

Insights of Research Commercialisation through University Technology Transfer Office

Nurshafiza Ismail¹, Nabilla Afzan Abdul Aziz¹ and Arif Hartono²

¹Universiti Teknologi PETRONAS, Malaysia, {shafizaismail95@gmail.com, nabilla.aziz@utp.edu.my}

²Universitas Islam Indonesia, Indonesia, {arif.hartono@uii.ic.id}

ABSTRACT

In university, technology transfer office (TTO) acts as a merger between the industry and academia for research commercialisation activity. The purpose of this research study is to gain insights of TTO on the factors contribute to commercialising research products in a Malaysian university based on Soares et al. (2020) maturity model efficiency for TTO. This includes a sharing experience from TTO handling issues related to the commercialisation. The study uses qualitative method incorporating components in Soares et al. (2020) maturity model efficiency for technology transfer office. Interviews were conducted with the technology transfer office personnel to obtain qualitative findings in terms of organisation management, technology, industry links and networking as a technology management centre. The study discovered insights that contribute to the evolutionary development of technology transfer in a university setting. Active engagement is required between researcher and TTO to unfold and resolve the issues faced in commercialisation. In conclusion, strategies, framework and organisation structure determine the success implementation of research commercialisation. These findings are anticipated to equip researchers and management in academic setting to strategise based on structure and administration, that leads to efficiency and achievement of the desired goal.

Keywords: technology, transfer, commercialisation, insights.

I INTRODUCTION

Technology transfer office (TTO) is a major stakeholder in universities that provide several services to the researchers such as managing licensing, introducing intellectual property, build personal engaged with inventor, assist on

proposal, distinct opportunities and security, encourage academia to disclose invention and industry technology requirements. Khademi et al. (2014) had clarified that TTO is responsible to help the researchers decide whether the technology suit for product commercialisation or not and facilitate the activities of IP protection before undergo commercialisation process.

Some studies have been reported regarding technology transfer office (TTO) roles (Khademi et al., 2014; Arenas, 2018). University Technology Transfer Offices (TTOs) need a wide range of abilities to facilitate commercial exploitation of research outputs; however, we know relatively little about how these important abilities are developed and refined over time (Weckowska, 2015). McAdam et al. (2012) stated that TTO consolidates the university technology transfer activity in a regional area. TTOs has been developed in universities to guide researchers regarding commercialisation process and establish linkages between industry and university.

However, academic research faces problem to transfer the IP product into commercial applications. Furthermore, other challenges for TTO is the process of IP commercialisation in the university which includes lack of support, lack of skilled manpower and lack of information on commercialisation process (Manap et al., 2017). In the past few years, several studies has examine the role and effectiveness of TTO in managing researchers to start technology invention (Xu et al., 2011).

Figure 1 shows the micro-level structure for national innovation system involving three major actors such as government (institution and policies), economic (firms and labour) and the academia (including education and researchers).

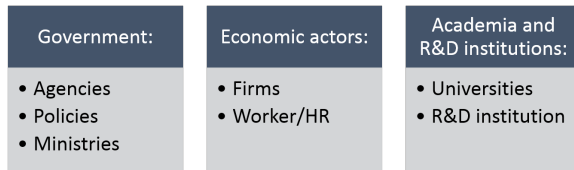


Figure 1: The Major Actors for Innovation System (Khademi et al., 2013).

According to the maturity model efficiency by Soares et al. (2020), there are several elements in technology transfer office that contribute to achieve successful product commercialisation and their findings was delineated based on weightage. Human resource (100%), Intellectual property (IP) management strategy and policy (80%), Organisation structure, internal management and design (20%), Technology (40%), Networking (60%) and Industry links (60%) are the elements that are highlighted in the study. Based on the maturity model efficiency, the questionnaire for TTO in a university was designed and the response was interpreted and supported with other research studies. The face-to-face interview with TTO personnel in a university has revealed their development, and the issues and challenges in educating researchers with policy and regulations to enter commercialise market which complements Soares et al. (2020) maturity model efficiency.

II TECHNOLOGY TRANSFER OFFICE

Currently, universities have established technology transfer office (TTO) to protect, promote, guide and commercialise the research outputs of researchers. TTO require strong connection with public and private sectors on R&D and transformation strategies for research output from academia to industry. Recent studies have reported that TTO is responsible for educating academician with knowledge business through interaction via a network of industrial partners. There are three main domains that defines TTO efficiency which are organisation, technology and networking.

