Technological Entrepreneurship for University Research Outcomes

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Abstract Commercialization of research by academic entrepreneurs have been recognized as an important driving force for technology transfer and wealth creation yet the level of success of commercialization of inventions (innovations) for IT products from higher institution to industry is questionable. There is a paucity of agreed commercialization in terms of execution processes to support inventions of prototypes and products moving from laboratories to the right market. This research aims to investigate the commercialization of research outcomes for IT products from the research centers to facilitate the commercialization objective. The analysis is carried out based on selective case studies in the technology and science park with venture capitalist and firms from industry in the commercialization program engagement. The commercialization of technology and products are investigated based on resource based perspective and dynamic capabilities based on selected case studies. The research outcomes are expected to offer a research commercialization model and practical contribution for successful commercialization and licensing among academics' entrepreneurs.

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1 Introduction

Entrepreneurship is described as the ability to associate all activities in order to gain profit and wealth from labor, land, capital (Berger, von Briel Davidsson and Kuckertz 2021; Alvarez and Barney 2020) and recently from knowledge and technology (Gedeon 2010). The entrepreneurial qualities of academia could be a driving force towards economic development through job creations and new ventures (Täks et al. 2015). However, there is currently no consistent mechanism for tracking the impact of commercialization although there are significant flow of scientific knowledge sharing between universities and academia (Berger et al. 2021; Rubin, Aas and Stead 2015). The personal attributes of entrepreneurs include autonomy and independence, creativity, moderate and calculated risk taking, drive and determination towards success (Berglund, Bousfiha and Mansoori 2020; Ajagbe, Isiavwe, Ogbari and Sholanke 2015). What is common among all references listed above are the association of risk or the ability of the entrepreneurs to take risk by exploiting those resources (Gedeon 2010; Täks, Tynjälä and Kukemelk 2015; Ajagbe et al. 2015). The reward for risk taking definition can be traced way back in the twentieth century Risk Theory (Gedeon 2010). This research addresses the importance of entrepreneurship qualities such as risk taking and capabilities in managing the resources coupled with the scientific knowledge to commercialize the innovations successfully (Berger et al. 2021).

The definitions of entrepreneurship evolve and widely applied into that academia who actively engaged both in research and commercialization of their innovations (inventions) (Mowery and Shane 2002; Olanrewaju, Hossain and Whiteside 2020; Siegel, Waldman, Atwater and Link 2004; Wright, Vohora and Lockett 2004). Academic entrepreneurship can be defined as the leadership process of creating value through acts of organizational creation, renewal or innovation that occurs within or outside the university that results in research and technology commercialization based on case studies in MIT University (Mowery and Shane 2002).

Unlike many previous literature, this article focus more on academic entrepreneurial characteristic rather than specific gender or (Aminova, Mareef and Machado 2020; Gholami and Al Tahoo 2021).This article seek insights for processes and activities that occur at the level of individuals or groups of individuals acting independently or as part of faculty or university systems, that results and creates new organizations, or initiate innovation within the university (Wright et al. 2004; Minguillo and Thelwall 2015). Value from academic entrepreneurship is achieved through the integration of scientific activities, academic activities and commercialization activities (Berglund et al. 2020; Siegel et al. 2004; Yusof, Siddiq and Nor 2009).

This research investigates case studies on how higher education institutions develop potential Intellectual Properties (IP) for commercialization and spin-offs.

As the number of patents granted do not reflect economic return and wealth generation for successful entrepreneurships (Berger et al. 2021; Henry, Hill and Leitch 2005). The inabilities of Intellectual Properties to generate economic return give an impression of universities ability to increase the number of IP however fails in the commercialization. Hence, further research is significant to investigate surrounding issues in the process in order to bridge the gaps between the number of Intellectual Properties and the commercialization rate. With regards to the commercialization of Intellectual Properties in university academics play their roles to ensure the innovations succeed which will complement the paucity in the literature (Berglund et al. 2020; Gedeon 2010). The research findings provide a guideline model for technology commercialization implementation in universities.

2 Literature Review

Rubin et al. (2015) who conducted studies research commercialization on technological business incubator program in both Australia and Israel proposed a model that comprises the interrelationships among three main stakeholders that include the:

1) Technological Knowledge Bearer (inventors, universities and etc.)
2) Market Knowledge Bearer
3) Financial Knowledge Bearer

The interaction, communications and collaborations of stakeholders drive the knowledge flow in technological business incubators. The research hypothesized that knowledge flow become a catalyst for the commercialization of universities' innovations (Rubin et al. 2015).

