# Exploratory research into intellectual property commercialisation: The role of polytechnics in facilitating small and medium enterprise development in Singapore

---

Tian Soon Sim

This thesis is submitted to The University of Adelaide Business School in fulfilment of the requirements for the degree of Doctor of Philosophy

March 2021

# Table of contents

# List of tables

# List of figures

## List of abbreviations

| | |
|---|---|
| A*STAR | Agency for Science and Technology Research |
| AUTM | Association of University Technology Managers |
| CAQDAS | Computer Aided Qualitative Data Analysis Software |
| COI | Centre of Innovation |
| CPI | Creativity Productivity Index |
| DTBC | Design, Technology, Business, and Customer |
| EDB | Economic Development Board |
| ESC | Economic Strategies Committee |
| FTO | Freedom-to-Operate |
| GDP | Gross Domestic Product |
| GII | Global Innovation Index |
| GLC | Government-Linked Company |
| HC | Human Capital |
| IHL | Institution of Higher Learning |
| IP | Intellectual Property |
| IPOS | Intellectual Property Office Of Singapore |
| IPTC | IP Transfer and Commercialisation |
| KPI | Key Performance Indicator |
| MNC | Multinational Corporations |
| MOE | Ministry of Education |
| NDA | Non-disclosure Agreement |
| NP | Ngee Ann Polytechnic |
| NRF | National Research Foundation |
| NUS | National University of Singapore |
| NYP | Nanyang Polytechnic |
| R&D | Research and Development |
| RBV | Resource-based View |
| RC | Relational Capital |
| RDT | Resource Dependence Theory |
| RI | Research Institute |
| RIE | Research, Innovation and Enterprise |
| RP | Republic Polytechnic |
| RQ | Research Question |
| SC | Structural Capital |
| SME | Small and Medium Enterprise |
| SP | Singapore Polytechnic |
| SPRING | Standards, Productivity and Innovation Board |
| SQ | Subsidiary Question |
| SRL | System Readiness Level |
| TA | Thematic Analysis |
| TP | Temasek Polytechnic |
| TRL | Technology Readiness Level |
| TT | Technology Transfer |
| TTO | Technology Transfer Office |
| U-I | University–Industry |
| U-I-G | University-Industry-Government |
| UEN | Unique Entity Number |
| VRIN | Valuable, Rare, Inimitable, Non-substitutable |
| WIPO | World Intellectual Property Organization |

# Abstract

Over many years, *intellectual property transfer and commercialisation* (IPTC) scholars have paid significant attention to knowledge generation in universities and its commercialisation. However, little is known about the process and the value of commercialising the IP taken from polytechnics, although the polytechnic education sector provides a practice-based workforce and collaborates with industry in various innovative activities.

The exploratory research has extended the discourse of IPTC scholars or practitioners to encompass the overall experience of small-medium enterprise (SME) uptake of polytechnic IP in the city-state of Singapore, which is pursuing the goal of becoming an innovation hub. The overarching IPTC problem explored by this research was how to encourage more SMEs to look beyond traditional IP producers (universities or research institutes) and explore IPTC with polytechnics. Taking a polytechnic translational IP allows SMEs to collect the maximum amount of validated learning from end-users with the least development effort.

The research adopted a case study design to investigate SMEs' relationships with IP providers. Through documentary research, the characteristics of public-private IPTC stakeholders in Singapore were investigated, focussing on the plans and policies of the city-state, institutes of higher learning (IHL), and SMEs. Following the documentary research, semi-structured interviews were conducted with SME managers to ascertain their views of the IPTC process. Thematic analysis was used to interrogate the data.

Recommendations to facilitate IPTC included implementing a deferred royalty payment, ensuring an IP co-ownership framework, and upholding simple and business-friendly IP valuation methods. A lack of IP due diligence, considerable variability in IP awareness, unrealistic IP valuation and the incompatibility of the financial goals of the potential partners in IPTC were identified as barriers to the successful negotiation and culmination of contracts.

The research findings challenge the generally accepted idea that polytechnic IPTC should ideally adopt a 'naked' technology licensing approach, contributing nothing more than the IP. The results of interviews showed that most of the participant SMEs preferred that a polytechnic continue technology, design and knowhow support after the exchange of IP, and that IPTC take-up should be understood as a function of connecting the business world to the research world in order that both may benefit from one another's strengths. Polytechnics supply innovative designs and technologies, while SMEs provide dominant resources in business and customer insight – DTBC resources. Then, together, they make innovation happen.

The research sought to broaden the application of the theories of the resource-based view (RBV), appropriability regime (AR), and dynamic capabilities (DC) that explain the internal means by which strategic resources can be enhanced but challenged AR's general acceptance of tight legal mechanisms for IP protection as unnecessary. The inter-organisational theory of resource-dependence (RDT) that looks at partner relationship complexities was also considered in the context of IPTC. At the strategic level, an enhanced RDT model would demonstrate how SMEs choose IPTC partnerships (dependent, interdependent or independent) based on the SME's control over the DTBC resources. At the operations level, it is useful to apply the two-level strategy to secure, develop and deploy strategic resources by combining inward (RBV) and outward-looking approaches (RDT).
**Keywords**: intellectual property, commercialisation, polytechnic, technology transfer, SME

## Declaration

I certify that this work contains no material which has been accepted for the award of any other degree or diploma in my name, in any university or other tertiary institution and, to the best of my knowledge and belief, contains no material previously published or written by another person, except where due reference has been made in the text. In addition, I certify that no part of this work will, in the future, be used in a submission in my name, for any other degree or diploma in any university or other tertiary institution without the prior approval of the University of Adelaide and where applicable, any partner institution responsible for the joint-award of this degree.

I give permission for the digital version of my thesis to be made available on the web, via the University's digital research repository, the Library Search and also through web search engines, unless permission has been granted by the University to restrict access for a period of time.

I acknowledge the support I have received for my research through the provision of an Australian Government Research Training Program Scholarship.

Signature:

Date: 3 Mar 2021

## Acknowledgements

Throughout the writing of this thesis, I have received a great deal of support and assistance. First and foremost, I would like to thank my supervisors, Dr Barry Elsey and Associate Professor Allan O'Connor, for their unwavering support, insightful feedback, valuable guidance, and enormous patience. During this long journey conducting this research as a remote candidate, they encouraged me to persevere and provided me with the right direction to complete my thesis. Although they have to remain anonymous, I would like to acknowledge my research participants for their candid and engaging sharing of their unique IPTC experiences. Not only did they answer my research questions, they recommended many ideas for improvement of IPTC processes.