A. Organisation

Establishment of division labour is important in order to deliver the outcomes of the organisation. This section discussed on the evolutionary flow of a matured organisation structure that strives for improvement and efficiency. Transformation of

inputs to outputs depend on the designed framework to deliver solutions. In an organisation process usually comprised of resources such as materials and manpower, tools and system.

Organisation Structure, Internal Management and Design

The critical success factor of TTO staff is to understand the academic environment and have established insights and experience regarding the business environment for knowledge transfer to society. Despite this, the professionalism of TTO staff to serve the business and academic community is crucial. There is no specific background to recruit manpower under TTO, since most of it could be learned and going through practical (Nguyen, 2020). To summarize, the TTO department has expanded into several units due to their expanding responsibility through time based on demand of the functional unit, which consists of intellectual unit, commercialisation unit, and consultancy unit. Moreover, TTO is responsible to develop the researcher's know-how on the research product before the commercialisation process. Table 1 shows the summary findings from the TTO that has been more than a decade in technology transfer arena.

Table 1. Findings Summary based on Organization Factors of the Studied Technology Transfer Office.

Maturity Model Elements (Soares et al. 2020)	Questionnaire	Concluding findings
Organization structure, internal management and design	What is the evolution of university technology transfer ability in the process of innovation?	<ul style="list-style-type: none"> • TTO department was expanded into several units because of wider scope. <ul style="list-style-type: none"> ○ Intellectual unit ○ Commercialisation unit ○ Consultancy unit • TTO is responsible to develop researcher's know-how on the

		research product before commercialisation process.
How many researchers were success in inventions last 3 years from 2017-2019 and how many units involved?	<ul style="list-style-type: none"> • Only 5 researchers succeed in inventions. • Early 2000s Starting in 2008, manager is responsible just to manage research. Research and innovation office built in 2010 until 2017 that consists of two units: <ul style="list-style-type: none"> ○ Management unit (provide funding) ○ IP associate research (filing IP paper) • Both units combined as: Research and Management Center (RMC) <ul style="list-style-type: none"> ○ Manage funding ○ Technology Transfer Office (TTO) • Expand due to broader scope of duties. • Develop researcher's know-how in research <ul style="list-style-type: none"> ○ IP unit (manage IP) ○ Commercialisation Unit ○ Consultancy unit 	
In what field (Product/Processes/research field) has the TTO been most active in	<ul style="list-style-type: none"> • TTO is most active in product field. Every technology will produce a new product to enter the market. 	

	commercializing discoveries?	Technically, any process will become a product in the future.
--	------------------------------	---

Intellectual Property (IP) Management Strategy and Policy

According to Hegde & Luo (2017), patent applications were 20% able to be licensed after conducting research and it is more significant to be licensed in the phase between publication and research completion. Thus, the percentage of disclosure results in patents commonly depends on researchers how much they would like their findings to be disclosed. If the content is completely to be published in publication, it cannot be patented.

Managing conflicts of interest in the commercialisation of inventions are important for a successful commercialisation process (Van Norman & Eisenkot, 2017). A sharing by the technology transfer office highlighted that the invention policies involved address the ownership of invention will not have any conflict of interest. If the research was conducted with the university resources and facilities, the outcome belongs to the university. For start-up, if the university is going to initiate a start-up and it is owned by one of the university staff, the university staff must declare upfront on the shareholder of that company. If not being declared, the process will be terminated.

If the inventor moves to another institution and wants to improve their license or follow-on IP, the institution will negotiate on how IP right for marketing and licensing (Van Norman & Eisenkot, 2017). Thus, it is mandatory to seek permission from previous universities if the researchers move to another university.

SRAs is an agreement between a commercial entity and a university researcher to develop and commercialise a product technology invention. Identifying suitable SRAs for the inventor is another role of the TTO (Van Norman & Eisenkot, 2017). SRAs benefit the university by

developing research opportunities and as a crucial source of university income. Kadir & Shamsudin, (2019) stated that most research opportunities in R&D Malaysia were funded by Ministry of Science, Technology, and Innovation (MOSTI), and by the Malaysian Technology Development Corporation (MTDC) in the form of Technology Acquisition Fund (TAF). Table 2 indicate the summary findings with the established TTO on IP management strategy and policy.