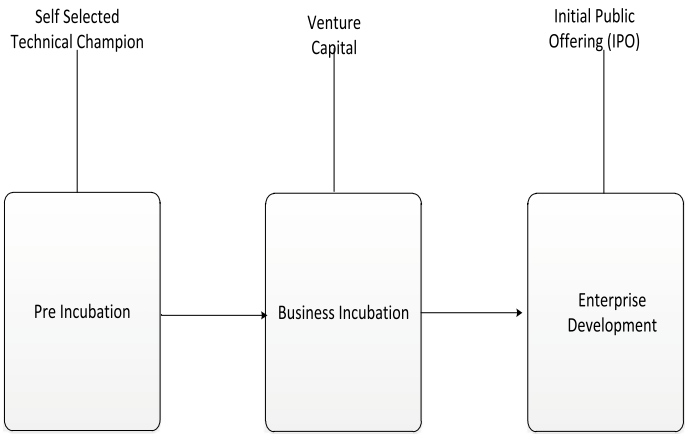
However, despite the fact that there is evidence of significant knowledge flow between stakeholders (Rubin et al. 2015) the ineffective and inefficient commercialization program might not be actively contributing to university technology transfer but rather the universities' resources. Rubin et al. (2015) estimates that 75% of university inventions and patents are not licensed at all. This poses a greater challenge for the inventors and innovators for commercialization of the Higher Education (HE) products as this maybe drag the journey towards commercialization long and fraught with problems (Fini, Rasmussen, Wiklund and Wright 2019).

Moreover, as stated by Markman et al. (2005) the relationship between universities (via the technology transfer office) with new venture creations and the commercialization program (science park) is poorly understood. More research is needed to understand the challenges of the entrepreneurs particularly on their ability to carry out the invention (knowledge transfer) from the university and their ability to sell off their inventions farther beyond the proof of concepts and prototype phase.

There is no evidence that university patenting licensing is profitable although a small number of them do succeed in attracting substantial additional revenues. The Intellectual Properties research in selected universities in five European countries in Germany, Finland, Belgium, France and Italy compares that unlike US, scientific

discoveries are too pre mature for commercialization. The findings are generalized across all disciplines and in different technology fields. In other words, there is a huge gap between scientific discoveries and actual commercialization initiatives. In addition, the research output does not reach the same audience in Europe as in US. This finding raises challenges to fill the gap to improve the communication between the academia and the industry (Munari and Toschi 2021).

The commercialization of research from developed in universities and research institute explains the characteristics, roles and functions with regards to university-industry commercialization. Siegel et al. (2004) map the process of commercialization as which begins from scientific discovery towards negotiations and licensing. The process flow presented by Siegel et al. (2004) is quite comprehensive and has similarities with the generic process below suggested by Commonwealth Scientific and Industrial Research Organization (CSIRO) - the largest Australia national research agency (Battaglia, Paolucci and Ughetto 2021).



Generic Process Propose By CSIRO for new Venture Capital (Upstill & Symington 2002)

The innovation first starts at the research center before the venture capital engagement in the business incubation. The commercialization proceeds to the third phase for Initial Public Offering (IPO) in the Enterprise Development phase for further growth and exploit the technology.

However, being the Australia greatest research organization with annual budget of some US$700 million does not spare CSIRO from issues in commercializing their research. As stated by Thorburn (2007) that the business unit which responsible for commercialization do not have the expertise to ensure the commercial opportunities are fully exploited. The commercializing issue highlighted the importance of networking in determining the commercializing success. The commercializing issues of CSIRO is an evidence that incorporating market capabilities and expertise

into the technology thorough engagement and collaboration with external entity are crucial components that need to be address for successful research commercialization (Battaglia et al. 2021; Thorburn 2007).

Moreover, the research conducted in five research universities in US do not prove that the transfer office (business unit) roles play significantly in commercialization success. In many cases the commercialization success is determined by the individual factors of the academic scientist (Wu et al. 2015) and the business entities (firm/entrepreneurs) from the industry (Munari and Toschi 2021; Wu et al. 2015; Markman et al. 2005). The TTO merely is a management entity providing paper works and documentation and an intermediary between the researchers and the firms from the industry. The transfer office only involves mainly during the licensing and negotiation stage before the product launch in the market (Battaglia et al. 2021; Siegel et al. 2004).

A part from market channel, the industry players (VC/firms) offer more sustainable long term future funding resource than Federal Government. National ICT Australia (NICTA) for example, upon receiving declining funding from the government has established partnership models with industry and research from non-government. This is crucial in order to continue NICTA's record of research excellence and wealth creation in the future (Seneviratne and Percival 2005). Since this trend continues, this research therefore attempts to investigate the VC/firms engagement in research commercialization (Munari and Toschi 2021).

The literature above is evidence that commercialization efforts must be concentrated to incorporate the academia and the business entities such as venture capitalist/firms and how to facilitate processes and activities. Unlike Siegel et al. (2004), this research focus on the commercialization process of the innovations (inventions) in fulfilling both technical and market requirements as suggested by Maine and Garnsey (2006). This is important as technology advancement alone do not guarantee the innovations acceptance (Wright et al. 2004). This research seeks further insight how the inventor or the academia entrepreneurs presents the inventions and collaborate with the industry to fulfill the market requirements. The activities encompass all processes involved in the recognition of needs or potential market for a university product. On the other hand, it involves technical knowledge, which generally available as results of research activities in the universities (Maine and Garnsey 2006). However more often than not the new scientific discoveries for certain reason fail to penetrate the market due to the inability of the researcher tailor and match the inventions according to the market or industry requirements (Woltjer, Van Galen and Logatcheva 2021). All these activities normally take place in the research institute or university technology parks. Experimental development and design, trial production and marketing involve a process of 'matching' the technical possibilities and the market (Maine and Garnsey 2006).