I would also like to thank the academic and professional staff, and fellow research students at the University of Adelaide Business School for the community support I received throughout the candidature.

Meanwhile, I would like to express my sincere gratitude to my editor, Barbara Brougham, a very professional copywriter, who always provided the language editorial feedback on time, even during her busy schedule.

Besides, I would like to thank my wife and daughters for their moral support and empathetic ears. You were always there for me.

Finally, I could not have completed this thesis without my employer's strong support.

# Exploratory research into intellectual property commercialisation: The role of polytechnics in facilitating small and medium enterprise development in Singapore

Chapter 1

# Introduction

## 1.1 Background and study rationale

Performance data suggest that the university technology transfer industry in North America has had a positive impact on improving lives and creating jobs in the US and Canadian economies, as university research is moved to the market (Allen 2014; Sanberg & McDevitt 2013). The Association of University Technology Managers (AUTM), drawing membership from universities in the US and Canada, conducts an annual licensing activity survey amongst its members. In 2014 it reported that impressive year-on-year growth in the number of new start-ups formed (914) and new products commercialised (965) in North America had resulted in US$28 billion in product sales (AUTM 2015). Naturally, other research universities and technology producers, including those in Singapore, would like to replicate this success in transferring the intellectual output of their institutions to the market.

Dr Phyllis Speser (2006), an experienced university technology transfer practitioner, considers technology transfer to be:

> *The transfer of a technology from one person to another across organisation lines. Almost always, technology transfer involves early-stage technologies that are just emerging from R&D or offer a substitute for technology recently introduced into a market niche. In technology transfer, the intellectual asset package that constitutes the technology is literally handed from one party to another. This transaction is called a deal. The deal commonly involves money, but as with any contract, it does not matter what is being traded in exchange for the intellectual asset package.*
> *(Speser 2006, p. XXiii)*

Speser writes about the transfer of technology as the transfer of a package of intellectual assets, i.e., knowledge, associated with that technology, while Davenport and Prusak (1998) point out that whenever any type of new knowledge is created by individuals, it can be converted into revenue and profit. Knowledge, in the form of technology or otherwise, is therefore largely an opportunity lost if not either applied in-house or commercialised. It represents the culmination of insights gained from the generation and interpretation of information, and as Davenport and Prusak (1998) state:

> *A fluid mix of framed experience, values, contextual information, and expert insight that provides a framework for evaluating and incorporating new experiences and information. [Knowledge] originates and is applied in the mind of knowers. In organisations, it often becomes embedded not only in documents or repositories but also in organisational routines, processes, practices and norms.*
> *(Davenport & Prusak 1998, p. 5)*

Davenport and Prusak (1998) believe that knowledge may be treated as a valuable asset and can be exchanged for a mutually agreed price in what is known as the knowledge market, working similarly to markets for goods and services. They point out that participants in the knowledge market include buyers, sellers, brokers and companies. Knowledge buyers are people seeking answers to complex issues; knowledge sellers are organisations and individuals with a reputation for having substantial knowledge about a process or subject and who are willing to sell it. Knowledge brokers make connections between buyers (those who need knowledge) and sellers (those who have it) (Davenport & Prusak 1998). Brokers might be institutional structures, organisations or individuals, but their goal is always to make 'research and practice more accessible to each other' (Ward, House & Hamer 2009), and to foster the equitable sharing of, and benefit from, knowledge, ideas and information.

**Intellectual property (IP).** Documented or codified new knowledge and ideas are the basis of *IP*. Innovation is often involved, such as new knowledge related to products, services, processes and experiences. To protect the creators, codified new technologies are patented, while books, poetry, music, art and design, including logos and trademarks, are legally protected by copyright and registration (Ng-Loy 2008). The holders of patents and copyrights can profit from their IP in a wide variety of ways, including technology transfer, the sale of copyrighted books, music or artwork, or product branding. Documenting and protecting knowledge in these ways removes ambiguity from the marketplace and promotes ease-of-transfer, facilitating innovation.

Dubickis and Gaile-Sarkane (2015) found that in the literature, definitions of innovation and technology transfer intersect, with technology transfer widely perceived as the application of technology to a new use or a technology being adopted by a new user. Nevertheless, as a technology is not the only source of innovation, for this research, innovation is defined as:

> *A feasible, relevant offering such as a product, service, process or experience with a viable business model that is perceived as new and is adopted by customers.*
> *(Van Wulfen 2016, p. 23)*

For an innovation to be viable, the change must add value or bring benefits to the end-users (Bhargava 2013; LaSalle 2014); it can be just any incremental business or societal improvement which seeks and captures the opportunity to differentiate in value-adding.

Moreover, the term IP has been used for both the technological and non-technological intellectual assets embodied in product, service, process or experience innovations.

### 1.1.1 The problem

Singapore, a city-state, is recognised by the global innovation benchmarking report as the leading performer in providing a conducive environment to innovation, but somewhat lacking in terms of innovation outcomes (Cornell University, INSEAD & WIPO 2019). One of Singapore's innovation challenges is to promote more *intellectual property transfer and commercialisation* (IPTC) between public technology producers and industry.

Besides providing a practice-based workforce, the polytechnic education sector in Singapore collaborates with industry in a range of innovative activities of varying intensities. Over the years, scholars have paid more attention to IPTC knowledge generation that is usually linked to a university early-stage technology, but little is known on the value of commercialising an IP taken from applied-learning institutions such as polytechnics.

Notably, documentary evidence sourced from various polytechnics' websites and newspaper articles suggest that polytechnics are increasingly valued as public technology producers. As revealed in a local newspaper article, the polytechnics in Singapore collectively licensed 91 separate pieces of IP to industry between 2005 and 2016 (Teng 2016). While this may be true, related literature and in-depth data that helps to make sense of the IPTC relationships in this space are virtually non-existent. Hence, the need for this exploratory study to extend the discourse of IPTC scholars or practitioners, as well as organisational scholars, in order to enhance the overall experience of small and medium enterprise (SME) uptake of polytechnic IP commercialisation outcomes.

According to a survey conducted by Wong, Ho and Singh (2006) on how companies in Singapore create and exploit IP, only 2% of SMEs invest in innovation. This mediocre innovation performance motivated the researcher to investigate what role the polytechnic sector might play in facilitating a bilateral idea flow between a polytechnic and a SME.