Table 2. Findings Summary based on IP Management Strategy and Policy of the Studied Technology Transfer Office.

Maturity Model Elements (Soares et al. 2020)	Questionnaire	Concluding findings
Intellectual property (IP) management strategy and policy	How has the university generally handled IP rights and licences when researcher leaves the enter/leave the university?	It is mandatory to seek permission from previous universities, if the researcher enter employment with IP and license that has been generated at other university. As the researcher leaves the university, inventorship remains and the IP ownership usually remains with the originating institution.
	Do patents create barriers that hinder innovation and research?	<ul style="list-style-type: none"> • Strategy is crucial to empower research and innovation. • Mutual market is good to have protection to enter market sector. • TTO has experienced in monitoring technology that has an impact to

		<p>the market and TTO role is important to evaluate whether the technology directly enters the market or through technology patent.</p> <ul style="list-style-type: none"> • University patenting is a research tool for intellectual property, and licensing is the factor that often slows down the progress of research.
	What has the TTO experience for software patents, copyrights, trademarks and licences?	<ul style="list-style-type: none"> • Mostly is from software patents because it is easy to commercial compared to engineering product and the software development advances rapidly. • TTO will give a licence once the product is ready to enter market.
	How does TTO manage disclosures of invention TTOs?	<ul style="list-style-type: none"> • Disclosure of invention <ul style="list-style-type: none"> ○ Fill in disclosure form, then submit to TTO. TTO will decide on the IP whether it is patentable or not. • Patent (costly but more valuable) <ul style="list-style-type: none"> ○ If TTO exploits patent, we could get more income similarly with copyright.

		TTO will disclose to community for decision, whether the product is valuable or not.
	How do you decide which inventions to patent?	<ul style="list-style-type: none"> • TTO conduct evaluation on the invention patentability, review on title of the invention and file a patent application. Gain information on fund availability for the application and consideration on the duration taken for the patent application.
	What is the level and quality of resources that the TTO offers to support commercialisation?	<ul style="list-style-type: none"> • Networking with agency <ul style="list-style-type: none"> ○ MESTEC • Agency provide assistance for technology towards commercialisation <ul style="list-style-type: none"> ○ Funding • Provide internal support facilities: <ul style="list-style-type: none"> ○ Laboratory ○ Research equipment

According to Malhal (2010), and academic researchers who disclose an invention to the TTO becomes dependent to the efficiency of the TTO to market it. Some researchers stated that inventions tend to be disclosed at the early stage of development before entering the commercial phase (Thursby et al., 2001) and give a positive impact on university patenting and licensing (Wu et al., 2014). However, to avoid issues on disclosure that might lead to patent failure, engagement with TTO in disclosure activity is crucial because TTO is more capable of solving applicability problems related to the invention (Wu et al., 2014). Furthermore, high amount of research funding, might lead to higher numbers of licenses and licensing income (Chapple et al. 2005). Ho et al. (2014) highlighted that patent applications are closely related to funding and licensing. Based on the findings, TTO staff is best to decide on the IP whether it is patentable or not. If TTO exploits a patent, they could get more income similar with a copyright as patent is costly but more valuable or impactful.

The interaction of TTO with academic staff is significant regarding royalty sharing and reward to the achievement (Siegel et al. 2007b; Anderson et al. 2007). Higher royalty shares to the academic researchers are associated with greater licensing income (Friedman and Silberman, 2003; Lach and Schankerman, 2004). TTO provide royalties to the inventors after considering all costs and factor in the source of funding whether internal or external. The remaining cost will be given to investors. For example, the net profits of above RM 101 will provide a 50% profit to both inventors and the university. The challenges before commercial start-up in the commercialisation of technology innovation require developed model, justified production facilities, market value, target market, cost structure, profit potential, and partner networking (Kadir & Shamsudin, 2019). University technology transfer offices do not govern commercialisation before start-up and provides licensing from an industrial partner.

B. Technology

There are several dimensions involved that can lead to success and failure in the process of commercialisation such as technology, market, organisation, product, strategy, and environment (Kim & Ko, 2014; Jung et al., 2015). According to the interview with TTO, characteristics that lead to the success and failure in the commercialisation are the cost to produce a product, invention that is sustainable, able to compete with other investors, right timing to penetrate the market, no product testing but claimed ready to market and high probability of failure could occur if researchers did not benchmark with others in the field.

