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What really matters for TTOs efficiency? An analysis of TTOs in developed and developing economies

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Abstract

The university's role in reaping the benefits from research by transforming knowledge and technology into commercially usable forms is becoming increasingly important. In this article, we seek to deepen the understanding of the technology transfer office (TTO). TTOs are primarily responsible for the protection of university created intellectual property (IP) and the management of the commercialization process. The aim of this study is to determine which internal efficiency factors are statistically significant for the efficiency of TTOs, and which barriers cited in literature are experienced by TTOs, and to, furthermore, compare these between developed and developing economies. To achieve this objective, we created a survey that was sent to 103 TTO's distributed in 21 countries. Our results demonstrate that it is apparent that developed economies (EU and UK) have overcome certain barriers experienced by developing economies (BRA, ISA and SA). Additionally, this paper has shown that TTOs have a built-in conflict with researchers. The results also emphasize the important role of networking and industry links.

Keywords Technology transfer · Technology transfer office · Efficiency · Developed economies · Developing economies

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1 Introduction

In the context of the global knowledge economy, the traditional roles of universities are evolving and playing a greater role in transferring knowledge generated by university researchers into industries and economies (Fernandez-Alles et al., 2018; Lafuente & Berbegal-Mirabent, 2019). The university's role in reaping the benefits from research by transforming knowledge and technology into commercially usable forms is becoming increasingly important. As such, universities have been striving to turn ideas and inventions into jobs, wealth, and career opportunities (Harman and Harman 2004). This has stimulated entrepreneurship and innovation both inside and outside of the university (Cunningham et al., 2019). Research on technology transfer has emerged and become popular, not only among scholars, but also among managers and entrepreneurs, who search the available literature for useful information to aid in their endeavors (Bozeman et al., 2015; Good et al., 2019). Universities have the potential for social and economic development by creating and providing knowledge and influencing the competitiveness and prosperity of their region (Cunningham et al., 2019; Good et al., 2019; Kashyap & Agrawal, 2019). But the process of transferring knowledge from one organization to another, or technology transfer, is facing numerous challenges, and to assist in facilitating this process, intermediaries have assumed the role (Good et al., 2019; Kashyap & Agrawal, 2019).

There are several types of knowledge and technology transfer intermediaries that are involved in the innovation process, each with different forms of action and roles. Among them are; technology transfer offices, public research organizations, regional economic development agencies, knowledge intensive business service firms, and professional associations (Landry, 2013). In this article, we seek to deepen the understanding of the technology transfer office (TTO). TTOs are primarily responsible for the protection of university created intellectual property (IP) and the management of the commercialization process (Markman, 2005; Gubitta et al., 2016; Holgersson and Aaboen, 2019). A can be considered, according to Tahvanainen and Hermans (2011), as a process catalyst, a knowledge converter, and an impact amplifier.

Several studies (de Falco, 2015; Tahvanainen & Hermans, 2011) have shown, however, that many TTOs operate inefficiently (Anderson et al., 2007). These inefficiencies can be attributed to several internal and external factors. Internally, several factors determine the efficiency of the TTO at technology transfer, while externally several barriers exist that affect efficiency. According to a model created by Heher (2006), it can take up to 10 years for an institution, and 20 years nationally, to attain a positive rate of return from an investment in research and technology transfer. Oliveira and Teixeira (2010) state that only half of the TTOs in the USA are earning a profit. Another survey on TTOs in the USA found that over 50% lose money on their technology transfer operations, while only 16% are self-sustaining (Abrams et al., 2009). Furthermore, their study found that fewer than 10% of U.S. institutions' technology transfer programs are primarily motivated by financial return. Considering how few TTOs are financially self-sustaining and are motivated by financial returns, focusing on monetary values alone is not an accurate measure of efficiency.

Indeed, to date, Data Envelopment Analysis has been regarded as a proper approach to measuring TTO efficiency (Kim et al., 2008; Lafuente & Berbegal-Mirabent, 2019). This approach focuses on measurable outcomes of technology transfer which mostly relate to

monetary values or tangible factors. These include the number of disclosures, the annual number of patent applications, licensing agreements, the formation of university spin-off companies, and the financial revenue generated through these activities. Using income from technology transfer, however, does not measure real performance as it does not provide, nor is it based on, the potential for technology transfer based on university research (Vinig & Lips, 2015). Sorensen and Chambers (2008) have emphasized the importance of the balance between economic metrics and non-monetary benefits for the assessment of technology transfer.

Furthermore, several papers (Bercovitz, 2001; Oliveira & Teixeira, 2010) have highlighted the importance of the formulation and implementation of a technology transfer strategy in improving efficiency. Within said strategy, non-monetary factors such as information flow, organizational design and structure, human resource management practices in the TTO and the presence of reward systems should be addressed (Libecap, 2005). Moving from this, Secundo et al., (2016, 2017), and De Beer et al., (2017) developed and tested a self-assessment tool which determines the efficiency of TTOs using intangible and non-monetary indicators. According to De Beer et al., (2017) efficiency is generally regarded as the conversion of inputs into outputs (quantitative in nature), but suggests that this definition is broadened to capture the qualitative nature of technology transfer, and therefore denotes the ability to successfully engage in technology transfer activities. In this paper we adopted the De Beer et al., (2017) vision for efficiency.

A study by Jung et al. (2014) cites the barriers to technology transfer which can determine the efficiency of technology transfer. These are grouped into four categories: organization, Market, Environment and Technology. Aside from these, technology transfer can be hampered by some barriers that are further aggravated in developing economies (Kumar et al., 2015; World Bank Group, 2017). Padilla-Pérez and Gaudin (2014) noted that systemic failures in developing economies can hamper the innovation system, which is affected by failures in the public education system and the financial system. Furthermore, developing economies usually have weak institutional structures and mutable public initiatives (Padilla-Perez and Gaudin, 2014). Additionally, in developing economies, there is a technical skill deficit, with a limited ability to generate original knowledge, and a limited number of technically skilled workers (World Bank Group, 2017; Chege et al., 2019). Thus, some important issues in the technology transfer policy in most developing economies still need attention (Kumar et al., 2015). As such, the aim of this study is to determine which internal efficiency factors are statistically significant for the efficiency of TTOs, and which barriers cited in literature are experienced by TTOs, and to, furthermore, compare these between developed and developing economies.