The HEs research commercialization adapt the major processes modeled by Siegel et al. (2004) and CSIRO to shed lights differences and similarities in different context as a comparative research. However, from the institutional perspective the entire process can also be explained thorough the lens of Institutional Theory (Wu et al. 2015; D'Este and Perkmann 2011). According to this theory, institutional rules function as natural or social phenomenon which organizations incorporate, gaining legitimacy, resources, stability, and enhanced survival prospects (Shoib, Nandhakumar and Currie 2009).

Rubin (2015) highlighted that the objectives research commercialization is mainly focused on entrepreneurship development with the assistance of the venture capitalist/firms as facilitators in order to benefit the graduates and the university indirectly from royalties of licensing. (Rubin et al. 2015). To support Higher Education (HE) commercialization by allocating resources is crucial. The HE supports comes from various angles in order to create sufficient resources and conducive environment for commercialization (Ab Aziz 2011). This contributes to a technology-entrepreneurial conducive ecosystem which consists of industry market, funding agencies, and venture capitalist/firms, consultants for research-development-commercialization and HEs as a sharing knowledge platform. The incubator program provides facilitation to identify potential innovative HE products that can be nurtured into real commercial enterprises. The establishment and formation of the commercialization initiatives are meant to boast the university technology commercialization (Munari and Toschi 2021).

HE backed incubators have a sound background in providing infrastructure and facilitation, such as, human expertise, funding, location, to produce innovation and commercialization enhancement opportunities (Chandra and Silva 2012). However, extended research is required to investigate the utmost goal of commercialization if there are really materialized to shed lights the effectiveness of this program. The commercialization programs are the ideal scenario where entrepreneurs are encouraged to access the innovations and should have pushed (pull) to the industry (Rubin et al. 2015). The processes explain how to facilitate access and sell the university artifacts, before matching the entrepreneurs and venture capitalist/firms with the inventor. Next, an agreement of profit sharing among inventors (innovators) – entrepreneur and venture capitalist/firms for commercialization is decided (Rubin et al. 2015). Another literature by D'Este and Perkmann (2011) collected from physical and engineering science faculty in UK universities shows mixed result pertaining individual academic entrepreneurs with regards to attitudes towards commercialization. The result shows that although attitudes towards entrepreneurship and commercialization are positive among academia, the attitudes do not translate into real and actual commercialization engagement and success. This scenario adds more interesting research questions on motivations for commercialization, infrastructure, commercialization process and any possible factors that lead to commercialization (Ratinho, Amezcua, Honig and Zeng 2020). This finding strengthens the need for further research to shed the lights of dynamic capabilities (Eisenhardt and Martin 2000) and the capacity for research commercialization. Jeremy (2005) categorizes these factors as;

1. Capabilities as which are intangible factor and processes
2. Capacity as tangible resources (infrastructure and etc.)

Both combination of factors above is crucial for innovations (inventions) that contribute to university commercialization success (Jeremy 2005).

They are different types of spin-offs model may be attributed to differences in the structure for technology transfer and commercialization at universities' incubators which are consist of newly developed firms from the derived technologies (Ab Aziz, Harris and Norhashim 2011; Wright et al. 2004; Wu, Welch and Huang 2015). The technology incubator financial grant and supports are received from the universities or external funding entities from the industry (Ambos et al. 2008; Maine 2006; Ratinho et al. 2020; Rubin 2015).

However, academics involvements in the spin-offs venture capitalist/firm companies are not well described. The academic involvement is definitely very different from the research and development phase which are merely academic exercises (Wright 2004). How researchers involve in commercialization activities and collaborate with the VC/firms as a new stakeholder is an unexplored research problem which is worth investigation. The research commercialization must explore the levels of technology transfer and commercialization activity at university incubators and further identify barriers and factors that contribute to the generation of opportunities and associated supportive business systems and processes (Ab Aziz et al. 2011; Wright et al. 2004). Subsequently the business processes explain the academics involvement in relation to the commercialization of HE's invention (Ratinho et al. 2020).

Issues of spin-offs are surrounded by questions on how the investors at the university should engage in the commercialization of their inventions. Bulsara, Gandhi, and Porey (2010) classify two major kinds of scientist in this regard, namely those scientists (inventor) with entrepreneurial characteristics and enterprising traits and those without entrepreneurial characteristics. Bulsara et al. (2010) suggest two options, firstly for technology entrepreneurs to commercialize their patented technology innovations engage actively in the techno-entrepreneurship. However, the scientist inventors who does not possess enterprising traits should opt for technology transfer (licensing) as a second option (Bulsara et al. 2010). This option is important to compensate their inability to seek opportunities derived from their inventions and discoveries. The second option is in accordance with the notion of lack of ambidexterity capabilities suggested by (Ambos 2008). The second option for the non-ambidextrous scientist gives opportunity for CV/firms to exploit the innovations (inventions) without the scientist interference (Ratinho et al. 2020).

