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Technological Entrepreneurship Framework for University Commercialization of Information Technology

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Abstract

One effective way of accelerating the commercialization of university innovations (inventions) is to execute a "Technological Entrepreneurship" framework that helps the execution of agreements between universities and industry for commercialization. Academics have been encouraged to commercialize their research and findings yet the level of success of commercialization of inventions (innovations) in industry is questionable. As there is no agreed commercialization framework to guide the execution of processes to support inventions moving from laboratories to the right market. The lack of capabilities of appropriate processes have undermined the turning of innovation and products into wealth. The research questions are designed to identify the constraints and hindrances of commercialization and the characteristics of successful processes built from framework based on selected case studies of incubation capabilities within universities commercialization program.

Keywords: Technological Entrepreneurship, Venture Capitalist, Incubation Programs

Introduction

Entrepreneurship is described as the ability to associate all activities in order to gain profit and wealth from labor, land, capital and recently from knowledge and technology (Gedeon, 2010, pp. 18-21). The entrepreneurial qualities of academia could be a driving force towards economic development through job creations and new ventures (Täks, Tynjälä, & Kukemelk, 2015). However, there is currently no consistent mechanism for tracking the impact of commercialization although there is a significant flow of scientific knowledge sharing between universities and academia (Rubin, Aas, & Stead, 2015). The personal attributes of entrepreneurs include autonomy and independence, creativity, moderate and calculated risk taking, drive and determination towards success (Ajagbe, Isiavwe, Ogbari, & Sholanke, 2015). What is common among all references listed above is the association of risk or the ability of the entrepreneurs to take risk by exploiting those resources (Ajagbe et al., 2015; Gedeon, 2010, pp. 18-21; Täks et al., 2015). The reward for risk taking definition can be traced way

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back in the 20th century Risk Theory (Gedeon, 2010). This research address 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.

The definitions of entrepreneurship evolves and since the last two decades is applied to those in academia who actively engage both in research and commercialization of their innovations (inventions) (Mowery & Shane, 2002; Siegel, Waldman, Atwater, & Link, 2004; Wright, Vohora, & 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 (Mowery & Shane, 2002).

The research and commercialization occurs 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 initiates innovation within the university (Swamidass 2013; Zhao * 2004). Value from academic entrepreneurship is achieved through the integration of scientific activities, academic activities and commercialization activities (Siegel et al., 2004; Yusof, Siddiq, & Nor, 2009).

This paper investigates on how Higher Education (HE) institutions develop potential Intellectual Properties (IP) for commercialization and spin-offs. The number of patents granted does not guarantee and reflect economic return and wealth (Henry, Hill, & Leitch, 2005). The inabilities of Intellectual Properties to generate economic return give an impression that HE fails in the commercialization although able to increase the number of IP. 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. This article attempts to shed light how university academics play their roles to ensure the innovations succeed. The result will complement the paucity in the literature (Gedeon, 2010). The result of this research is expected to improve commercialization of IT research outcomes in universities.

Literature

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, etc.), 2) Market Knowledge Bearer, and 3) Financial Knowledge Bearer (Porter, 2008). 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) estimate that 75 % of university inventions and patents are not licensed at all. Without a structured execution of processes to channel the HE invention (innovation) the academic scientists pose a greater difficulties turning their potentially commercialized research into wealth (Markman, Phan, Balkin, & Gianiodis, 2005).

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 (Geuna & Nesta, 2006; Swamidass, 2013). Guena and Nesta (2006) conducted a comparative Intellectual Properties research in selected universities in five European countries, Germany, Finland, Belgium, France and Italy. The findings show that 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.

The commercialization of research developed in universities explains how are the characteristics, roles and functions with regard to successful commercialization of IT products. Since Universities are institutions these characteristics can be explained by Institutional Theory (D'Este & Patel, 2007; Perkmann & Walsh, 2007; Wu, Welch, & Huang, 2015). Institutional theory perceived organizational structure as an adaptive vehicle shaped in reaction to the characteristics and commitments of participants as well as to influences and constraints from the external environment (Scott, 1987). Institutional (HE) Theory explains how the characteristics, roles and functions of participants (academics and entrepreneurs in VC/firms) carried out the research commercialization objectives. Siegel et al. (2004), for example, explain and map the process of commercialization which begins from scientific discovery towards negotiations and licensing in HE. The explanation of the process is quite comprehensive and has simililarities with the generic process below suggested by Commonwealth Scientific and Industrial Research Organization (CSIRO) - the largest Australia national research agency (Upstill & Symington, 2002).