2 Literature review

2.1 Knowledge and technology transfer between university and industry

Universities emerged with the leading role of teaching. However, throughout the nineteenth and twentieth centuries, two other missions were integrated into this, the research, and after the 1980s the responsibility to contribute to social development and economic growth (Philpott et al., 2011; Schulte, 2004). In the last two decades it has been observed that more and more universities have been involved in innovation and industrial development in the most diverse countries (Wang et al., 2015). This has led to many large companies,

especially those deeply involved in research and development, to move closer to universities (Lam, 2007). This change of role occurred in response to the social demands arising from globalization and technological change. The change in economic thinking, which shifted from the focus on physical capital to knowledge, also led to a new focus on universities (Audretsch et al., 2014), intending to transform the knowledge generated in its scope into an economic and social value (Etzkowitz, 2003). The aim was to drive knowledge-based economic and social development in economic and academic systems at different stages of development (Etzkowitz, 2017).

Given the consensus on the importance of knowledge as the main source of competitive advantage for organizations (Schiuma et al., 2012) and one of the main engines for long-term economic growth (Mascarenhas et al., 2019), greater attention has been given to the creation and commercialization of knowledge generated in universities. Whether through joint research, consulting, patents, publications, licensing agreements, spin-offs, and other forms of contact (Lafuente & Berbegal-Mirabent, 2019; Muscio, 2010), the transfer of knowledge and technology from universities to industry has become an important strategy because of its benefits. For universities, it provides sources of funding for their research, opportunity for faculty to work on innovative research, as well as the possibility of generating solutions to urgent global challenges (Muscio, 2010; Edmonson et al., 2012; Fernandez-Alles et al., 2018). For companies, this interaction represents a source of innovation (Muscio, 2010; Fernandez-Alles et al., 2018). Faced with the rapid pace of the evolution of science and technology companies, including the largest ones, there has been an inability to exploit all the knowledge that can contribute to the improvement and innovation of their processes and products. This led them to use cooperation strategies to create knowledge with other partners, including universities (Dietrich et al., 2010). For policy makers, the transfer of knowledge and technology from universities to industry is a source of economic development (Muscio, 2010; Fernandez-Alles et al., 2018) and, according to Cartalos et al. (2018), crucial for national and regional growth policies.

Thus, in view of the recognition of universities as important institutional providers and the growing interest in university-industry interaction, many universities began to foster links between knowledge users, facilitating technology transfer (Fernandez-Alles et al., 2018; Lafuente & Berbegal-Mirabent, 2019). In this sense, the universities accumulated a range of new functions, such as technology transfer offices (TTOs), science parks and incubator facilities (Brown, 2016). In this article we focus on TTOs, which are organizations that have been given the responsibility of facilitating the technology transfer process from universities to industry, acting as a bridge between these two environments (Good et al., 2019).

This process, however, did not occur in the same way in all countries. If in developed nations, policymakers and strategists have been dedicated to creating initiatives to boost this relationship for some decades, in developing countries, this movement is more recent (Padilla-Pérez, 2014; Fischer et al., 2017). In Brazil, for example, the collaborative practices between industry and university have been challenging due to the development model of universities that historically has been linked to technological imports. It was only in the 2000s that universities began to prepare themselves to assume the role of an "entrepreneurial university" (Faccin et al., 2021).

Besides the university development model, the late search for interaction with companies led to the formation of a cognitive gap between university and industry in these countries, so that different views are still barriers to collaborative practices. Thus, such nations end up constituting innovation systems "characterized by weak, inefficient ties between

agents giving additional importance to UIC externalities that might translate into further academic entrepreneurial capabilities" (Fischer et al., 2017).

As a way of leveraging universities as knowledge disseminators, policymakers in these "lagging" countries have invested in initiatives to foster U-I collaboration, intending to improve the capabilities of regional and national innovation systems. The Innovation Law, enacted in Brazil in 2004, is an example of an initiative that fostered the institutionalization of TTOs (Fischer et al., 2017).

In South Africa, even though technological development has had a different history from that of Brazil, with the construction of a solid base of research and technological capacity until 1994, throughout the 1990s investments and R&D fell significantly. Also, although the link between research organizations and industry is classified as strong, this relationship has had little impact on the country's economic growth. This result is attributed, in large part, to the similarity of what occurs in Brazil, the gap between knowledge generators and the market. Thus, intending to overcome what they called the "innovation chasm", political decision-makers began to foster public policies that contributed to overcoming the chasm (Wolson, 2007). Thus, it is clear that when the focus is on a developing country, this relationship also takes other forms. Thomas et al., (2020) argue that these societies have many social challenges so that universities end up having to go beyond their teaching, research, and collaboration missions with industry for innovation.

Thus, it is clear that this type of relationship (U–I) is complex and there is no single approach. Each approach will depend on the context and aspirations of the actors involved. However, despite the differences, an issue that seems to be paramount is the development of an adequate environment with strong mechanisms of incentive to the actors. Furthermore, the culture of the university involved needs to support commercialization without compromising its first two missions (Harman and Harman, 2004).

At the same time that university-industry collaboration came to be recognized as a promoter of economic development, innovation, and competitiveness, the literature on the subject has advanced significantly since 2005. In a search carried out on the Web of Science (WoS) for the keywords "collaboration", (and) "university", (and) "industry", (or) "university-industry", (or) "industry-university", (or) "UI", (or) "IU", applying the filters "article", "business" and "management", 181 articles were found from 1981 to 2005, and 938 articles from 2006 to 2020. This represented an increase of about 518% in the number of publications in the last 15 years, which demonstrates the importance assumed by the field.

Shute et al. (2017) in bibliometrics carried out with 435 articles from the WoS database, from 2011 to 2016, point out that the field is complex, multifaceted and that uses different theoretical perspectives and models, which reflect a certain fragmentation. Among the most researched themes are characteristics and motives of the actors involved in the commercialization of research, as well as their effects; characteristics, and motives of the actors involved in collaborative activities, as well as the effects; and regional policies to encourage U-I collaboration. Also, the authors point out that the U-I collaborative process is shaped by a variety of elements and that there are several predictors of the scientific and economic impact of this type of activity.

Cunningham et al. (2017) reviewed the qualitative case methods that have been used in technology transfer between 1996 and 2015. Among the main findings indicate a clustering of themes around technology transfer mechanisms and TTOs, academic entrepreneurship, U-I collaboration, commercialization as well as R&D and firm knowledge transfer. Besides, the authors identify that most research is focused on developed countries in

Europe, the United States, and Canada. Among developing countries, China has a similar number of studies to developed countries (but below the USA and the United Kingdom). South Africa, India, and Argentina are also among the 38 most studied countries, but with a significantly lower percentage than the former. In addition, Santini et al. (2021) highlight that most studies on the U-I relationship are focused on North American and European universities, so that little is known about this relationship in developing countries.