Under sub-section 4.1.2, the researcher described polytechnic innovation characteristics with evidence to support the bilateral flow of ideas between polytechnics and SMEs. This evidence includes the existence of different Centres of Innovation (COIs) and several case examples of commercially deployed products. In addition, most SME managers echoed the importance of bi-lateral exchanges of knowledge in design, technology, business, and customers (DTBC) is critical to determine the nature of the IPTC partnership.

Any innovative ideas, involving an early-stage technology or not, ought to be developed and translated nearer to being a production prototype to mitigate the risks of IPTC failures. The overarching IPTC problem is how to encourage more SMEs to look beyond the traditional IP producers (universities or research institutes [RIs]) and explore with polytechnics the transfer and commercialisation of a wide range of IP, including applied incremental IP.

Rombach and Achatz (2007) have mapped the roles played by different players, big and small, against a six-step generic technology transfer process model. According to them, universities tend to dominate the basic research role, creating more fundamental or scientific IP (models, principles), while RIs (another educational IP producer) act as the applied researchers in creating more engineering IP. Based on secondary evidence of polytechnics' applied research capabilities, it seems appropriate to tentatively position polytechnics between applied research to functional-level prototyping in a real-life environment (in-vivo prototyping), a position that requires the translation of basic research to near-market prototypes by aggregating known and proven technologies, hence an IP 'translator' role. According to the Economic Strategies Committee (2010), idea or IP translation is the innovation capital that creates value from R&D

investments, and Lane and Flagg (2010) define knowledge translation as a process of moving knowledge into practice.

Figure 1.1 shows the suggested positioning of polytechnics graphically as IP producers between universities and RIs. Polytechnics, equipped with applied R&D capabilities, seem to match the profile of technology or IP translators that can apply and aggregate today's knowledge and technologies into prototypes (Rombach & Achatz 2007). Innovative ideas, involving early-stage technology or not, ought to be developed and translated nearer to being a production prototype to mitigate the risks of IPTC failures.

### 1.1.2 Background of technology transfer

During the early stages of industrialisation in Britain, entrepreneurial individuals sought to transfer technology in the forms of production machinery, expertise, information and labour into other European countries, despite such transfer being discouraged by the government during the 1840s (Wengenroth 2000). Ultimately, between 1825 and 1850, there was a proliferation of engineering knowledge across the European continent, as not only were technologies brokered and exchanged until technology transfer reached a stage of institutionalisation, but skilled labour was often engaged across borders to work with new machines and instruct in new processes that were being applied to old technologies (Wengenroth 2000, p. 15).

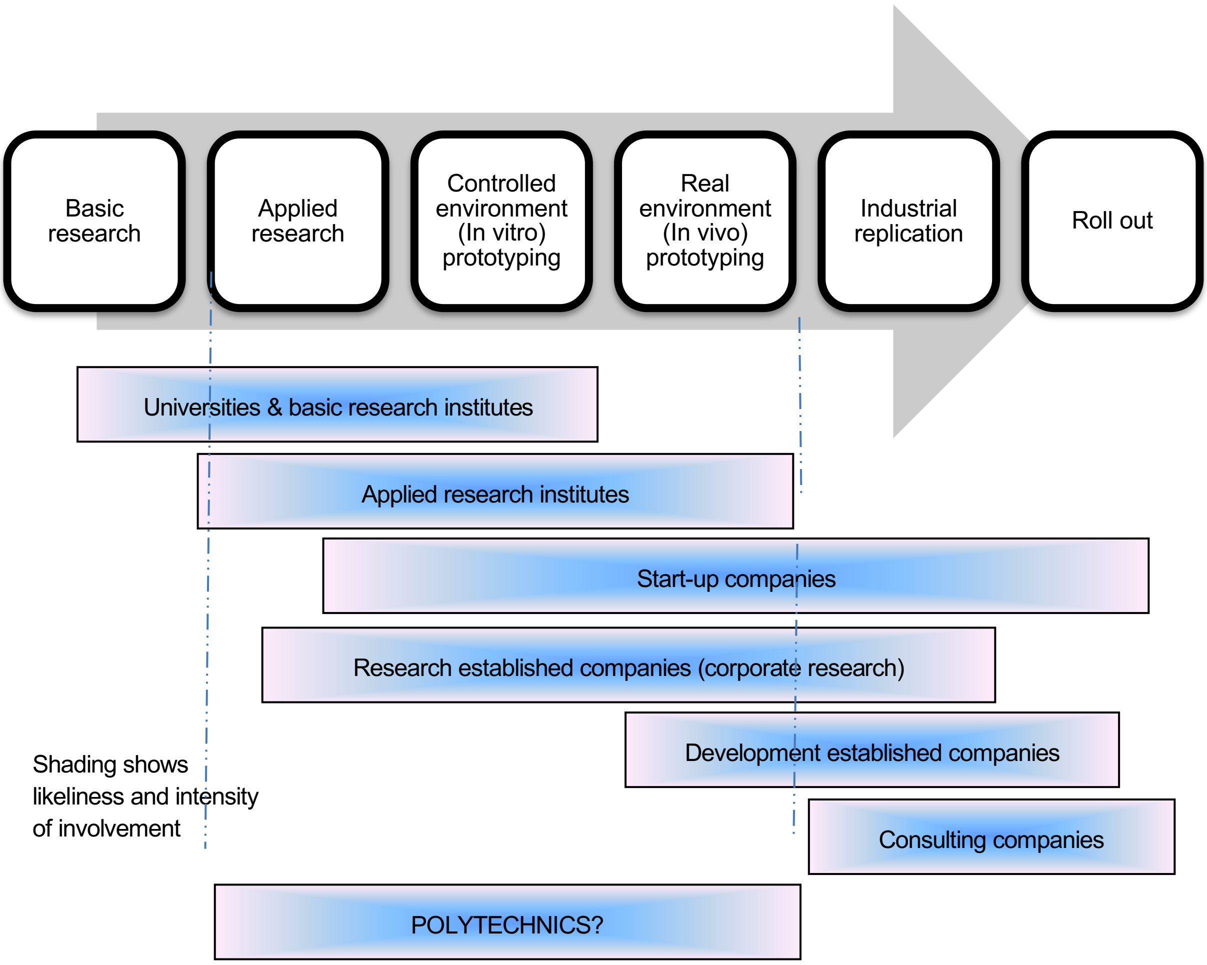



**Figure 1.1 IPTC process and roles played by the different players in the ecosystem. Source: Adapted from Rombach & Achatz 2007, p. 2.**