Entrepreneurship characteristics contribute as major criteria to propel and succeed in a new venture firms as it could be more important determinant factor than advancement of the research itself. There are possibilities for good research that is not commercialized due to the inabilities of the researcher to sell-off the inventions. Ajagbe et al. (2015) explains further that the main characteristics that would be expected of a technology entrepreneur to be successful such achievement, autonomy and independence, creative tendency, moderate and calculated risk taking, drive and

determination (Ajagbe et al. 2015). As a comparison, the above notions are somehow consistent with cases described at University Technology of Malaysia (UTM) in terms of whether or not the scientist or university investors were involved actively in the new venture. The previous study from UTM which classified the spin-offs mode into 4 categories (Major UTM - Minor Inventor/Investor, Minor UTM – Major Inventor/Investor, Major Company – Minor UTM and UTM 50% - Inventor 50%), Wright et al. (2004) only classifies the university spin-offs/spin-outs into two main categories which are University Spin-out (USO) and Joint-Venture Spin-out (JVSO) (Wright et al. 2004).

USO is a new company founded by university entrepreneurs around a core technological innovation which had initially been mainly developed using the university resources. The creation of a USO is dependent on the transfer of IP from the university to the new venture, which is established to exploit and commercialize the IP. On the other hand, JVSO is another alternative in which external firms or entities are formed to work with the university entrepreneurs and inventors to exploit the IP (Ab Aziz et al. 2011). Based on the author's comparison between the two types of formation, Wright, Vohora & Lockett (2004) recommend JVSO formation since it has greater potential as a rich source of surrogate entrepreneurs, with greater managerial and marketing capabilities and supply. Wright, Vohora & Lockett (2004) prevail that based on 5 UK universities the research discoveries are disruptive innovations. As appose to sustaining innovations, the disruptive innovations are highly potential to dominate new market. Disruptive innovations have a greater competitive advantage against their rivals. As the owners of Intellectual Properties (IPs) of a new disruptive technology the USOs do not need to compete in a conventional way to capture a new market. However, the false impression of academic scientist of the commercial value of their discoveries was a result of having insufficient prior market knowledge. Market knowledge is crucial and the inability of USOs on how to serve the market caused the USOs short lived. The business incapability and lack of current market awareness to pin-point unmet customer needs Wright, Vohora & Lockett (2004) highly suggest JVSOs model. JSOs model is a better option for non-ambidextrous to avoid the false market impression. In addition, HEs research commercialization framework seek possibility to incorporate the incubation program to avoid the unmet market needs.

As recommended by (Maine and Garnsey 2006) the comprehensive framework enables the agreement between technological challenges (university) and market challenge (industry) must be met. Hence, the commercialization of IPs is necessary to frame the entire components of commercialization program to enable a streamline work processes and resources.

2.1 Research Questions

Applying the Institutional Theory in research commercialization in HE has its limitation as the success of commercialization are contributed by individual factor of the entrepreneurial qualities of the inventor, academic scientist (Wu et al. 2015; D'Este and Perkmann 2011) rather than the institution (institutional factor). For example, Wu et al. (2015) who made a generalization based on 675 patents awarded in different universities in US concluded that the commercialization success of is contributed by individual factor and collaboration with industry (Wu et al. 2015; D'Este and Perkmann 2011). Based on this literature, the research commercialization must be concentrated into investigating academia as individual entrepreneurs, scientist and technology entrepreneurs who do not only possess the knowledge and expertise but the dynamic capabilities to play their roles to sell-off the product and services (Fini et al. 2019; Eisenhardt and Martin 2000).

From resource-based perspective (theory) the availability of these resources both tangibly and intangibly are intertwined with academic entrepreneurs' dynamic capabilities and have relative impact on firm's success (Eisenhardt and Martin 2000; Jeremy 2005). From the capability's perspective, the availability of those resources only significantly contributed to commercialization success if those resources are exploited with the right process, functions and roles played to meet the commercialization objectives.

Mowery and Shane (2002) argue that the best solution for university technology commercialization requires that economic actors (VC/firms) and incubation program in this case) who have a comparative advantage in the commercialization (Markman et al. 2005). The commercialization involves a tacit set of skills including identifying customer needs, developing product concepts, designing products and processes and manufacturing that university inventors rarely possess (Mowery and Shane 2002). Therefore, this research investigates the component of a commercialization program to compensate the academic scientist lack of competence to undertake commercial initiatives as they require different skills and abilities than purely academic ones (Ratinho et al. 2020; Ambos 2008).