Thus, despite the advances in the field with the increase in the number of studies, the contextual differences and the very course of the U-I collaboration process, existing between developed and developing countries, make the policies of the former and even theoretical and empirical advances be considered with reservations when the focus is on developing countries (Rucker Schaeffer et al., 2018). In this sense, Thomas et al. (2020), point out that there is a theoretical gap regarding the promotion of innovation and regional development in these nations.

2.2 Technology transfer offices (TTOs)

Historically, TTOs began in the United States in the mid-1980s, but soon expanded to other countries, and became an organizational structure preferred by universities (Siegel et al., 2007), within the scope of the universities' third mission. One of the events that helped with the university's third mission was the passage of the Bayh-Dole Act in the USA, which established changes to the Patent and Trademark Law. From this act, universities were given the right to patent their inventions and license their use to private companies (Holgersson & Aaboen, 2019; Fernandez-Alles et al., 2018). According to Siegel et al. (2007) universities established TTOs to manage and protect their IP while marketing it to businesses. "The main goal of TTOs is to help any research product reach its potential and focus on intellectual performance. The development of new companies and licensing of intellectual content are seen as the main ways to commercialize research" (Kireyeva et al., 2020, p. 736). Therefore, the role of TTOs is to facilitate the transfer of technology or knowledge by licensing inventions for industry or other forms of IP from university research. Thus, these offices are responsible for identifying breakthroughs and innovative ideas, charting the best course of action for their development, and exploiting them economically (Gubitta et al., 2016; Lafuente & Berbegal-Mirabent, 2019). As a result, they act as knowledge intermediaries, bringing together researchers, companies, and investors (Lafuente & Berbegal-Mirabent, 2019), as well as identifying potential spin-offs and seeking support from universities for the first validation phases (Gubitta et al., 2016). Moreover, these initiatives are responsible for stimulating the entrepreneurial behavior of academics, encouraging the dissemination of scientific results and later supporting the commercialization phase of research (Lafuente & Berbegal-Mirabent, 2019). TTOs are also responsible for identifying spinoff companies that are worth receiving university funding to support their early validation phases (Gubitta et al., 2016).

Hence, empirical studies on the performance of these offices, as well as on indicators that make it possible to analyze their performance, have been observed in a growing body of literature, as some TTOs are more successful than others in the process of commercializing research results (Heisey & Adelman, 2011; Lafuente & Berbegal-Mirabent, 2019; Fernandez-Alles et al., 2018). The success of the TTO can be understood in terms of profitable operation. However, to measure this, it is not possible to take into account only TTO revenue, as there are non-monetary factors such as age and size of the TTO that influence the success (Secundo et al., 2016). In turn, the commercialization of technology is

considered successful when the increase in technology transfer generates an increase in profit in the transferred companies or growth in the global economy (Jung et al., 2014). In this sense, the "technology transfer up to the stage of product commercialization involves a constant multilevel exchange of information" (Kireyeva et al., 2020, p. 744).

Recently, Lafuente and Berbegal-Mirabent (2019) suggested that organizational practices and resource allocation strategies may explain the significant differences in performance among TTOs. According to Fernandez-Alles et al. (2018) differences in features and characteristics of TTOs could explain changes in their performance. In addition, other important factors for more efficient TTOs are pointed out in the literature. Secundo et al. (2016) highlights some major components that influence this process, namely IP strategy and policy; organization design and structure; human resource; technology; industry links; and networking. In this sense, Siegel et al. (2003) points out that in terms of human resources, increasing the staff size of a TTO significantly increases the number of licensing agreements reached by the university. The authors further add that the older the TTO, the more efficient they will be in generating revenue. Similarly, Thursby and Kemp (2002) confirmed that larger TTOs are more likely to have more licensing agreements. Horner et al. (2019) corroborates that organizational design and technical human capital are important characteristics that influence the effectiveness of technology transfer.

As pointed out, different factors may influence the effectiveness of technology transfer. Thus, investigating these indicators becomes essential for a better understanding of how this process occurs, enabling the maintenance of the universities' competitive advantage. In this way, the next topic addresses the efficiency factors and barriers experienced by TTOs.

2.2.1 Efficiency factors and barriers of TTOs

University technology transfer can be improved internally (by addressing factors which impact on the efficiency of the TTO) and externally (by removing barriers experienced by the TTO during the process of transferring technology outside the university) (De Beer et al., 2017). Granieri and Frederick (2015) lists, what they call, the critical success factors for TTOs. These factors are grouped according to thematic similarity into five areas: Capability, Capacity, Opportunity, Desire, and Environment. Secundo et al., (2016) expanded on this basis, and defined six areas in which internal efficiency factors need to be managed: human resources, IP policy and strategy, networking, university-industry links, technology, and organization design and structure. The area of "Human resources" includes 02 factors, adapted from Phan and Siegel (2006) and Chapple et al. (2005), in order to analyze the skill sets of the human resources involved. The second area "IP Strategy and Policy" comprises 07 factors, elaborated primarily from Siegel et al., 20,047 which focus on institutional support given to technology transfer. The area of "Network", made up of 03 factors, sought to measure the interaction between the parties involved, and was developed from Kim et al. (2008) and Curi et al., 2012. The fourth area, "Industry links", focuses on understanding the needs of the industry, covering 03 factors from Anderson et al., 2007 and Kim et al., 2008. The "Technology" area emphasizes the importance of the stage of development of the disclosed technology, as well as the academic merit of the discloser. This was measured by 02 factors, proposed by Stock & Tatikonda, 2000. Finally, the 03 factors that made up the area "Organization design and structure", initially proposed by Bercovitz et al., 2001 and further elaborated by Siegel et al., 2007, which examined the TTO and surrounding support functions.

Successful technology transfer is, therefore, dependent on these critical success factors. But additional external factors, or what we call barriers, are also experienced, and Jung et al. (2014) cited barriers to success found in the literature. According to this study, the barriers to technology transfer are grouped into four factors: Organization, Market, Environment and Technology. These barriers can be divided into those that are critical to the success of the TTO, and those that were critical to the success of technology transfer. The study identified 08 barriers critical to the success of the TTO and 18 barriers critical to the success of technology transfer.