Universities always face severe structural problems to gain venture capital funding to help start-ups process technology innovation (Van Norman & Eisenkot, 2017). The interests of universities and venture capitalists are needed and usually relied to a technology transfer office to publicize and brainstorm new ideas until commercial stages (Samila & Sorenson, 2010). By contrast, the lack of a local venture capital community and the government funding of academic research will give an effect on the patenting process (Hsu, 2006). To highlight at this point, the TTO respondent does not provide any venture capital to academic research. The term “technology transfer” itself had described the process of movement of technology and refers to several strategies that promote the transfer of innovations, knowledge, technologies, and skills from one setting to another. Some examples to promote technology innovation to the local community by developing skills in entrepreneurship, marketing strategies for marketing products, and strategies on rural and regional development based on needs and trends (Vac & Fitiu, 2017). Table 3 indicate the summary insights based on technology domain in the technology transfer process.

Table 3. Findings Summary based on Technology Aspect of the Studied Technology Transfer Office.

Maturity Model Elements (Soares et al. 2020)	Questionnaire	Concluding findings
Technology	What does the TTO observe based on the inventor’s responsibility in finding commercialisation funds?	TTO assist to match the inventor with the industry, whereas the inventor’s role is to support the technical innovation.
	How does the university typically allot royalties to inventors?	University provides royalties to the inventors after considering all cost and factor in the source of funding whether internal or

		external. Remaining cost will be given to the investors. For example, the net profits of above RM 101 will provide 50% profit to both inventors and university.
	What factors that can lead to success and failure in the process of commercialisation?	Invention and innovation that could overcome current problems in industry. Invention that is sustainable and able to compete with other investors. Costing to produce a product. Right timing to penetrate the market. Probability of failure could occur if researchers did not benchmark with others in the field. No product testing but claimed ready to market.
	What policies does the university have in place regarding conflicts of interest in commercialisation of inventions?	<ul style="list-style-type: none"> •University resources and facilities belong to the university. •Ownership of the university will not have any conflict of interest (valid for university) and useful for spin off but not for start-up. •For start-up, if the university is going to initiate start-up or company is owned by one of the university staff, the university staff must declare up front, such as the shareholder of that company. If not

		declared, the process will be terminated.
--	--	---

C. Industry Linkages and Networking

Technology transfer processes are being set up to promote research commercialisation (Belitski et al., 2019). Thus, TTO is deemed important in the product field. Every technology will produce a new product to enter the market. Technically, any process will become a product in the future. Universities do not provide incentives to the company. However, universities need to collaborate with the industry to market their research product. A matured TTO with established experience more than a decade, contributes opinion based on the decision-making environment, in stages to reach the desired end. This section aims to provide an overview of possible strategies related to commercialisation activity.

Universities do not provide incentives to the company to develop a commercial product. Therefore, universities need to collaborate with the industry to market their research product. Besides, TTO gives an exclusive license to the company and the company decides whether to downgrade or upgrade the product, as long as it is within the specific region approved by the university. Past studies have reported that exclusive licenses are commonly used when researchers are making a high-risk investment (Van Norman & Eisenkot, 2017).

According to Sithole & Rugimban (2014), the models of the incubation process consist of three important stages such as pre-incubation (to identify tenants for the incubator and brainstorm ideas), the incubation (entrepreneurs provide facilities and strategic support), and post-incubation (take-off stages when the business can continue working outside the incubator) are important for successful commercialisation. TTO in incubation phase is important to develop relationship between universities and industry to identify and screen technology (Hess & Siegwart, 2013). The main issue in the pre-incubating process is industry expectation. Most industry players usually prefer ready product to

commercialise. Table 4 shows the summary findings based on the insights from the studied TTO based on industry linkages and networking.

Table 4. Findings Summary based on Industry Links Aspect of the Studied Technology Transfer Office.