Interestingly, Wengenroth (2000) critically questions the traditional view of a linear relationship between science, technology and industry (science pushes technology which pushes industry into innovation and entrepreneurship) to argue that their triangular relationship is much more complex and the flow of knowledge is nonlinear, which can be observed from the beginning of the Industrial Revolution, noting:

> *What was technologically new about mid-nineteenth century industry was not dominant. The organisation of labour and space, information about markets, and a new entrepreneurial spirit seem to have been among the more prominent concerns of most new industrialists. Such issues as how to design a factory or where more labour was to be employed in order to move things around rather*

> *than to operate machines were probably the greatest challenges to be met until well into the twentieth century. (p. 4)*

Often, the hypothesis that industry translates technology from scientific discovery is disputed by evidence that some machine tools or inventions were mainly developed based on empirical data rather than mathematics and theoretical mechanics (Wengenroth 2000). Reverse knowledge transfer was observed in Germany, where institutes of technology kept abreast of technological changes by hiring graduates with prior working knowledge in the industry as faculty members (Konig 1996).

**Modern technology transfer.** Technology transfer, the movement of technological and technology-related organisational knowhow among partners (individuals, institutions and enterprises) throughout the entire innovation process, aims to strengthen at least one partner's knowledge, expertise and competitive position (Abramson, Encarnacao & Reid 1997), and usually benefits the knowledge of all stakeholders.

Technology transfer has evolved to occur through a variety of mechanisms, including publications or reports, conferences or informal interactions, staff training or exchanges, contract research or consultancy work, technology licensing or sale, and setting up spin-off companies or joint-labs (Abramson, Encarnacao & Reid 1997; Abreu et al. 2009; D'Este & Patel 2007; Geuna & Muscio 2009; Meyer-Krahmer & Schmoch 1998; Perkmann et al. 2013; Perkmann & Walsh 2007). In the modern era, it was in Germany and America that the establishment of the patent licensing, technology transfer offices, applied research centres, high-tech incubators, and research parks that occurred in the late 1970s demonstrated the nexus between university, industry and innovation (Abramson, Encarnacao & Reid 1997).

The diverse technology or knowledge transfer mechanisms can be categorised broadly as *commercial* or *non-commercial* (Perkmann et al. 2013; Upstill & Symington 2002).

**Commercial and non-commercial (academic) technology transfer mechanisms.** A study of how the Australian Commonwealth Scientific and Industrial Research Organisation (CSIRO) engages with industry shows that technology can be transferred through non-commercial mechanisms, commercial mechanisms, or new company formation (Upstill & Symington 2002). Non-commercial transfer mechanisms involve knowledge transfer via publications or reports, conferences or informal interactions, staff training or exchanges, while the commercial transfer is legally bounded by contractual mechanisms, such as contract research or consultancy work, technology licensing or sale.

Perkmann et al. (2013) assert that non-commercial transfer through various academic engagements, although not as widely researched as commercial technology transfer, often opens doors to subsequent commercialisation opportunities either by accident or design. Licensing of IP, a focus of this research, is regarded as the most common IP commercialisation mechanism (Cripps et al. 1999).

*Spin-off companies.* Spin-off companies, as a commercial technology transfer mechanism, occur in one of three ways:

- direct spin-off involving university background IP and former university staff
- indirect spin-off involving only former university staff
- technology transfer company that involves only background IP
  (Upstill & Symington 2002).

Vohora, Wright and Lockett (2004) note that the achievement of returns and financial profitability is challenging when spinning off new companies. One way to create economic benefit is through a four-stage university spin-off, whereby a viable business concept is developed that is then translated into a business process, creating a firm that adds value for stakeholders and shareholders (Ndonzuau, Pirnay & Surlemont 2002). The product brought to the market by the spin-off may relate to new technology and science, or to new ways of doing familiar things, as long as it can find a niche in the marketplace.

There are other models for start-ups. For example, Vohora, Wright and Lockett (2004) present a refined model of five stages, but the primary consideration must be the business concept or opportunity recognition, without which there is no valuable IP to present to the market.

*Domain-specific technology transfer.* Given the inherent need for different technologies and knowledge in different sections of an economy, technology transfer between universities and industries tends to be sector-specific, resulting in discrete mechanisms of technology/knowledge transfer characteristic of those sectors (Bekkers & Freitas 2008).

Bekkers and Freitas (2008) have found that most biomedical and computer industries prefer to collaborate with universities for knowledge discovery, although larger material and chemical companies often prefer to enter into technology licensing contracts with universities for product development.

**Barriers to technology transfer.** Marsili (2001) points out that new and small companies (start-ups or spin-offs) which lack scale and in-house advantage will encounter high entry barriers to innovations in material and chemical processes. This also holds true with manufacturing firms, especially those that innovate and adopt new technology, or are learners and adapters of technological improvements (Marsili 2001; Pavitt 1984). In contrast, both Marsili (2001) and Pavitt (1984) suggest that small and new companies (start-ups or spin-offs) encounter a lower technology entry barrier in the production technologies of mechanical or instrumentation innovations.

In addition to technological barriers, cultural misunderstanding, unfriendly university organisational and managerial factors (including reward systems, resource allocation, policy, processes and staff competency), have all been identified as barriers to technology transfer in a qualitative study of three types of technology transfer stakeholders – firms/entrepreneurs, TTO directors and university administrators, and university scientists (Siegel et al. (2004). While the relationships of universities and industry vary due to historical and cultural contexts, universities are expected to comply with local rules, governance and constraints when dealing with industry (WIPO 2007), rendering technology transfer research a contextualised field.

Culturally, Singapore has been accustomed to international competition since its independence, and the IHLs have had a culture of interaction with industry through internships, project collaborations, IPTC, adjunct appointments, and consultative committee memberships (WIPO 2007). Generic IPTC barriers identified by WIPO (2007) include conflicting value and risk perception, low IP awareness, increased transaction IPTC costs, limited access to appropriate human resources, and a conservative academic attitude. More details are elaborated in subsection 2.2.5.