The barriers which are critical to the success of the TTO from an organizational dimension include the marketing and financial capacity of the TTO, and the willingness, ability and technical capability of the adopter of the technology. The market condition (market dimension) and cooperation with the discloser of the technology (environment dimension) are also critical. The remaining 02 barriers relate to the technology dimension and include the effort undertaken to improve the technology, and the provision of technology that complements the one initially developed.

The barriers which are regarded as critical to the success of technology transfer from an organizational dimension are insufficient funds for product/prototype development, excessive royalties asked for by the TTO, a tense negotiation process with the TTO, complicated processes implemented by the TTO or university to license the technology, the lack of cooperation between the TTO and adopter after the licensing agreement, and/or non-compliance with the licensing agreement. The deterioration of the market and/or business conditions (market dimension), and the lack of technology specialists for product/prototype development, the correct research environment/equipment, additional complementary technology in the market, and/or unexpected governmental regulations (environment dimension) are additional success factors. The remaining 06 factors relate to the technology dimension and include technological deficiency (where the TTO patented a technology too early, and it is under-developed), difficulties in acquiring the raw material needed for product/prototype development, patent infringement, difficulties in technical improvement of the product, unexpected costs of producing the product, lack of physical space for mass production of product, and/or technical difficulties in the mass production system.

There is a substantial body of literature from developed economies which documents and investigates technology transfer and TTOs and provides insight on how to be more efficient at technology transfer (Rasmussen, 2008). However, the application of these insights to the developing economy context has not been very successful. Miller et al. (2016) state that technology transfer performance measurements are emergent with many measures not being adequately addressed such as tacit based activity costs and effectiveness and therefore, there is a need for more fine-grained technology transfer performance measures. Framed on the above premises, this study will determine the efficiency of university technology transfer using intangible indicators. Once a determination can be made around the efficiency of technology transfer, steps can be taken to improve it.

At an external level, barriers to the successful transfer of technology have been identified in literature and a determination if these barriers are experienced is needed. On the other hand, Alexander et al. (2020) identified that the presence of barriers can be inherent to the decision-making process and its application within organizations and not a result of any strategic or structural deficiencies. Thus, it is necessary to explore more the reality of developing countries, such as India, to see if the barriers vary depending on the context and structural deficiencies. The contextual specificities need to be raised, since there are few studies on these countries (Kashyap & Agrawal, 2020). It is, furthermore, valuable to know if TTOs have found ways of overcoming these barriers.

3 Data and methods

Using the studies by Granieri and Frederick (2015), Secundo et al. (2016) and Jung et al. (2014) as a basis, we developed a survey that was divided into two sections. Section 1 involves the analysis of the significance of the internal efficiency indicators at TTOs. Section 2 involves a frequency analysis of the barriers experienced by TTOs. The study concludes with an analysis of the interviews conducted post-survey to determine a suite of best practices which might be shared to improve efficiency.

The survey was sent to 103 TTOs distributed in 21 countries, as given in Table 1. The TTOs were arranged according to the economic development of the countries in which they are based, using the classification proposed by the World Economic Situation and Prospects (WESP, 2019). For analytical purposes, WESP classifies all countries of the world into one of three broad categories: developed economies, economies in transition and developing economies, reflecting basic economic conditions of the country (Table 2).

3.1 Section 1: analysis of the significance of the internal efficiency indicators

Section 1 of the survey measures various intangible indicators, on a scale of 1 (completely absent) to 5 (wholly present), grouped into six efficiency areas as proposed by Secundo et al. (2016).

The survey was sent to TTOs with the request to rate the presence or absence of each of the items on a scale of 1–5. The data collected was then analyzed using descriptive analysis

Table 1 Countries in which the TTO's are based, number of TTOs that participated in the survey, and their WESP rating

Country	Number of TTO	WESP rating
Austria	2	Developed economies
Belgium	4	Developed economies
Bulgaria	1	Developed economies
Czech Republic	5	Developed economies
Denmark	1	Developed economies
Estonia	1	Developed economies
Finland	1	Developed economies
France	1	Developed economies
Germany	4	Developed economies
Greece	2	Developed economies
Italy	1	Developed economies
Netherlands	3	Developed economies
Poland	1	Developed economies
Romania	1	Developed economies
Spain	1	Developed economies
Sweden	2	Developed economies
Switzerland	1	Developed economies
United Kingdom	20	Developed economies
Israel	17	Developing economies
Brazil	20	Developing economies
South Africa	14	Developing economies

Table 2 Summary of efficiency factors and their sources

Area	Factor	Reference(s)
Human resources	(1) Sufficient employees	(1) Phan and Siegel (2006)
	(2) Knowledge of IP portfolio management	(2) Chapple et al. (2005)
IP policy and strategy	(1) Vision	(1) Libecap et al., (2005)
	(2) Involvement with researchers	(2) Siegel et al. (2004)
	(3) Royalties to researchers	(3) Friedman and Silberman, (2003), Lach and Schankerman (2004) and Debackere and Veugelers (2005)
	(4) Incentives for researchers	(4) Siegel et al. (2004)
	(5) Resources for TTO	(5) Libecap et al., (2005)
	(6) Incentives for TTO	(6) Libecap et al., (2005)
	(7) Education	(7) Siegel et al. (2004)
Networking	(1) TTO relates to researchers	(1) Curi et al. (2012)
	(2) Relationships	(2) Kim et al., (2008) and Siegel and Waldman (2003)
	(3) Events	(3) Curi et al. (2012)
University-industry links	(1) Understand industry	(1) Siegel et al., (2003) and Anderson et al., (2007)
	(2) Networking	(2) Kim et al., (2008) and Siegel and Waldman (2003)
	(3) Education	(3) Siegel et al. (2004)
Technology	(1) Advanced stage of research	(1) Stock and Tatikonda (2000)
	(2) Researcher is a professor	(2) Stock and Tatikonda (2000)
Organization design and structure	(1) Business incubator	(1) Bercovitz et al., (2001)
	(2) External to university	(2) Oliveira and Teixeira (2010)
	(3) Decentralized management	(3) Siegel et al., (2007)

(Hair et al., 2008) to determine statistically significant internal efficiency indicators. Furthermore, the data was analyzed using a Pearson's correlation analysis to determine statistically significant relationships between the various areas of efficiency. Upon completion of the correlation analysis, linear regression was performed to determine if a statistically significant impact was noted by considering the degree of economic development of the countries (Hair et al., 2008).