Without disregarding institutional factors, Cunningham, Lehman, Menter and Seitz (2019) and Wu et al. (2015) claim that the likelihood of successful commercialization and licensing is more significant for those individual entrepreneurs' contributions than the institutional factors' contribution. There is limited evidence of institutional factors contributions such as, university and technology transfer office however is quite surprising that Ambos et al. (2008) find that the experience and breadth of support of the transfer office is not significant predictors of commercial success. The role of transfer office is only important in the later stages of commercialization process Ambos et al. (2008). The initial decision to commercialize is dependent on the academic entrepreneurs' motivation. If Ambos et al. (2008) findings are generalized into this research context it is worthwhile to investigate the effective roles of commercialization programs and the participation level of the VC/firms and academics entrepreneurship factor.

1. What are the characteristics of roles and functions of commercialization programs with regards to successful commercialization of IT products? - #R1

   Proposition 1 (P1)
   The incubator which has a high level of technology (products) is more successful in research commercialization.

   Proposition 2 (P2)
   The incubator which has high marketing capabilities is more successful in research commercialization.

2. How do Venture capitalist/firms engage with the Higher Education (HE) inventions and innovations developed in commercialization programs? - #R2

   Proposition 3 (P3)
   The VC capitalist/firm which has high level of technology expertise is more successful in research commercialization.

   Proposition 4 (P4)
   The VC capitalist/firm which has high marketing capabilities is more successful in research commercialization.

3. What are the capabilities that catalyze the commercialization of HE inventions and innovations? - #R3

   Propositions 5 (P5)
   The academic who catalyzes research commercialization has high entrepreneurships characteristics.

   Proposition 6 (P6)
   The VC capitalist/firm which has high marketing capabilities is more succeed in research commercialization.

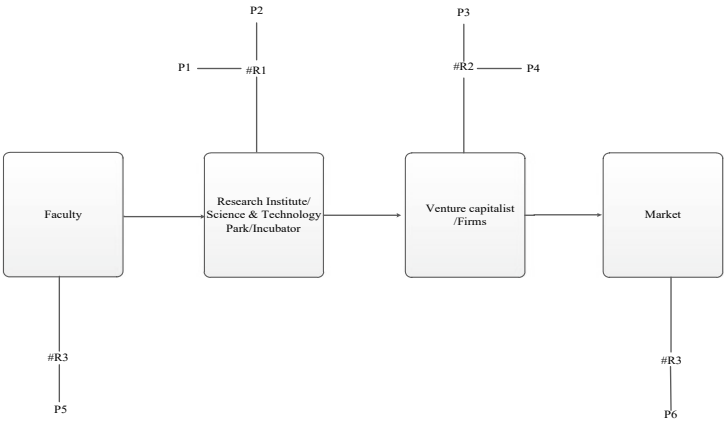


Fig. 1 Conceptual framework of commercialization process flow

The Fig. 1 below provides a very high-level description of data generation and knowledge integration processes as adapted from the knowledge integration process. This research applies and investigates the relevant approach to technology commercialization by incorporating qualitative method such as description of agile development approach with the quantitative method. The research context offers explanation of this methodology's relevance in HE commercialization context. Hence, the research outcomes will contribute towards creations of a theoretical and practical framework in the field of university technology entrepreneurships. The final product of case studies provides a conceptual framework in research commercialization (Albert and Gaynor 2006; Wang, Soetanto, Cai and Munir 2021).

3 Research Design

This research design is meant for eliciting the research objectives of the development of commercialization for technology products and innovations (inventions). The case study approach is chosen due to the nature of the context-specific purpose (Yin 2013). The contexts where data for prototyping and product development take place are in the HE commercialization program. This research incorporates positivist and interpretive paradigm into the research cases. The case study is important to assess the validity of the research questions whilst offer better participant enrichment and giving more accurate assessment in the surrounding issues of technology commercialization cases in HE (Teddlie and Tashakkori 2009). This emphasis the needs to explore the relationships among the stakeholders whose include the technology entrepreneurs, VC/firms, the university-industry commercialization programs in regards with the commercialization initiatives. The combinations of qualitative-quantitative approaches are also supported by Basias and Pollalis (2018) in the importance of process measures when evaluating information systems and the need to explore the necessary relationships between a computer system and the perceptions of its users (Basias and Pollalis 2018).

The successes of commercialization programs are very much dependent on the availability of resources and how those resources are utilized to manifest the commercialization. There is a widely renewed interest displayed in the role of resource-based capabilities as a means of creating competitive advantage. It is important to differentiate between the ordinary resources and capabilities (Grant 1991) as it determines the ability of individuals as a main source of competitive advantage of products and services. Wu, Welch and Huang (2015) categories these resource as factors both scientist and academia as: 1) individuals; and the 2) universities as institutions (Wu et al. 2015). Based on national survey commercialization 2010 of academic scientists in the United States, Wu et al. (2015) advocate that the influence of individual factors is more dominant to determine the Intellectual Property licensing than the institutional factors. These individuals are academia entrepreneurs, scientist and technology entrepreneurs who do not only possess the knowledge and expertise but the dynamic

capabilities (Eisenhardt and Martin 2000) to play their roles to sell-off the product and services.