Maturity Model Elements (Soares et al. 2020)	Questionnaire	Concluding findings
Industry links & Networking	What are the problems in pre-incubating process?	The main issue in pre-incubating process is industry expectation. Most industry players are interested to product readily available to commercial. Thus, TTO will only highlight the products that is ready to market.
	What is the process of technology commercialisation before start-up?	Technology transfer office do not govern commercialisation before start-up. They provide with licensing from industrial partner. For example, for start-up to commercialise it must have a concept, prototype, intellectual property and eventually upscale to the market.
	What are the strategies the university utilize to	• Participation in exhibition

	<p>promote the dissemination and utilization of discoveries made in research on campus?</p>	<ul style="list-style-type: none"> • Technology with industry (selected industry) • Partnership with university in ASEAN countries • Innovation technology day
--	---	---

Process Imagining stage to the incubating stage is a challenge as majority researchers do not have entrepreneurial skills. Lee et al. (2012) stated that most public universities are not involved in commercializing technology product compared to industries due to the commercialisation process among academician is complicated than industry in managing responsibilities and business activities (Ab. Aziz et al., 2012; Perkmann et al., 2013; Salter et al., 2014).

TTO directs potential industrial funding for the development of technology by university researchers (Guerrero et al., 2016; Theodoraki and Messeghem, 2017).

III CONCLUSION

This research study shared the insights in context of research commercialisation process and activities of academic research in a university. Technology transfer office (TTO) performance impacts the university commercialisation activities. TTO acts as a merger between the industry and academia. In conclusion, an effective TTO is capable to accelerate the commercialisation process by providing services in several aspects such as facilitate IP, provide licensing, mismatch partner industry, organizing spin off company, marketing strategy to the researchers and supporting proposal in the context of commercialisation. The study successfully discovered insights that contribute to the evolutionary development of technology transfer in a university setting. These findings are hoped to motivate researchers and management

to strategise based on factors that may impede research commercialisation.

ACKNOWLEDGEMENT

The authors are thankful for the support from Technology Transfer Office especially Zaimizi Bin Hamdani @ Hj Othman and Sharizul Azlan Azizi, Institute of Hydrocarbon Recovery (IHR) Director, AP Dr Syahrir Ridha, fund from International Collaborative Research Fund (ICRF) Grant No. 015ME0-115 and Universitas Islam Indonesia (UII) for their support to the project.

REFERENCES

Ab. Aziz, K., Harris, H., Richardson, S. and Ab. Aziz, A. (2012). "Drivers for university research performance: investigating the researchers' dynamics", *IBIMA Business Review*, Vol. 2012 No. pp. 3-65.

Anderson, R., U. Daim, and F. Lavoie. 2007. Measuring the Efficiency of University Technology Transfer. *Technovation* 27: 306–318.

Arenas, J. J., & González, D. (2018). Technology transfer models and elements in the University-Industry collaboration. *Administrative sciences*, 8(2), 19.

Belitski, M., Aginskaja, A., & Marozau, R. (2019). Commercializing university research in transition economies: Technology transfer offices or direct industrial funding?. *Research Policy*, 48(3), 601-615.

Chapple, Wendy, Lockett Andy, Siegel Donald, and Wright Mike. 2005. Assessing the relative performance of U.K. university technology transfer offices: Parametric and non-parametric evidence. *Research Policy* 34: 369–84.

Guerrero, M., Urbano, D., Fayolle, A., 2016. Entrepreneurial activity and regional competitiveness: evidence from European entrepreneurial universities. *J. Technol. Transfer* 41 (1), 105–131.

Hess, S., & Siegart, R. Y. (2013). University technology incubator: Technology transfer of early stage technologies in cross-border collaboration with industry. *Business and Management Research*, 2(2), 22-36.

Ho, Mei Hsiu-Ching, John S. Liu, Wen-Min Lu, and Chien-Cheng Huang. 2014. A new perspective to explore the technology transfer efficiencies in US universities. *The Journal of Technology Transfer* 39: 247–75.

Hsu, D. H. (2006). Venture capitalists and cooperative start-up commercialisation strategy. *Management Science*, 52(2), 204-219.

Jung, M., Lee, Y. B., & Lee, H. (2015). Classifying and prioritizing the success and failure factors of technology commercialisation of public R&D in South Korea: using classification tree analysis. *The Journal of Technology Transfer*, 40(5), 877-898.

Kadir, B., & Shamsudin, M. F. (2019). A Case Study Analysis of Typhidot: An Example of Market-Oriented R&D Commercialisation in Malaysia. *International Journal of Financial Research*, 10(5).

Kelly, R., & Kim, H. (2018). Venture capital as a catalyst for commercialisation and high growth. *The Journal of Technology Transfer*, 43(6), 1466-1492.