The resource-based (capital, labour, technology, etc.) theory which Jeremy (2005) applies is concentrated on how firms succeed in the industry. However, comparing the results with the HE might differ as the orientation of success in the firms determines the survival in the competing industry. On the other hand, commercialization success in HE is rather driven by academic research orientation.

In Table 1, both tangible assets (resources) and intangible assets are divided in different rows. Jeremy's RBT intangible resources are listed down and mapped with the proposed model as shown in Figure 2:

- 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. Tacit assets in this context are referred to the capabilities that include the knowledge and technology expertise of HE faculty members to carry out research commercialization. On the other hand, venture capitalist/firms will be measured based on their commercialization collaboration in the commercialization program within the same category (intangible).

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

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

Table 1 Mapping Resource-Based View with HE Resource-Based View

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

In addition, the result of this research will provide a confirmation based on the notion that the firms' dynamic capabilities (Eisenhardt & Martin, 2000) (know-how, skills and expertise) are the most prominent factor in determining the firms' success based in the HE case context. The research questions can be explained from the diagram in Figure 1.

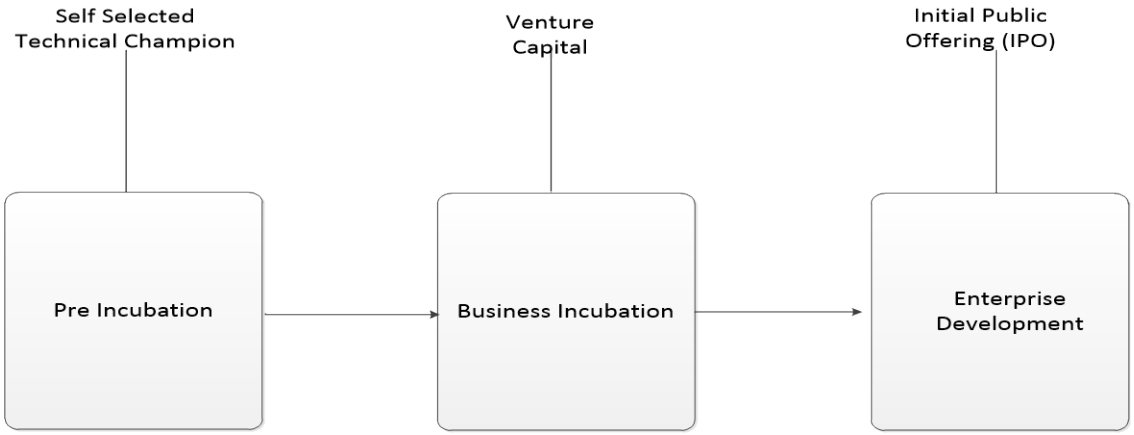

Figure 1. Generic Process Proposed by CSIRO for new Venture Capital
(Upstill & Symington, 2002)

Research Question

Applying the Institutional Theory in research commercialization in HE has its limitation as the success of commercialization are more frequently contributed by individual factor of the entrepreneurial qualities of the inventor and academic scientists (D'Este & Patel, 2007; Perkmann & Walsh, 2007; Wu et al., 2015) 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 the US, concluded that the commercialization success are contributed more prevantly by individual initiatives rather than by their universities as institutions (D'Este & Perkmann 2011; Wu et al. 2015). These individuals have determination to engage with industry even with minimum support by their respective institutions. Based on this literature, the research commercialization must be concentrated into investigating academics as individuals entrepreneurs, scientists, and technology entrepreneurs who do not only possess the knowledge and expertise but the dynamic capabilities (Eisenhardt & Martin, 2000) to play their roles to sell-off the product and services.