**The role of polytechnics.** Polytechnics in Singapore have a unique IPTC context. Based on the researcher's more than two decades of work experience in one of Singapore's polytechnics, it appears that polytechnics hire IP creators with prior industry work experience more often than other institutions. IPTCs, through industry consultancy or commissioned projects, are more established than IP patenting and licensing. Polytechnics tend not to spin-off companies into deep technology start-ups to experiment with early-stage technology, but appear to depend more on established SMEs in their IPTC relationship building. These observations are further discussed in Chapter 4, supported with evidence from this research.

### 1.1.3 Technology and knowledge transfer in the US

In the US, universities have engaged with industry in commercial and non-commercial technology transfer since the 1920s (Mowery 2009), as summarised below:

- From 1927-1946, pharmaceutical and chemical companies tended to locate R&D laboratories in proximity to top research universities to facilitate university-industry collaborations. Similarly, some UK colleges were founded based on strong local industry linkage; for example, the Royal College of Advanced Technology, which became the University of Salford in 1967 (Decter 2009).
- In 1940, about 65% of PhD graduates from the University of Illinois chemistry department were employed in the industry to facilitate knowledge transfer.
- In late 1970, large firms scaled down their central R&D laboratories, embracing open innovation by seeking external IPs through mechanisms such as licensing, acquisition or inter-firm alliances with universities or other firms.

Relevant government policies can increase or alter university-industry interactions. Table 1.1 shows the historical development of technology transfer in the US associated with relevant government policies, culminating in the most recent legislation that reshaped the landscape in the US and beyond. Before the landmark *Bayh-Dole Patent and Trademark Amendments Act* in 1980, inventors had been obligated to assign their inventions to the federal government if their research was government-funded. Since the 1980 act, universities, small businesses or non-profits have been able to retain ownership of their IP (Decter 2009).

Under the *Morrill Land Grant Act* (1862), universities were incentivised to service the community and local industry (Decter 2009; Mowery, Sampat & Ziedonis 2004). Massachusetts Institute of Technology (MIT) was one of the universities founded under the *Morrill Act* (1862), which co-opted industry leaders (AT&T Edison Illuminating Company and

Westinghouse) as members of the university's advisory committee to bridge the university-industry relationship gap (Mowery 2009).

**Table 1.1 Public policy that shaped IPTC behaviour. Derived from (Decter 2009; Mowery 2009).**

| Year (s) | Public Policy | Key policy features | Technology transfer risks mitigation measures | Remarks |
|---|---|---|---|---|
| 1862 | *Morrill Land-Grant Act* | Donation of public lands to build colleges that provide service to the community. | Co-opting industry leaders as an advisory committee. | MIT co-opted industry leaders as members of the advisory committee. |
| 1890 | *Sherman Antitrust Act* | Illegal to price-fix and market-share through monopolies or cartels Limitation on competitor's merger or acquisition (Davis, GF & Adam Cobb 2010) | IP acquisition from external sources Firms mergers | AT&T acquired the 'triode', the first vacuum tube amplifier from independent inventor Lee de Forest. |
| 1980 | Bayh-Dole Patent and Trademark Amendments Act | Uniform public patent policy allowing publicly funded R&D outcomes to be patented and commercialised. | More publicly funded patents are licensed through intensified marketing efforts. | Universities filed less than 250 patents before 1980, but more than 2,000 patents by 2000. |

The 1890 *Sherman Antitrust Act* was essentially a law restricting how two or more parties should conduct trade and was directed at business competition (Davis, GF & Adam Cobb 2010). The Act focuses on licensing and under Section 1 it covers agreements between parties for IP licenses (Saint-Antoine 2011). Section 2 limits the actions of those who own the IP, as it relates to their market presence and how they can affect that market (Saint-Antoine 2011). In the US, licensing is deemed as pro-competitive and looks to maximise the full potential of patents, copyrights and all types of IP. Nevertheless, under Section 1 of the *Sherman Act* (1890), all licenses are reviewed with regards to how any anti-competitive provisions may affect the market (Saint-Antoine 2011).

The *Bayh-Dole Act* (1980) gave license to universities in the US to profiteer from federally funded research activities through patenting or licensing of research to private industry (Andes 2016). The 1980 legislation formed a universal patenting policy that empowered institutions to seek opportunities to generate revenue while retaining ownership of their inventions (Andes 2016). In 2002, the *Economist* referred to it as 'perhaps the most inspired piece of legislation to be enacted in America over the past half-century' (Andes 2016, p. 1). Arguably, considering the value of the *Bayh-Dole Act* (1980) beyond economic terms, the legislation has had far-reaching effects on how governments and universities globally have enacted similar legislation and exploited technology transfer.

The *Bayh-Dole Act* (1980) is regarded as de facto technology transfer legislation in the university technology transfer literature (Sharma, Kumar & Lalande 2006). Before this Act, larger firms in the US had worked with the *Sherman Antitrust Act* (1890) by turning to external IP acquisition to complement in-house R&D capabilities, a departure from closed innovation to an open innovation paradigm (Mowery 2009). The *Bayh-Dole Act* made new knowledge more accessible to businesses, increased the number of patent applications, and led to technology transfer office (TTO) formation (Phan & Siegel 2006) and start-ups in the US (O'shea et al. 2005), contributing positively to economic development and job creation (Sharma, Kumar & Lalande 2006).

While the *Bayh-Dole Act* (1980) directly empowered universities and non-profit organisations, the *Stevenson-Wydler Innovation Act* (1980) targeted federal laboratories intending to transfer technology to industry (Link, Siegel & Van Fleet 2011) via the establishment of Offices of Research and Technology Applications (Kerrigan & Brasco 2002), a TTO equivalent.

While there is consensus that the *Bayh-Dole Act* (1980) intensified the propensity to patent, increasing activity in knowledge generation, translation and transfer were simultaneously given impetus by maturing new research fields, such as molecular biology and microelectronics. However, it is not apparent that the *Bayh-Dole Act* (1980) directly improved the commercial applicability of inventions in new research fields, patented or not (Sharma, Kumar & Lalande 2006).

On a negative note, the *Bayh-Dole Act* (1980) has been blamed for lack of commitment to open science, as university researchers find it useful to intentionally delay disclosure of patentable ideas through publication in order to seek patent protection (Sampat 2006). Furthermore, granting exclusive use of patented ideas to specific firms can limit the diffusion and use of an invention or related knowledge for public benefit, a challenge for IP commercialisation policy (Mowery, Sampat & Ziedonis 2004).

