journals indexed in Scopus, ISI-Listed or ISI-WOS), it is suggested that examining other articles published by other publishers may yield more valuable results.

Disclosure statement

No potential conflict of interest was reported by the authors.

Notes on contributors

Seyedeh Khatereh Daneshjoovash is a Ph.D. student of Entrepreneurship Management in the Department of Entrepreneurship Management, College of Management and Economics, Science and Research Branch, Islamic Azad University, Tehran, Iran. Her research interests include Entrepreneurship, Commercialization of Entrepreneurial Ideas, High technology, and Entrepreneurship Education.

Parivash Jafari is an associate professor of Educational Administration in the Department of Educational Administration, College of Management and Economics, Science and Research Branch, Islamic Azad University, Tehran, Iran. Her research interests include Leadership, Entrepreneurship, Organizational Behavior, Organizational Culture, and Development of Human Resource.

Abbas Khamseh is an assistant professor of Technology Management in the Department of Industrial Management, College of Management and Accounting, Karaj Branch, Azad University, Karaj, Iran. His research interests include Technology Management, R&D Management, Innovation Management, and Entrepreneurship.

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