From resource-based perspective (theory) the availability of these resources (tangible) provided by the institutions intertwined with academic entrepreneurs intangible dynamic capabilities

(Eisenhardt & Martin, 2000) have relative impact the on firms success (Jeremy, 2005). From the capabilities perspective, the availability of those resources only significantly contribute to commercialization success if those resources are exploited with the right process, functions, and roles played to meet the commercialization objectives.

Markman et al. (2005) and Mowery and Shane (2002) however argue that the best solution for university technology commercialization requires those economic actors (VC/firms) and HE engage and collaborate through incubation programs. HE academics commercialization engagements with VC/firms who have a comparative advantage in the commercialization are expected to improve the marketability of the innovation (inventions). The commercialization involves a set of skills including identifying customer needs, developing product concepts, designing products and processes and manufacturing that university inventors rarely possess (Mowery & Shane, 2002; Zhao*, 2004). Therefore this research investigates the component of an 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 (Ambos, Mäkelä, Birkinshaw, & D'Este, 2008),

Without disregarding institutional factors, 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 the university and technology transfer office (Wu et al., 2015). It is not surprising that Ambos et al. (2007, 2008) find that the experience and breadth of support of the transfer office is not significant predictors of commercial success (Ambos, Mäkelä, Birkinshaw, & D'Este, 2008. The role of the transfer office is only important in the later stages of commercialization process (Ambos et al., 2007). The initial decision to commercialize is dependent on the academic entrepreneurs' motivation. If Ambos et al. (2007) 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. The findings of this research shed light the VC/firms significant roles in commercialization program instead of the transfer office towards commercialization success. Research questions (RQ) are as follows;

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 (Albert & Gaynor, 2006; Bergek & Norrman, 2008; Mian, 1997).

   Proposition 2 (P2)

   The incubator which has high **marketing capabilities** (Albert & Gaynor, 2006; Borg, 2001) 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 (Albert & Gaynor, 2006; Bergek & Norrman, 2008; Mian, 1997).

   Proposition 4 (P4)

   The VC capitalist/firm which has high **marketing capabilities** (Albert & Gaynor, 2006; Borg, 2001) 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 (T. C. Ambos et al., 2008; D'Este & Patel, 2007)

Proposition 6 (P6)

The VC capitalist/firm which has high marketing capabilities (Albert & Gaynor, 2006; Borg, 2001) is more succeed in research commercialization

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 a positivist and interpretive paradigm into the research cases. The case study is important to assess the validity of the research questions whilst offering better participant enrichment and giving more accurate assessment in the surrounding issues of technology commercialization cases in HE (Teddlie & Tashakkori, 2009) These emphasize the need to explore how academics from the HE and VC firms from the industry engage in the incubation program to commercialize the IT research outcomes.

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 (tangible) and capabilities (Grant, 1991), which are intangible yet crucial as they determine the ability of individuals as a main source of competitive advantage of firms.

Wu, Welch and Huang (2015) categorize these resource as economic factors for both scientist and academic as individuals and the universities as institutions. Based on a 2010 national survey commercialization of academic scientists in the United States, Wu, Welch and Huang advocate that the influence of individual factors are more dominant to determine the Intellectual Property licensing than the institutional factors. These individuals are academic entrepreneurs, scientists, and technology entrepreneurs who do not only possess the knowledge and expertise but the dynamic capabilities (Eisenhardt & Martin, 2000) to play their roles to sell-off the product and services.

From resource-based perspective (theory) the availability of tangible and intangible resources and have relative impact the on firms success (Jeremy, 2005). Jeremy (2005) further categories the tangible-intangible resources as follows:

1) Tangible resources which include (Grant, 1991)
   (a) Financial assets
   (b) Physical assets
2) Intangible resources that are assets which include
   (a) Intellectual property assets (Hall, 1993)
   (b) Organizational assets (Fernández, Montes, & Vázquez, 2000); (Hall, 1993)
   (c) Reputational assets (Dowling, 2006)
3) Intangible resources that are skills and dynamic capabilities (Eisenhardt & Martin, 2000) (expertise, knowledge, technology) (Hall, 1993)

Tangible financial assets are financial capital, cash on hand, and investments measured by the firm's balance sheet. Tangible resources include those factors containing financial or physical value which can be recorded in the institutions' balance sheet (Jeremy, 2005). In the commercialization context, the financial tangible assets include funding, investments and grants received to carry out research and commercialization activities. The tangible physical assets include buildings for incubators 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 assets (intangible) as it signals external entities about the trustworthiness and credibility (Dowling, 2006) and is developed and gained over time through the organizations' success.