From resource-based perspective (theory) the availability of these resources both tangibly and intangibly are intertwined dynamic capabilities (Eisenhardt and Martin 2000) and have relative impact on firm's success (Jeremy 2005). Jeremy (2005) further categories the tangible-intangible resources as follows:

1) Tangible resources which include

   (a) Financial assets
   (b) Physical assets

2) Intangible resources that are assets which include

   (a) Intellectual property assets
   (b) Organizational assets
   (c) Reputational assets

3) Intangible resources that are skills and dynamic capabilities (expertise, knowledge, technology)

Tangible financial assets are financial capital, cash on hand, investments measured by the firm's balance sheet. Tangible resources include those factors containing financial or physical value as argue that there is generally no disagreement over what encompasses tangible resource (Jeremy 2005). In the commercialization context, the financial tangible assets include funding, investments and grant received to carry out research and commercialization activities. Whilst, the tangible physical includes buildings for incubator as well as all necessary infrastructure such as labs, meeting rooms and all necessary facilities that can be evaluated in the balance sheet. Reputation is a valuable asset as it signals external entities about the trustworthiness and credibility and developed and gained over time through the organizations' success (Dowling 2006; Munari and Toschi 2021).

Thorburn (2007) explain the capabilities of tacit knowledge which is described as a complexity, its continual evolution, and its embodiment in personal skills, which vary from person to person. Tacit knowledge exchange and flows has a central role in organizational learning. The success of formal technology licensing can be increased when tacit knowledge is also transferred in the commercialization programs.

However, according to Jeremy (2005) capabilities are argued to be the utmost sources of firm success. As intangible resource capabilities contribute more significantly to firm success than either tangible assets or other intangible assets (reputations, organizational and etc.). Capabilities in terms of skills, expertise and know-how are tacit and not easily copied by competitors. Grant (1996), for example, argues that the success of any firm is dependent upon the knowledge (know-how) of its employees which is largely complex, specialized and most difficult resources to duplicate (Munari and Toschi 2021).

4 Methodology

As suggested by Yin (2013) there are namely three types of case studies namely exploratory, descriptive and explanatory case studies (Yin 2013). With regards to commercialization of universities' product and technology the explanatory is used to explain research commercialization context in order to relate multiple and interlinked factors and elements that had an effect in order to get an insight whether a particular theory match the case. The outcome will provide an explanation of the case being studied in relation to theories from the literature (Oates 2005).

A similar program held at Singapore Management University's Institute of Innovation and Entrepreneurship that helps students and faculty to grow their own businesses through a variety of competitions and programs. The programs have raised $3.7 million in grant funding and $9.4 million more in follow-up funding to further invest in the 110 companies they have helped generate (Mitchell and Watstein 2015).

4.1 Data Collection Methods

Wang, Qiu, Sangaiah, Liu, Bhuiyan & Ma (2020) and Yin (2013) identifies several sources of evidence that work well in case studies namely from observation to documents analysis. This research proposes a combination of the followings;

1. Interviews (structured, semi structured and open ended),
2. Observations
3. Examining the artifacts and products.

This combination is particularly useful to examine the outcome of the HE researches commercialization activities. The entire business processes are studied to comprehend the entire work flow until the development of the artefacts. This involves a thorough examination expands from proof of concepts phase, prototypes to the end users. The goal of this data collections method is to obtain rich set of data surrounding the specific research problems as well as capturing the contextual complexity. In the HEs commercialization context, the methodology will assist the researcher by providing evidence and explanations with regards to the commercialization of products and artefacts in the commercialization program (Gable 2020).

In this research, the third method (examining the artifacts and products) is expected to be more challenging yet interesting as the process involves the technical process of the product development. The process comprises of, product design and development, prototyping, proof of concept and pilot testing, IP creation until the technology is push to the market.

As depicted from the figure below the data collection method illustrates how the data generation are carried out based on qualitative method that incorporated in the selected case studies in universities commercialization program. The inferences resulted from these cases are detextualized to form the research commercialization

research questions as suggested by the literatures (Gable 2020; Yin 2013). Farquhar, Michels & Robson (2020) for example, complement quantitative data from questionnaires with qualitative evidence from observations and interviews (Farquhar et al. 2020). This case studies approach is performed to assess the objectives of the research. The feedback from qualitative perspective is gathered and analysed to conceptualize the HEs commercialization.

All elements of the qualitative data source are assessed and evaluated to build up and refine the conceptualization of the HE commercialization model. Qualitative data are useful for understanding the rationale or the underlying theory. Future research is required to reveal relationships in the qualitative data or directly suggest which theory can then be strengthened by quantitative data source (Farquhar et al. 2020).

4.2 Data Analysis Techniques

With regards to commercialization of HEs' artefacts and products dynamic capabilities (tacit knowledge, skills and expertise) are resided at commercialization programs and among the academic members (Wang et al. 2021). These capabilities are unique as the ability of these capabilities to generate value and benefits for commercialization is relatively dependent on the knowledge sharing process across the proposed model embodiment. The commercialization program will serve as platform for the knowledge sharing and a forefront entity to penetrate the market.