3.2 Section 2: analysis of barriers experienced by TTOs

The barriers identified by Jung et al., 2014 were listed in Sect. 2 of the survey and respondents were asked to indicate their response among the levels: No, we do not experience this barrier; Yes, and we do not have a solution; Yes, but we have a solution. The data collected by the survey was then further interpreted using frequency analysis, indicating the predominant response in TTO's in developed and developing countries.

3.3 Post-survey interviews: determining a suite of best practices

Based on the survey results, certain respondents were interviewed to better understand the solutions they had devised to barriers experienced by other TTOs. The interviews were transcribed and analyzed using word cloud technology to determine a suite of best practices.

Weckowska (2015) showed that TTOs learn through experimentation and failure, and by sharing these experiences with other TTOs, thereby improving the technology transfer process. In a study of the transnational sharing of best practices, Kostova (1999) states that the socio-economic environment in which the best practice is found versus where it will be adopted, is a challenge. This becomes evident in the case of developing economies where the process of innovation is different from that of developed economies, in that mature technologies are often being adopted with limited success (Hobday, 2005). As such organizing our results in developed versus developing countries may serve as the basis for sharing appropriate best practices.

4 Results and discussion

The results will be discussed according to the three headings described in the methods section above.

4.1 Section 1: analysis of the significance of the internal efficiency indicators

Initially, a descriptive analysis was performed with all variables studied, as shown in Table 3. We seek to identify the factors that in general were most relevant to the efficiency of TTOs. Therefore, we adopted the average limit of 3.5 as the criterion for the relevance of the variables. Factors with an average above 3.5 were considered more relevant. Generally, we observed that seven main factors are indicated by the respondents.

We observed that seven factors, of the twenty investigated, obtained an average higher than 3.5 showing main factors to efficiency of TTOs. We found factors belonging to the networking category, namely: The TTO organizes events or facilitates networking among

Table 3 Descriptive statistics for study variables

	Variable	Mean	SD
Human resources	The TTO has a sufficient number of employees	2.786	1.2179
	At least one employee has the knowledge to manage the IP as a portfolio	3.82	1.1834
IP strategy and policy	The TTO has a clear, transparent and consistent vision for technology transfer, with strategic goals and priorities	3.398	1.1827
	The TTO has frequent and reciprocal involvement with researchers (without being compulsory)	3.66	1.0986
	Researchers receive a portion of the royalties that the university receives	4.04	1.0749
	Incentives for researchers to disclose new IP	3.252	1.1352
	There is sufficient allocation of resources to the TTO	2.777	1.2675
	There are incentives for TTO employees	2.379	1.1557
	The TTO provides education to overcome the informational and cultural barriers between the TTO and the University	3.252	1.1001
Networking	TTO employees know and relate to researchers	4.08	.8822
	The TTO facilitates the formal and informal relationship between researchers	3.466	.9982
	The TTO organizes events or facilitates networking among the researchers from different departments of the University	3.62	1.0011
Industry links	TTO understands industry needs	3.86	1.0199
	The TTO facilitates the formal and informal networking between university and industry	3.71	1.0630
	The TTO provides education to overcome informational and cultural barriers between the university and industry	3.097	1.0619
Technology	Most of the technologies developed by researchers are disclosed to the TTO at an advanced stage of development	2.340	1.1845
	Most members of the University who disclose technologies are professors	3.282	1.2866
Organization design and structure	A business incubator is available at the University	3.204	1.5234
	The TTO is external to the University	2.175	1.4648
	The TTO has a decentralized management style	2.738	1.3573

the researchers from different departments of the University (3.62) and TTO employees know and relate to researchers (4.08). These results are corroborated by the literature, where studies claim that TTOs are actors known for creating synergistic networks among scientists, industry, university and governments (Belitski et al., 2019; Holgersson & Aaboen, 2019).

It was also observed the importance for TTOs to establish strategies and policies to maintain the link with researchers and provide returns for them. About this, they are pointed out as relevant factors: Researchers receive a portion of the royalties that the university receives (4.04) The TTO has frequent and reciprocal involvement with researchers (3.66). This can be expected as universities across the world are increasingly expected to embrace the "third mission" (Etzkowitz & Leydesdorff, 2000), of acting entrepreneurially in addition to teaching and research. In this sense, Baldini (2010) found that universities routinely share recipes with their inventors and as a result, greater patenting activity can be observed. The establishment and capacitation of TTOs, and incentivizing researchers to disclose technologies are two mechanisms by which universities are acting more entrepreneurially.

We also found that it is necessary for TTOs employees to have knowledge to manage IP as a portfolio (3.82). These results are confirmed by Bigliardi et al. (2015), the authors found that skills and knowledge of the human resources of TTO strongly influence the number of innovations presented, affecting the performance of TTOs.

The results also showed the importance of TTOs understanding the needs of the industry (3.86) and facilitating formal and informal networking between university and industry (3.71). Thus, in addition to generating revenue for universities, TTOs should promote collaboration between universities and industries (Hayter et al., 2020; Brescia et al., 2016).

So, with these results, we classify our group of respondents into two levels, above average and under average. The independent sample t-test has been used to compare the means of independent samples (Table 4). It was possible to observe statistically significant differences between the means of these groups, showing that these factors that presented an average above 3.5 are statistically significant for the efficiency of TTOs.

In general, an important finding refers to the fact that in both groups, developed countries and developing countries, the most relevant factors were similar (Table 5). However, a comparison (t-test) was done between developed and developing economies and the results showed significant differences only for two variables: Researchers receive a portion of the royalties that the university receives ($t = -2.052$; $p = 0.043$) and most members of the university who disclose technologies are professors ($t = -5.72$, $p = 0000$).