Thorburn (2000) explains that tacit knowledge is complex, continually evolved, embedded in personal skills, and varies from person to person. Tacit knowledge exchange and flows have a central role in organizational learning. The success of formal technology licensing is expected to increase when tacit knowledge is transferred and shared in the commercialization programs.

Jeremy (2005) argues that capabilities are the utmost sources of a firm's success. As intangible resources, capabilities contribute more significantly to a firm's success than either tangible assets or other intangible assets (reputations, organizational, etc.). Capabilities in terms of skills, expertise and know-how are tacit and not easily copied by competitors. Grant (1991), 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 the most difficult resources to duplicate.

Figure 2 provides a high-level description of data generation and knowledge commercialization integration processes which is adapted from Siegel et al. (2004). All research questions (R) and the respective propositions (P) are presented along the process flow. The process flow also indicates both tangible and intangible resources and assets belong to HE and VC/firms. The conceptual framework explains how the research objectives and data will be gathered from the commercialization process flow. This research applies and investigates the relevant approach to technology commercialization by incorporating qualitative method.

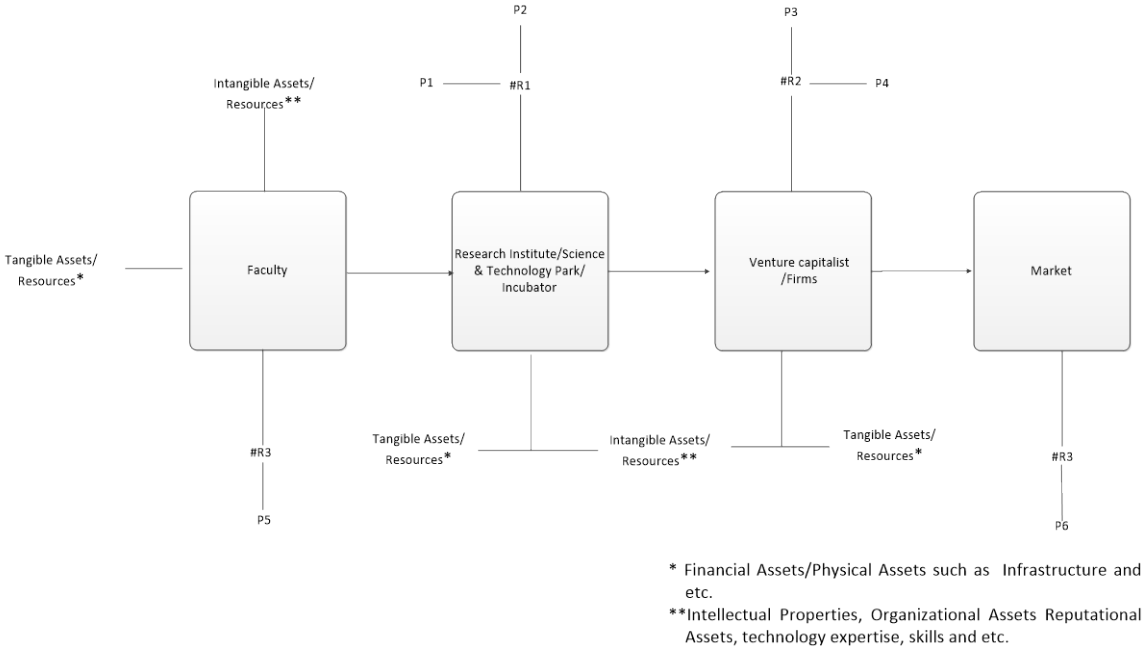

Figure 2 Conceptual Framework of Commercialization Process Flow

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 (Mintzberg & Waters, 1982) in research commercialization.