The data will be gathered on selected cases of universities' innovation and commercialization (incubation) programs. The data will be generated from:

1. Participants –there are two types of academics/scientists
    i. An ordinary academics who are only engage in teaching and research
    ii. Entrepreneurial academics who are actively engaged in commercialization a part from teaching and research
    iii.. Entrepreneurs from VC/firms and industry.
2. Interviews – semi structured interviews among academic scientist entrepreneurs and managers from VC/firms in HE.
3. Observations – the researcher observed activities in the in the selected universities incubator such as science and technology park.
4. Thematic analysis – The data collected from interviews and observations are analyzed using thematic analysis to answer the research questions. The data are compared and contrast with the existing literature to prove the consistency (inconsistency).

All inputs (data) from the cases in the HE commercialization programs are continually iterated till saturation is reached. Theoretical saturation is a point at which incremental learning and improvement are minimal because the researchers are observing

phenomena seen before (Farquhar et al. 2020). In the context of Higher Education (HE) commercialization, saturation is achieved when the incremental provide minimum or no improvements to the proposed model.

Technology entrepreneurs pose a great challenge for matching technological capabilities to market needs. The matching process involves triangulating activities both technical challenge and market challenge (Maine and Garnsey 2006). Technical challenge requires technical knowledge that is definitely available within the HE as a result of discoveries and research activities. However, the market is no less challenging as this challenge requires the entrepreneur to push the technology within diverse regulations and defensive response as a result of an organizations resistance. From the entrepreneurs' perspective identifying potential market is coupled with experimental development, design and prototyping, trial production and which involve a lengthy business process. Matching both technical possibilities and the market needs are practically very iterative process. On the other hand, from the end-users' perspective adapting (or adopting) new technology involves the recognition of needs (Woltjer, Van Galen and Logatcheva 2021).

5 Research Aims

This research aims to develop the research commercialization model based on the capabilities (Cunningham et al. 2019; Eisenhardt and Martin 2000) of tangible-intangible resources derived from resource-based theory (Battaglia et al. 2021; Wright et al. 2004; Jeremy 2005). The resource-based theory in which Jeremy (2005) applies is concentrated on identifying the firm's success. The results might differ as the orientation of success in the firms where the theory applies determines the survival in the competing industry. On the other hand, commercialization success is rather driven by academic research orientation.

Resource-Based Theory (RBT) advocated by Jeremy (2005) is hypothesized and tested among manufacturing and services firms operating in Australia (Jeremy 2005). Adapting RBT in HEs research commercialization will offer new insight as the HEs are better off in accessing the technology compared to ordinary firms in the industry although their market capabilities comparatively might be low. However, market knowledge and capabilities of ordinary firms is better (medium to high) than the HE ventures capitalist/firms (low to medium). RBT is suggested due to the practicality in theorizing the application as tangible-intangible Resource Base Theory and dynamic (Eisenhardt and Martin 2000) capabilities (Eisenhardt and Martin 2000) can be replicated for HE commercialization initiative (Fini et al. 2019; Wright et al. 2004). These resources and assets are mapped in HE commercialization model as attributes in Table 1.

In the table above, both intangible assets (resources) and intangible assets are divided in different rows. Jeremy RBT intangible resources are listed down and mapped with the proposed model as follows:

Table 1 Mapping the Jeremy resource-based theory with HE resource-based view

	Jeremy Firms RBT	Adapted RBT on HE
Intangible Resources/Intangible Assets	• Capabilities • Organization • Reputation • Intellectual Property	• Faculty/Research Programs • Commercialization Programs • VC/Firms collaboration & capabilities
Tangible Assets	• Infrastructure/Building • Financial Capital • Financial Investment	• Incubator Infrastructure • Funding/Grants/Investment (for commercialization)

- Research institute/Science and Technology Park
- Venture Capitalist/Firms collaborations

Faculty and commercialization programs are categorized as intangible assets based on the tacit nature of these assets. On the other hand, venture capitalist/firms will be measure based on their commercialization collaboration in the commercialization program within the same category (intangible) (Fini et al. 2019).

The tangible resources which consist of physical assets and financial resources will be mapped in the same way as below:

- Incubator Infrastructure (building, facilities and etc.)
- Funding/Grants/Investment (for commercialization)
- Human Resource (HR) staff involved in the technology transfer office

In addition, the result of this research will provide a confirmation based on the notion that the firms' dynamic capabilities (Eisenhardt and Martin 2000; Munari and Toschi 2021) (know-how, skills and expertise) are the most prominent factor in determining the firms' success based in the HE case context (Battaglia et al. 2021). The research questions can be explained from the diagram below.

5.1 Research Objectives

This article seeks insights to the following objectives:

1. To understand the characteristics of roles and functions of commercialization programs with regards to successful commercialization of IT products.