Outside the US, the *Bayh-Dole Act* (1980) has been emulated by many countries (Sampat 2006; Sharma, Kumar & Lalande 2006), including Japan, which incorporated elements of the *Bayh-Dole Act* (1980) into the *Industrial Revitalizing Law of 1999* (WIPO 2007). China and South Africa have similarly passed laws that promote patenting in the publicly funded research sector (Graff 2007). As a relatively young nation, Singapore, too, had enacted the first patent act in 1994, more than a decade after the *Bayh-Dole Act* (1980).

Primarily, technology transfer licensing was established in the US as a way for universities to prevent unauthorised appropriation of university IP by entrepreneurs who were using universities' inventions without royalty payments. The Act virtually created a supplementary source of university funding (Andes 2016; Leydesdorff, Etzkowitz & Kushnir 2016). The emergence of universities capitalising on academic knowledge in the early part of the 20th century created a nexus between innovative academic science and the business sector. It propelled universities from simply registering IP and moved them towards value creation of new products and subsequently, new enterprises (Etzkowitz 2002).

### 1.1.4 The Singapore *Patent Act* (1994)

In Singapore, the Ministry of Law oversees various aspects of IP policy, including patents, trademarks, copyright, registered designs, plant varieties, geographical indications and trade secrets. The Ministry of Law implements IP policy through its agency, the Intellectual Property Office of Singapore (IPOS) (Government of Singapore 2017a). Since 2014, Singapore has been recognised by the World Economic Forum's Global Competitiveness Index as a world leader in terms of designing and managing an IP regime (Government of Singapore 2017a).

The Singapore *Patent Act* (1994, Chapter 221) was first enacted in 1994 and further revised in 2005 to facilitate technology transfer activities. Among other provisions, the Singapore *Patent Act* (1994) defines an employer's rights to own IP created by employees, and a licensee or licensor's responsibilities (WIPO Lex 2017). In addition to the Singapore *Patent Act* (1994), the Ministry of Law, IPOS and related agencies have negotiated a cross-agency National IP

Protocol and Master Research Collaboration Agreement to simplify, standardise and facilitate IPTC by public technology producers in industry (Government of Singapore and IPOS 2017).

In the early 1990s, Singapore started its innovation journey by investing heavily in an innovation ecosystem, which was later augmented by a 10-year IP Hub Master Plan implemented in 2013 (Government of Singapore and IPOS 2017). The Government of Singapore and IPOS (2017)published a report in 2017 on the Master Plan, identifying gaps and making recommendations for growing Singapore's IP expertise, as well as advancing the IP regime or system. In the same report, the development of a more effective IP marketplace to attain better innovation outcomes through more successful IPTC was also canvassed. New initiatives were designed to strengthen existing human resources (IP forecasting and analysis), structural resources (IP and business strategy tools), financial resources (tax incentives, new IP financing model) and relational resources (innovation network).

### 1.1.5 Technology readiness and its impact on technology transfer

Early-stage technologies are the result of fundamental research conducted by research universities or research institutions, and are generally driven by researcher curiosity rather than market needs.

**The readiness level of technology.** Private SMEs are unlikely to transfer these early-stage technologies from universities, leaving such high-risk ventures to be undertaken by university start-ups (Geiger 2006). Technologies are human capabilities to address the whole value chain or life-cycle of innovation, starting from fundamental research, engineering design, functional prototyping, product manufacturing, after-sales support and maintenance (De Wet, G 1995). De Wet's technology space map provided the foundation for technology seekers such as SMEs a viable audit tool to measure their technology readiness and capability to absorb transferred technology. A survey conducted by Thursby and Thursby (2004) found that 40% of firms that licensed university technologies considered the licensed technology to be in the proof-of-concept stage, while 37% felt that they were in the prototyping (lab scale) development stage.

Only a small number (7%) of respondents regarded the technologies available for licensing as ready for practical use.

However, despite the high risk of failure, take-up statistics show that early-stage technologies are desirable. Nevertheless, the top reason that the technology transfer process failed was a failure of the technology (46%), followed by the distance to market (26%), and the reasons for failure are closely associated with early-stage, rather than late-stage, technologies (Thursby & Thursby 2004). According to Geiger (2006), only a handful of ground-breaking biomedical patents have been 'mega winners' for US research universities.

**Costs of improving technology readiness level.** Mankins (1995) argues that a technology costs more to develop as the *technology readiness level* (TRL) increases, starting from low-cost pure research (level 1), finishing at production environment technology prototyping and validation (level 9), with level 8 having the highest cost. Based on a cost-recovery basis, Mankins's cost analysis suggests that an IP with a higher TRL could therefore ask for higher IPTC fees.

Since, traditionally, polytechnics are in the business of producing technology in a more advanced stage of readiness for immediate use, it is interesting to speculate whether a polytechnic's IP could fetch a higher fee than a university for their IP. Realistically, higher IPTC fees may stifle interest among potential stakeholders, leaving the IP un-commercialised. Galbraith, Ehrlich and DeNoble (2006) point out that most early-stage technologies remain scientific knowledge, and most patented technologies remain invention knowledge, not translated into innovation.

### 1.1.6 The complications of the technology transfer process

There are many activities involved in translating an idea into an innovation, and product commercialisation through technology transfer is complicated and demanding (Spivey et al. 2009). Sometimes ideas are transferred through licensing deals arranged with existing companies, and sometimes a new start-up is formed to bring those ideas to the market. A technology transfer process can be divided into two stages, starting with technology protection, then followed by technology commercialisation through mechanisms such as joint R&D,

contract consultancy, technology licensing, technology assignment, and spin-off formation (Kundríková 2015).

Harmon et al. (1997) point out that IP can be transferred through a formal arm’s-length IPTC model, an informal networking IPTC model or a hybrid IPTC model to extend an established firm’s product line, grow a young start-up or launch a new firm. The cost and uncertainty of IP translation mean that IPTC processes often involve multiple organisations to share the risk, and as such are complicated. Acting in the university-industry (U-I) space, and perhaps, a university-industry-government (U-I-G ) space, involves inter-organisational interactions of buyers, sellers, brokers, and others, including the IPs (universities or polytechnics), IP recipients (industries) and government agencies (funders and regulators).

Rogers, Takegami and Yin (2001) have shown that the technology transfer process can be managed by measuring performance in six equally weighted indicators:

- the number of invention disclosures
- the number of patent applications
- the number of technology or IP licenses
- the number of revenue-generating technology or IP licenses
- the number of start-up companies
- the total amount of annual licensing royalties.