Methodology

As suggested by Yin (2013) there are three types of case studies, namely, exploratory, descriptive, and explanatory case studies. With regards to commercialization of universities' product and technology, the explanatory is used to explain research commercialization context in order to relate multiple and inter-linked factors and elements that have an effect on HE commercialization success. 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 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 & Watstein, 2015)

Data Collection Methods

Yin (2013) identifies several sources of evidence that work well in case studies, namely, from observation to documents analysis. This research proposes the a combination of the followings;

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

The combination above is particularly useful to examine the outcome of the HE research commercialization activities. The entire commercialization process flow are studied to comprehend the entire phase, which begins from the faculty research until it penetrates the market (Figure 2). This involves a thorough investigation expanding from proof of concepts phase to prototypes to the end users. The goal of this data collection method is to obtain a rich set of data surrounding the specific research problems as well as capturing the contextual complexity (Benbasat, Goldstein, & Mead, 1987). 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.

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, and IP creation until the technology is pushed to the market.

The data collection method outlines how the data generation are carried out based on qualitative methods in the selected case studies in university's commercialization program. The inferences resulting from these cases are detextualized to form the research commercialization research questions as suggested by the literatures (Miles & Huberman, 1985, 1994; Yin, 2013). Eisenhardt (1989), for example, complements quantitative data from questionnaires with qualitative evidence from observations and interviews. This case studies approach is performed to assess the objectives of the research. The feedback from qualitative perspectives 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 (Eisenhardt, 1989).

Data Analysis Techniques

With regards to commercialization of HE IT products (prototype, proof of concepts, patents, etc.), dynamic capabilities (Eisenhardt & Martin, 2000), which comprises of tacit knowledge, skills and expertise, are considered most crucial in determining the HE commercialization success. These capabilities are further extended and shared across the process flow in order to push (pull) the innovation into the market. 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 as depicted in Figure 2.

The data from every phase, which begins from faculty research, science park/incubator, VC/firms and before market penetration, will be gathered as case studies. The data will be generated from:

- Participants –there are two types of academics/scientists (Ambos et al., 2007)
  - Ordinary academics who only engage in teaching and research
  - Entrepreneurial academics who are actively engaged in commercialization a part from teaching and research
  - Entrepreneurs from VC/firms and industry.
- Interviews – semi structured interviews among academic scientist entrepreneurs and managers from VC/firms in HE.
- Observations – the researcher observed activities in the selected university's incubator such as science and technology park.

Observation is required to understand the process of matching technological capabilities with the market needs. The matching process involves triangulating activities, both technical challenge and market challenge (Maine & 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 VC/firms to push the technology within diverse regulations internally (HE) as well as in the market. From the entrepreneurs' perspective, identifying the potential market is coupled with experimental development, design and prototyping, and trial production, which involves lengthy research, and all commercialization activities. Matching both technical possibilities and the market needs are a very iterative process.

- 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 (Eisenhardt, 1989). In the context of Higher Education (HE), commercialization, saturation is achieved when the incremental changes provide minimum or no improvements to the proposed model. The saturation is needed to understand whether or not the themes support the research questions and the respective propositions.

Conclusion

This article provides a comprehensive framework for successful commercialization and incubation programs and describes the complex relationship between resources (finance, funding, and investment) and knowledge, both tangible and intangible. Hence, it can provide an insight to enhance our understanding of the relationships between university and firms in the industry (Minguillo & Thelwall, 2015). Understanding the components that comprise the incubation framework and those resources involved are deemed necessary. The outcomes provide a model on how channel the universities' inventions (innovations) to the industry effectively.

This research is expected to highlight some of the specific practical implications for universities to improve commercialization from their research outcomes. Universities can establish their own incubation mechanisms to support commercialization activities. In addition, the HE can institutionalize that the development of commercialization activities within the university is a legitimate activity, and it does not compromise a the academicians' ability to further their academic career (T. Ambos, Makela, Birkingshaw, & D'Este, 2007).

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Biographies

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