This article seeks understanding the unique roles of academic both as researchers as well as entrepreneurs that push their innovations to the market. As these roles are unique it distinguishes them from the rest of their colleagues. Their roles are worth investigated because the nature of the academic world where the facts are discovered, new paradigms are envisaged, and new inventions are developed into future business solutions.

2. To explain the roles of Venture capitalist/firms engage with the Higher Education (HE) inventions and innovations developed in commercialization programs.

As many universities around the globe have shifted their paradigm to be more open, new players are invited to share their capabilities to engage in research commercialisation. As a result, this phenomenon brings new insight since this engagement has opened dialogue and sharing opportunities for the academic innovations pulled (pushed) to the market. This objective seeks the explanation and definition of the engagement with the HE. Their engagement shed light the VC/firms significant new roles towards the commercialisation success.

3. To highlight the capabilities that catalyze the commercialization of HE inventions and innovations.

Finally, the general capabilities that spear up the commercialisation success must be understood. HE as an organisation provide a conducive (inconducive) environment towards the commercialisation success. For examples, as mentioned in the literature, resources both tangible and intangible are crucial. Allocating resources require top down approach and decision. Since resources are scarce, HE may in a difficult situation to prioritise between resources for research and resources for commercialisation purpose.

6 Conclusion and Implications

This research contributes a theoretical model for successful commercialization and commercialization programs and describe the complex relationship between resources (finance, funding, and investment) and knowledge both tangible and intangible capabilities (Olanrewaju et al. 2020; Jeremy 2005). The first research question regarding the characteristic of roles of commercialisation program, it is obvious that research products which are more market oriented are more successful that the technology-oriented ones. Although the incubator that offers the high level of technology is important, the failure to align them to the market requirements is just perceived immature or merely a product of academic exercise.

The above objectives lead to the next objectives in which defines the roles of the external firms and venture capitalist's involvement. This firms bridge the inventions and innovations with the market. The new HE inventions and innovations are facing a vas and huge dead valley before reaching the market.

Since it is obvious that the business entities are more well verse with the market and closer to their customers than the HE. Synergising the HE technology and the VC/firms manage to shape the new technology to be more market oriented hence more successful to penetrate the targeted customers' market. As a result, the VC/firms engagement is remarkably important to close the dead valley gap between academic research with industry applications.

These business entities survive based on their customers' product. Technology advancement though is important, this firms need to tie up their innovation and technology solutions towards the market. Thus, market potential is more appetising for this business entities that the technological advancement.

The third objective pertaining the capabilities of HE commercialisation prove the academic entrepreneurship in their commercialisation success. However, only a handful of the respondents shows a genuine entrepreneurial capability. These entrepreneurial academic researchers play ambidexterity capabilities suggested by Ambos (Ambos 2008) that have talents and capabilities both in academic research and commercialisation venture. They not only excel in developing their research product into customers' end product but also have their talent pitching their innovation before the VC/firms and customers.

Pushing the technology against various regulation are tedious tasks. Hence the process is much more leveraged provided that this entrepreneurial academic able to share this responsibility with the VC/firms. As stated in the previous objectives, their involvement defines a new relationship with the academics and the HE.

Hence, it provides a new insight that enhance our understanding of the relationships between university and firms in the industry in terms of research commercialization (Minguillo and Thelwall 2015; Woltjer et al. 2021). Understanding the characteristics, roles and functions that comprises in the technology research commercialization and those resources involved are deemed necessary. The outcomes provide a model on how to channel the universities' inventions (innovations) to the industry effectively (Siegel et al. 2004; Wang et al. 2021; Wright et al. 2004; Yusof et al. 2009). Thus, the model offers best practice and guidelines for academic research commercialization (Ratinho et al. 2020; Siegel et al. 2004).

The outcomes produce practical implications and serves as guidelines and best practices for university and research-based innovations developed in research centers or incubators (Berger et al. 2021; Wu et al. 2015). The university-industry commercialization framework (Ambos 2008; Berglund et al. 2020) provides a valuable insight for academia technology entrepreneurship. There are many lessons learnt from the research commercialization program such as:

- Sophisticated university programs and selection criteria, such as pitches to a funding plenary, business plan competitions as well as an improved interaction through a structured process, increases the quality of supported ventures (Borg 2001; Minguillo and Thelwall 2015; Musibau and Kamariah 2013; Woltjer et al. 2021). The University incubators can overcome 'failures' in the technology market and reduce transaction problems, such as adverse selection, moral and financial supports.
- Higher commercialization rate of Intellectual Properties leads to high economic returns through licensing agreements (D'Este and Perkmann 2011; Markman et al. 2005; Ratinho et al. 2020). This quest for benefits for both academia entrepreneurs and the venture capitalist/firms.
- University incubation programs increase the quantity as well as quality of entrepreneurial activities at universities (Becker and Gassmann 2006). Potential IPs often fail to penetrate the market as academics are not well versed to venture the invention (innovations) (Borg 2001; Cunningham et al. 2019; Rubin et al. 2015) and access to potential funding and due to absence of VC/firms partnerships.

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