The statistically significant results show the higher average in developing economies. This can be explained because while TTOs may play an important role in this commercialization process, other actors can share some of the duties of TTOs. Moreover, despite the fact that in the developed economies the establishment of a culture of innovation in their university programs is observed for longer times, with a greater proportion of professors interested in commercialization, some often choose a 'backdoor route' to

Table 4 Independent sample t-test results—above and under average

		Média	SD	t	Sig
Factors for efficiency of TTOs	Above average	3.83	1.058	15.870	0.000
	Under average	2.93	1.297		

Table 5 Descriptive statistics and t-test—developed and developing economies

	Variable	Developed economies (n = 52)		Developing economies (n = 51)		T-value	Significance
		Mean	SD	Mean	SD		
Human resources	The TTO has a sufficient number of employees	3.00	1.24	2.57	1.17	1.818	0.072
	At least one employee has the knowledge to manage the IP as a portfolio	3.79	1.05	3.86	1.31	−0.316	0.752
IP strategy and policy	The TTO has a clear, transparent and consistent vision for technology transfer, with strategic goals and priorities	3.38	1.12	3.41	1.25	−0.116	0.908
	The TTO has frequent and reciprocal involvement with researchers (without being compulsory)	3.67	1.00	3.65	1.19	0.120	0.905
	Researchers receive a portion of the royalties that the university receives	3.83	1.09	4.25	1.02	−2.052	**0.043**
	Incentives for researchers to disclose new IP	3.21	1.03	3.29	1.24	−0.368	0.714
	There is sufficient allocation of resources to the TTO	2.96	1.17	2.59	1.34	1.504	0.136
	There are incentives for TTO employees	2.44	1.11	2.31	1.21	0.563	0.575
	The TTO provides education to overcome the informational and cultural barriers between the TTO and the University	3.38	1.09	3.12	1.11	1.235	0.220
Networking	TTO employees know and relate to researchers	4.17	0.73	3.98	1.01	1.110	0.270
	The TTO facilitates the formal and informal relationship between researchers	3.52	0.89	3.41	1.09	0.543	0.588
	The TTO organizes events or facilitates networking among the researchers from different departments of the University	3.65	0.90	3.58	1.09	0.331	0.741
Industry links	TTO understands industry needs	3.86	0.99	3.86	1.06	0.013	0.990
	The TTO facilitates the formal and informal networking between university and industry	3.85	0.98	3.57	1.14	1.328	0.187
	The TTO provides education to overcome informational and cultural barriers between the university and industry	3.21	0.98	2.98	1.14	1.106	0.271
Technology	Most of the technologies developed by researchers are disclosed to the TTO at an advanced stage of development	2.33	1.09	2.35	1.28	−0.111	0.912
	Most members of the University who disclose technologies are professors	2.65	1.08	3.92	1.16	−5.72	**0.000**

Table 5 (continued)

	Variable	Developed economies (n = 52)		Developing economies (n = 51)		T-value	Significance
		Mean	SD	Mean	SD		
Organization design and structure	A business incubator is available at the University	3.46	1.36	2.94	1.64	1.748	0.084
	The TTO is external to the University	2.08	1.35	2.27	1.58	−0.682	0.497
	The TTO has a decentralized management style	2.94	1.16	2.53	1.51	1.550	0.124

Table 6 Descriptive statistics and F-test by categories

Areas	Mean	SD	F-value	Sig
Human resources	3.30	1.3061	29.469	0.000
IP Strategy and policy	3.25	1.2492		
Networking	3.72	0.9936		
Industry links	3.56	1.0964		
Technology	2.81	1.3208		
Organization design and structure	2.70	1.5056		

Table 7 Descriptive statistics and t-test by categories

Areas	Developed economies (n = 52)		Developing economies (n = 51)		T-value	Sig
	Mean	SD	Mean	SD		
Human resources	3.39	0.86	3.22	0.97	0.982	0.327
IP strategy and policy	3.27	0.66	3.23	0.78	0.257	0.798
Networking	3.78	0.57	3.66	0.84	0.863	0.390
Industry links	3.64	0.79	3.47	0.94	1.000	0.320
Technology	2.49	0.92	3.13	0.86	−3.670	0.000
Organization design and structure	2.83	0.85	2.58	1.00	1.336	0.185

commercialization because they question the efficiency of TTOs as facilitators of research commercialization (Belitski et al., 2019). In developing countries, TTO is a new phenomenon, regulation has started to develop and mechanisms for commercialization and protection of IP rights are recent. In developed countries, TTOs face a high level of university bureaucracy (Belitski et al., 2019; Civera et al., 2020).

However, technology transfer is a process involving key actors in value exploration (researchers/scientists) and value exploitation (industry partners), universities often seek the right internal stakeholders. As such, some TTOs in developed economies focus only on engaging with exceptional researchers (often professors) (Mangematin et al., 2014).

In the sequence, we group the 20 factors in 6 predefined categories by the literature, these groups were constructed by the average of the constituent single factors (Table 6). The results show that the dimension that presented the highest average was networking (3.72). While the dimension with the lowest average was organization design and structure (2.70). At this point, we can highlight the statistically significant differences between the means, confirming the importance of establishing networks for the efficiency of TTOs (Belitski et al., 2019; Holgersson & Aaboen, 2019).

When we analyzed the categories from the differences between developed and developing countries, we could see that only the technology category showed significant differences between the groups (Table 7). Generally, comparing the results for each construct, only the technology construct presented a statistically significant difference ($t = -3.670$; $p = 0.000$). This can be expected as the environment (university-industry links) is more conducive to the development of technology which is significant for commercialization. Indeed, according to Balieri et al. (2014) universities in developed economies have been required to put more effort into creating industry linkages in order to shorten time to

prototyping. Specifically, in the U.S where the Bayh-Dole Act of 1980 led to increased university-industry interaction and the establishment of TTOs.

After obtaining these results, a Pearson's correlation analysis was performed to verify the relationship between the categories variables tested, as shown in Table 8. The areas "Human Resources", "IP Strategy and Policy", "Networking", "Industry links", "Technology", "Organization design and structure" were correlated with the greatest correlation force between "Networking" and "Industry links" (r = 0.601). This result could be explained by the interdependence of successful networking within the university (between the TTO and researchers) and the successful links between the university and industry to enable successful technology transfer. As alluded to by Mangematin et al. (2014) universities often seek the right alignment between internal and external stakeholders to ensure successful technology transfer.

Furthermore, it was observed that the relationships between "IP strategy and policy" and "Networking", and "Industry links" were statistically significant. This may be because the IP policy in universities often govern the networking and industry links components. Similarly, the statistically significant relationships between "Industry links" and "Human resources", and "Organization design and structure" can be explained by the reliance on the correct human resources and organization design to enable the links between the university and industry. A final statistically significant relationship between "Human resources" and "Networking" can be explained in the same way.

Upon completion of the correlation analysis, linear regression was performed. In the analysis below IP Strategy and Policy was selected as the dependent variable. This was done give that the IP Strategy and Policy governs the activities of the TTO, and would determine the vision and mission statement of the TTO. The results show (Table 9) that "Human resources", "Networking" and "Industry links" have a positive impact on the "IP strategy and policy". This explained the IP strategy and policy adopted by the TTO at 45.7% because the variables captured by the three constructs listed ("Human resources", "Networking" and "Industry links") influence the choice of policy and strategy adopted by the TTO.