In their study, Rogers, Takegami and Yin (2001) ranked MIT and Stanford Universities as the most active research universities in this composite measure of technology transfer effectiveness.

Not all product producers or IP recipients have the required resources to translate early-stage technologies. The technology transfer process can be influenced by the interaction between the firm’s capability and experience (resources), TRL, levels of inter-organisational interaction (Stock & Tatikonda 2008), and legal and funding systems (Mazurkiewicz & Poteralska 2015). On the point of inter-organisational interaction, Bauer and Flagg (2010) confirm that technology transfer activities are supported by multiple stakeholders, including resource providers who provide supporting resources to IP producers, IP recipients, product producers, and product consumers.

Recognising the need to satisfy the needs of multiple stakeholders, Bozeman, Rimes and Youtie (2014) proposed a Contingent Effectiveness Model of Technology Transfer that introduced seven effectiveness criteria:

- Out-the-door
  (Was technology transferred?)
- Market impact
  (Did the transferred technology have an impact on the firm's sales or profitability?)
- Economic development
  (Did technology transfer efforts lead to regional economic development?)
- Political
  (Did the technology agent or recipient benefit politically from participation in technology transfer?)
- Opportunity cost
  (What was the impact of technology transfer on alternative uses of the resources?)
- Scientific and technical human capital
  (Did technology transfer activity lead to an increment in capacity to perform and use research?)
- Public value
  (Did technology transfer enhance collective good and broad, societally shared values?)

### 1.1.7 Polytechnics as IP producers

In the context of Singapore's IP exchange, the overarching IPTC problem is how to encourage more SMEs to look beyond the traditional IP producers (universities or research institutes [RIs]) and explore with polytechnics the transfer and commercialisation of a broader range of IP. Any innovative ideas, involving an early-stage technology or not, ought to be developed and translated nearer to being a production prototype to mitigate the risks of IPTC failures.

Polytechnics, equipped with applied R&D capabilities, seem to match the profile of technology translators that can apply and aggregate today's knowledge and technologies into prototypes.

The research reported in this thesis reviewed public resources and explored some unique experiences of firm technology transfer managers in Singapore for insights into this complex IPTC process. There is evidence to support the notion that a polytechnic can be a technology translator.

**The history of polytechnics.** Non-university institutions, including institutes of technology and polytechnics, were established to meet the needs of relevant, skilled hands-on workers, artisans, or industrialists to the workplace. The establishment of the world's first institutes of technology were precursors to polytechnics, with the Berg-Scola in Hungary formed in 1735 (Danube Universities 2013). In the 1820s, Germany specifically created trade or polytechnic types of schools, later (beginning in the 1870s), rebranding them as institutes of technology, which coincided with German industrialisation (Wengenroth 2000).

Similarly, in the UK, the University of Bradford evolved from the Mechanics Institute, founded in the early 1830s (Rüegg & Ridder-Symoens 2010; University of Bradford 2017). The growth of these institutions reflected not only the advancement of technical sciences but paralleled the industrial revolution in European countries in the 19th century, where skills, empirical and technological knowledge were transferred to artisans, engineers and industrialists (Rüegg & Ridder-Symoens 2010; Wengenroth 2000).

The term *polytechnic* was first adopted in Britain upon the establishment of The Polytechnic Institution in 1838, which aimed to promote science and showcase new technologies and inventions to the public (University of Westminster 2017). The Polytechnic Institution was re-named Regent Street Polytechnic in 1891, and then Polytechnic of Central London in 1970, and finally the University of Westminster in 1992. In the early 1840s in the US, the European concept of 'polytechnic institute' was first explored by William Barton Rogers, a professor of geology at the University of Virginia, and later incorporated into the establishment of the Massachusetts Institute of Technology (MIT) (Etzkowitz 2002, p. 31).

Rapid industrialisation forced many European governments to develop the non-university sector to narrow the institution-industry knowledge gap, while leaving the university sector to pursue academic excellence independently in the 1960s and early 1970s (Rüegg & Ridder-Symoens 2010). The English polytechnics, French Instituts Universitaires de Technologie and

German Fachhochschulen are examples of prominent non-university institutions (Rüegg & Ridder-Symoens 2010).  Unlike the polytechnics in Singapore that do not award Bachelor's degrees; English polytechnics, French Instituts Universitaires de Technologie, and German Fachhochschule do award academic Bachelor's and Master's degrees

These institutions began by complementing universities to transfer applied knowledge in areas such as engineering, technology or business, pitched at diploma or first-degree levels. Many of these qualifications were deemed to be terminal degrees, closing opportunities to subsequent academic research. Over time, however, certain non-university institutions showed signs of increased involvement in academic research by distancing themselves from industry, while certain universities showed signs of drifting toward vocational knowledge transfer. The blurring of the institutional divide was evidenced by the fact that British polytechnics were incorporated as universities in 1992 (Rüegg & Ridder-Symoens 2010).

**Polytechnics in Singapore.** The first publicly funded technical and vocational education sector institution, or polytechnic, in Singapore was established in 1954. Singapore Polytechnic or SP was founded as part of the rebuilding of Singapore after World War II following the departure of British expats, a significant 'brain drain' that meant Singapore needed to establish quality training for Singaporean youth (Chua 2002; Varaprasad 2016). Upon Singapore's independence in 1965, there were two polytechnics, with Ngee Ann Polytechnic (NP) having been established in 1963. During the last three decades, three more polytechnics have been established – Temasek Polytechnic (TP) in 1990, Nanyang Polytechnic (NYP) in 1992, and most recently, the Republic Polytechnic (RP) in 2002 (Varaprasad 2016).

Singapore's approach from 1965 and through the 1970s was to attract foreign multinational corporations (MNC) and support rapid industrialisation in the manufacturing sector, assisted by strong industry ties to education and the polytechnics (Lee, SK et al. 2008). Singapore polytechnic education became part of the non-university education sector, providing highly trained and skilled staff at diploma, advanced diploma or specialist diploma level, and supporting the ethos of value-added manufacturing and services for export (Lee, SK et al. 2008).