Khademi, T., & Ismail, K. (2013). Commercialisation success factors of university research output. *Jurnal Teknologi*,

- 64(3).
- Khademi, T., Parnian, A., Garmsari, M., Ismail, K., & Lee, C. T. (2014). Role of Technology Transfer Office/Centre of Universities in Improving the Commercialisation of Research Outputs: A Case Study in Malaysia. 5.
- Kim, C. H., & Ko, C. R. (2014). Group Dynamics of Success and Failure Factors of Technology Commercialisation in Small Technology Firms: A Korean Case. *Asian Journal of Innovation and Policy*, 3, 025-049.
- Kumar, Malhar N. (2010). Ethical Conflicts in Commercialisation of University Research in the Post-Bayh-Dole Era. *Ethics & Behavior*, 20(5), 324-351.
- Lee, S. M., Hwang, T. and Choi, D. (2012), "Open innovation in the public sector of leading countries", *Management Decision*, Vol. 50 No. 1, pp. 147-62.
- Manap, A., Ismail, N., & Sidek, S. (2017). The roles of technology transfer offices to facilitate intellectual property commercialisation in the university: Issues and challenges. *The Social Sciences*, 12(6), 919-924.
- McAdam, R., Miller, K., McAdam, M., & Teague, S. (2012). The development of University Technology Transfer stakeholder relationships at a regional level: Lessons for the future. *Technovation*, 32(1), 57-67.
- Nguyen, Linh. (2020). 2020 VETEC Vademecum 2020.
- Perkmann, M., Tartari, V., McKelvey, M., Autio, E., Broström, A., D'Este, P., Fini, R., Geuna, A., Grimaldi, R., Hughes, A., Krabel, S., Kitson, M., Llerena, P., Lissoni, F., Salter, A. and Sobrero, M. (2013), "Academic engagement and commercialisation: A review of the literature on university-industry relations", *Research Policy*, Vol. 42 No. 2, pp. 423-42
- Samila, S., & Sorenson, O. (2010). Venture capital as a catalyst to commercialisation. *Research Policy*, 39(10), 1348-1360.
- Siegel, D.S., M. Wright, and A. Lockett. 2007b. The Rise of Entrepreneurial Activity at Universities: Organizational and Societal Implications. *Industrial and Corporate Change* 16: 489-504.
- Sithole, N., & Rugimbana, R. O. (2014). Commercialisation of research and technology: A multiple case study of university technology business incubators. *African Journal of Business Management*, 8(16), 641-659.
- Slater, S. F. and Mohr, J. J. (2006), "Successful development and commercialisation of technological innovation: Insights based on strategy type", *Journal of Product Innovation Management*, Vol. 23 No. 1, pp. 26-33.
- Soares, A. M., Kovaleski, J. L., Gaia, S., & Chiroli, D. M. D. G. (2020). Building Sustainable Development through Technology Transfer Offices: An Approach Based on Levels of Maturity. *Sustainability*, 12(5), 1795.
- Spronken-Smith, R. A., Brodeur, J. J., Kajaks, T., Luck, M., Myatt, P., Verburgh, A., ... & Wuetherick, B. (2013). Completing the research cycle: A framework for promoting dissemination of undergraduate research and inquiry. *Teaching and Learning Inquiry*, 1(2), 105-118.
- Theodoraki, C., Messeghem, K., 2017. Exploring the entrepreneurial ecosystem in the field of entrepreneurial support: a multi-level approach. *Int. J. Entrepreneurship Small Busi.* 31 (1), 47-66.
- Thursby, J.G., R. Jensen, and M.C. Thursby. 2001. Objectives, Characteristics and Outcomes of University Licensing: A Survey of Major US Universities. *Journal of Technology Transfer* 26: 59-72.
- Vac, C. S., & Fitiu, A. (2017). Building sustainable development through technology transfer in a romanian university. *Sustainability*, 9(11), 2042.
- Van Norman, G. A., & Eisenkot, R. (2017). Technology transfer: from the research bench to commercialisation: part 2: the commercialisation process. *JACC: Basic to Translational Science*, 2(2), 197-208.
- Weckowska, D. M. (2015). Learning in university technology transfer offices: Transactions-focused and relations-focused approaches to commercialisation of academic research. *Technovation*, 41, 62-74.
- Williams, H. L. (2017). How do patents affect research investments?.
- Xu, Z., Pary, M. E., & Song, M. (2011). The Impact of Technology Transfer Office Characteristics on University Invention Disclosure. *IEEE Transactions on Engineering Management*, 58(2), 212-227.