The impact of these variables was also analyzed considering the degree of development of the countries (Table 9). In the developing economies, the independent variables explained 65.4% of the dependent variable (IP strategy and policy), and the relationship between "Networking" and "IP strategy and policy" and "Industry links" and "IP strategy and policy" were significant. At the same time, in developed economies the predictive variables explained 28.6% of the dependent variable showing that only the relationship between "Human resources" and "IP strategy and policy" was significant.

Fai et al. (2018) state the importance of defining the mission statement of the TTO during the emergent phase of the TTO (as is the case for TTOS in emerging economies) as this determines the activities the TTO would pursue. In the case where the TTO pursues a "Commercialisation" mission, the Human Resources would be focussed towards staff who have skills in commercialising research; the Networking and Industry-Links would be a key focus for the TTO staff, and the Organization Design and Structure would most likely be a TTO which is external to the University to enable commercial activities to take place more effectively. Fai et al. (2018) argue that in the case with the mission is "Relationships" the Organization Design and Structure would most likely be a TTO which is internal to the University to enable closer interaction with Researchers, and so the Networking and Technology dimensions would be a key focus for the TTO staff.

Thus, considering Fai et al. (2018) we believe that these differences between countries were observed because in developed countries the mission of the TTO is often

Table 8 Pearson's correlation analysis

	Human resources	IP strategy and policy	Networking	Industry links	Technology	Organization design and structure
Human Resources	1					
IP strategy and policy	0.517**	1				
Networking	0.209**	0.549**	1			
Industry links	0.423**	0.580**	0.601**	1		
Technology	− 0.003	0.058	0.109	− 0.030	1	
Organization design and structure	0.285	0.248	0.298*	0.364**	− 0.030	1

**Correlation is significant at the 0.01 level (2-tailed)

*Correlation is significant at the 0.05 level (2-tailed)

Table 9 Linear regression of study variables in developed and developing economies

Dependent variables	IP strategy and policy	IP strategy and policy in the developed economies	IP strategy and policy in the developing economies
Human resources	.323 (.064)**	.364 (.781)**	.164 (.084)
Networking	.293(.094)**	.026 (.096)	.337 (.108)**
Industry links	.279 (.082)**	.125 (.174)	.398 (.099)**
Technology	.034 (.0.56)	− .243 (.129)	.153 (.091)
Organization design and structure	− .032 (.0.62)	.083 (.097)	− .052 (.071)
N	103	52	51
R2	.484	.356	.689
Adjusted R2	.457	.286	.654

**Significant at 1%; *Significant at 5%

The numbers in parentheses are standard errors

"Commercialization of Research" the success of which is dependent on the skills of the staff in the TTO "Human Resource". In developing countries, many TTOs have not yet defined their mission, or their mission may be to build relationships with industry and with researchers, in this case "Networking" and "Industry Links" are more important to be successful in this mission.

4.2 Section 2: analysis of barriers experienced by TTOs

When analyzing the survey data, using frequency analysis, it was found that about half of barriers listed by Jung et al., 2014 was experienced by developing economies and they did not currently have a solution, while the remainder were not experienced at all (Table 10). In developed economies these barriers were mostly not experienced, or a solution has already been found. The results also noted divergent issues between developed and developing economies, in that the barriers faced are not the same.

The barriers experienced by developed economies were: (i) Marketing capacity of the TTO; (ii) Willingness and ability to adopt technology; (iii) Financial capacity of TTO; (iv) Market condition. This may be due to the longevity of these TTOs, and the technology readiness levels of the disclosed technologies, which would mean that these TTOs engage more actively in the later commercial phases of technology transfer. In developed economies, TTOs state that for the barriers they do not experience, they already have solutions.

Whereas, for developing economies, the following factors have been identified as major barriers: (i) Marketing capacity of the TTO; (ii) Cooperation with technology developer; (iii) Efforts improve technology; (iv) Willingness and ability to adopt technology; (v) Financial Capacity of the TTO. It is important to notice that for these barriers TTOs in developing economies do not have solutions.

Additionally, the barriers critical for the commercialization of technology were studied (Table 11).

The results found that for developed economies the main barriers for commercialization were: (i) Insufficient funds for complementary technological development and/or prototyping; (ii) Lack of additional research environment and equipment; (iii) Occurrence of

Table 10 Frequency analysis of barriers critical to the success of the TTO

		Developed economies	Developing economies
Barriers critical to the success of the TTO	Marketing capacity of the ITT	***A solution has been found to this barrier***	**This barrier is experienced and there is not currently a solution**
	Cooperation with technology developer	*Do not experience this barrier*	**This barrier is experienced and there is not currently a solution**
	Efforts improve technology	*Do not experience this barrier*	**This barrier is experienced and there is not currently a solution**
	Willingness and ability to adopt technology	**This barrier is experienced and there is not currently a solution**	**This barrier is experienced and there is not currently a solution**
	Provision of technology that complements the one initially developed	*Do not experience this barrier*	*Do not experience this barrier*
	Financial capacity of TTO	**This barrier is experienced and there is not currently a solution**	**This barrier is experienced and there is not currently a solution**
	Market condition	**This barrier is experienced and there is not currently a solution**	*Do not experience this barrier*
	Technical capacity of the adopter	*Do not experience this barrier*	*Do not experience this barrier*

Table 11 Frequency analysis of barriers critical to the successful commercialization of technology

		Developed economies	Developing economies
Barriers critical to the successful commercialization of the technology	Insufficient funds for complementary technological development and/or prototypes	**This barrier is experienced and there is not currently a solution**	**This barrier is experienced and there is not currently a solution**
	Lack of additional research environment and equipment	**This barrier is experienced and there is not currently a solution**	*Do not experience this barrier*
	Shortage of complementary technology	*Do not experience this barrier*	*Do not experience this barrier*
	Lack of technology specialists for prototype and/or product development	*Do not experience this barrier*	*Do not experience this barrier*
	Occurrence of technological deficiency	**This barrier is experienced and there is not currently a solution**	**This barrier is experienced and there is not currently a solution**
	Excessive royalties	*Do not experience this barrier*	*Do not experience this barrier*
	Shortage of cooperative activities after licensing agreement	*Do not experience this barrier*	*Do not experience this barrier*
	Tense and tortuous negotiation or complicated process	***A solution has been found to this barrier***	**This barrier is experienced and there is not currently a solution**
	Unexpected governmental	*Do not experience this barrier*	*Do not experience this barrier*
	Non-compliance with the licensing agreement	*Do not experience this barrier*	*Do not experience this barrier*
	Deterioration of the market condition	**This barrier is experienced and there is not currently a solution**	**Do not experience this barrier**
	Deterioration of business circumstances	**This barrier is experienced and there is not currently a solution**	***A solution has been found to this barrier***
	Difficult in acquiring raw material for the development of the product	*Do not experience this barrier*	**This barrier is experienced and there is not currently a solution**
	Occurrence of patent infringement	*Do not experience this barrier*	*Do not experience this barrier*
	Difficulties in technical improvement after the launch of a new product	*Do not experience this barrier*	*Do not experience this barrier*
	Unexpected cost for production	*Do not experience this barrier*	*Do not experience this barrier*
	Lack of physical space for mass production	*Do not experience this barrier*	*Do not experience this barrier*
	Technical application difficulties for the mass production system	*Do not experience this barrier*	*Do not experience this barrier*

technological deficiency; (iv) Deterioration of the market condition; (v) Deterioration of business circumstances. It should be noted that most TTOs do not have solutions to these barriers.

TTOs from developing economies experience the following barriers to the commercialization of technologies: (i) Insufficient funds for complementary technological development and/or prototyping; (ii) Occurrence of technological deficiency (iii) Tense and tortuous negotiation or complicated process; (iv) Difficulty in acquiring raw material for the development of the product. Likewise, as for TTOs in developed economies, TTOs in developing economies have no solutions for most barriers.

4.3 Post-survey interviews: determining a suite of best practices

The TTOs who had indicated they had found solutions to the barriers listed above were interviewed to discuss these solutions. The interviews were transcribed, and word cloud analysis used to determine common themes. For each of the barriers listed, a separate word cloud was produced, as well as a word cloud summary of all solutions. Upon analyzing the word clouds, it was apparent that certain solutions overcame more than one barrier, and as such the most common solutions are discussed below. The most common solution seems to be employing staff with the correct critical skills and experience, and/or using external service providers where these are not present. Strong networks, both internally and with industry, can overcome many of the barriers in the commercialization phase. Funding is crucial in all phases, and the TTO should source funding to compliment projects. The barrier most experienced by TTOs in our sample is insufficient funds for technology development (proof of concept or prototype funding). This barrier occurs at over 80% of the TTOs in our sample in both developed and developing economies.

Funding is essential to enable the TTO to improve the technology. In this regard, external and regional funding is often sourced by the TTO as certain technologies are not yet at the proof of concept stage. Certain projects are governed by agreements that ensure funding is available for improvement, while other projects are a collaboration with industry which ensures the funding and expertise is available for improvement. These two options should be investigated in the early stages of the research project to ensure support is available downstream. Depending on where the TTO is based, many have access to regional, or national (government) funding. Other TTOs are allocated sufficient budgets or are fully funded by their University. For TTOs, where this funding is not readily available, or the funding is insufficient, they have complimented their funding streams by including a technology transfer component to research project budgets. Other TTOs maximize their third-stream/licensing income, and the university policy allows for the full amount to be returned to the TTO budget.

5 Conclusion

Technology Transfer Offices (TTOs) are a crucial bridge between academia and industry, and can fuel innovation, with a significant impact on the economy. They are the vehicles responsible for protecting university-generated IP and they manage the commercialization process of IP into the marketplace across industries; they are a process catalyst, knowledge converter, and impact amplifier. As TTOs become increasingly important for universities, industries, economies, as well as their countries and regions, understanding their internal

and external pressure points are critical to their future success. Dedicating research to the mechanisms that contribute to TTO efficiency and success has become useful for scholars, managers, and entrepreneurs who search for information to aid their efforts.

This paper has sought to enhance the understanding of TTOs and determine internal efficiency factors that are statistically significant for the efficiency of TTOs, as well as explore which barriers cited in literature impact TTOs and draw a comparison of these factors between developed and developing economies. We have sought to go past conventional models of TTO analysis that rely on monetary values or tangible factors, which inadequately measure real performance and fail to assess the potential for technology transfer based on university research. We specifically consider the balance between economic metrics and non-monetary benefits for the assessment of technology transfer.

As several studies have shown (de Falco, 2015; Tahvanainen & Hermans, 2011), there are numerous observable inefficiencies in the operation of TTOs (Anderson et al, 2007), which must be understood by considering both internal and external factors influencing the efficiency of the TTO. This critical understanding aids in improving the efficiency of TTOs. It is apparent that developed economies (EU and UK) have overcome certain barriers experienced by developing economies (BRA, ISA and SA), and best practices can be learnt. However, given the South-South similarities in the developing economies in this study, best practices can be shared as well. Future work will focus on increasing the sample size and countries represented, to continually improve the robustness of the tool and the analysis.

Additionally, this paper has shown that TTOs have a built-in conflict with researchers. One component traditionally used in measuring a TTOs success is IP disclosures, whereas a researcher's success is measured in published academic papers. This is an internal conflict at the heart of TTOs and further analysis of this conflict is needed. Future studies should focus on researchers' education, which will help to explain the researchers' impact on IP disclosure to their institute and for their career success. In addition, developing a university incentives model that would act to influence researcher motivation is needed, as well as building TTO teams focused on entrepreneurship, while sharing and maintaining a common language with researchers.

This study is not exempt from limitations. First, we do not measure indicator information on the efficiency of TTOs, for example, patents, licenses, spin-offs, revenues etc. It would be interesting to measure these variables which could serve as subsidies to create a model that would determine the success of TTOs. In addition, this study carried out an exploratory analysis on the factors that influence the efficiency of TTOs, we can see the factors that compose how they can be improved in order to carry out the validation of the scale used.

Another aspect of this paper that merits future research is our observations of best practices. In determining a suite of best practices to overcome barriers to TTOs success, we have identified that the most common solutions are employing staff with appropriate skills and experience, using external service providers where these are not present, strong networks, internally and with industries, to overcome barriers in the commercialization phase, and adequate funding in all phases—a critical and shared barrier for TTOs in both developed and developing economies.

Future research should be dedicated to developing and deepening our understanding of the similarities and differences experienced by TTOs in developed and developing economies as identified in this paper, with a major focus on funding streams. While TTOs from developing and developed economies have no solutions to most barriers, focusing future research on the most crucial barriers, such as funding streams and options, which is a

shared problem for all TTOs, has the potential to have the widest impact for understanding how to facilitate the success of TTOs regardless of region.

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