This resulted in significant growth in the number of students attending these institutions. In 1965, 3208 students attended the two polytechnics, and by 2005, four decades later, there were 64,422 students enrolled in five polytechnics (Goh & Gopinathan 2008). Paralleling the significant increase in student enrolments over the past 50 years, budgets for polytechnics have increased from S$2,400,000 to S$624,794,000, which not only reflects student growth but also government commitment to developing curricula that are industry-focused and prepare students for employment (Ng 2008).

The polytechnics capture about 40% of General Certificate of Education Ordinary level secondary school graduates and matriculate them into a variety of diploma, specialist diploma and skill upgrading courses (Haas 1999). Further, polytechnic graduates are accepted by both local and overseas universities with significant advanced standing.

Besides providing high-quality specialist technical education, polytechnics work closely with industry, as well as Singaporean economic planners and development agencies, to plan new programs required to meet market-driven demand for specialised subjects (Chan 2008). One polytechnic, NYP, established a particular niche through its pedagogy, developing a 'teaching factory', where an actual work environment was closely adopted in its laboratories. The term 'teaching factory' was coined by Lin Cheng Ton, the founding principal of NYP (Lin, CT 2002). According to Varaprasad (2016), the "teaching factory" concept offers the following:

- real-life challenges and projects proposed by industry partners were undertaken by NYP staff and students to meet the realistic training purposes.
- NYP charged the industry partner a market rate as any other vendor would.
- NYP signed project contracts under real-world commercial terms to deliver the agreed performance quality and milestones.
- completed projects were deployed in company operations

Arguably, Singapore's industrialisation was built on polytechnic education, since the polytechnics provided the technologists and mid-level managers required in engineering and other sectors that propelled emerging industries (Lee, SK et al. 2008). The symbiosis of industry and polytechnics has benefitted Singapore's economy and highlighted the value of knowledge transfer through human capital development, which has driven industrialisation in Singapore for over 60 years.

**IP transfer and commercialisation (IPTC) is an emerging phenomenon of polytechnic education in Singapore**. Like other public IP producers, polytechnics in Singapore protect and commercialise their IP to solve real-world problems through the provision of assistive devices and games, technology applications and health products (Teng 2016). In a newspaper article, Teng (2016) examines past polytechnic IPTC activities based on data received from all five Singaporean polytechnics. Table 1.2 collates cross-polytechnic IPTC performance over the 15 years since 2003. The difference in annualised performance in IP licensing and patenting suggests that not every polytechnic is equally active in encouraging such efforts. While other polytechnics are cautious in considering IP licensing and patenting as an industry outreach effort, NYP has forged ahead in embracing such industry outreach strategy.

Despite varying IPTC intensity, Teng's (2016) report suggests that there is increasing industry interest in IP generated by the polytechnic sector. His report is silent about the number of patents licensed for SP. However, of the amount of IP licensed for both NYP and TP, it is clear that many patents filed were not commercialised. The reduced commercialisation rate raises questions about the value of a polytechnic patent, as it seems to contradict the 2014 Creativity Productivity Index finding that patenting research outcomes will incentivise both universities and businesses to commercialise patent (The Economist Intelligence Unit Ltd & Asian Development Bank 2014). Since obtaining a patent will undoubtedly add cost to the recovery of IPTC fees, to patent or not to patent polytechnic IP is another intriguing question pursued by this research.

**Table 1.2 Polytechnic IPTC performance data. Derived from Teng 2016.**

| | | NYP | NP | RP | TP | SP |
|---|---|---|---|---|---|---|
| Licensing | Data period | 2009-2016 | 2010-2015 | 2009-2014 | 2005-2014 | Data not available |
| | No of licensing deals | 60 | 12 | 10 | 9 | |
| | Number of data years | 8 | 6 | 6 | 10 | |
| | Ave. licensing deals/year | 7.5 | 2 | 1.7 | 1 | |
| Patenting | Data period | 2007-2016 | 2001-2015 | 2003-2016 | 2005-2014 | 2010-2015 |
| | Number of patents filed | 160 | 8 patents granted | 7 | 91 | 23 |
| | Number of data years | 10 | | 14 | 10 | 6 |
| | Ave. patents filed/year | 16 | | 0.5 | 9.1 | 3.8 |

Documentary evidence, therefore, shows growing interest from SMEs in seeking commercially applicable technology from polytechnics (Chew, C 2009; Teng 2016; Wy-Cin 2009). However, literature and data about polytechnics' contribution to Singapore's research, innovation, and enterprise (RIE) landscape are limited, and research regarding the relationships between polytechnics and SMEs is virtually non-existent, further emphasising the need for this exploratory study.

### 1.1.8 Personal experiences in intellectual property transfer and commercialisation

Personal experience with two licensed IP creations arising from 15 years of teaching and undertaking applied R&D in a polytechnic engineering department was a knowledge resource the researcher brought to this research. The two IP licensing deals were marketed and negotiated independently by two different IP transfer and commercialisation (IPTC) managers, without the researcher's direct involvement. While this experience means that the researcher's perceptions of the context and data could be biased or coloured by historical experiences, it is also true that these perceptions have been richer and more profound than those of someone who was not familiar with the context of the case study.

**Direct observations in IP licensing.** In 2008, the researcher became interested in this research topic after being transferred from an IP creation and development department to a newly established TTO at a Singapore polytechnic. As a manager in the TTO, the researcher conducts due diligence on patent protection and maintenance and assists in fund management to empower the polytechnic community to innovate. IP capturing and protection, however, are outside the boundary of this case study research.

From 2012 to 2015, the researcher was a secretariat member to support the Ministry of Education (MOE), Technology-Innovation-Enterprise Management Committee that sets funding policies and tracks performance for polytechnics in terms of research, technology transfer, innovation and enterprise education programs. The researcher's role in the TTO provided various opportunities to interact with technology licensing colleagues, and colleagues with similar roles from other polytechnics. Through such interactions, the researcher noted the following:

- SMEs understand market wants and needs.
- SMEs seek market-ready prototypes to reduce scaling-up costs.
- Polytechnics could offer solutions and prototypes based on contemporary technology and knowledge. According to Rothwell and Gardiner (1985), an idea can be developed nearer to the marketable product through several prototype models designed to test the functionality, aesthetic design, and scalability
- As a non-commercial entity, polytechnics are dependent on SMEs to bring ideas to the marketplace.
- Government agencies are helping SMEs to commercialise IP, either through tax incentives or various grants, to maintain and increase the nation's innovation outputs.

Before the researcher's appointment in the TTO, he served as a faculty member at an engineering school where he was responsible for automation development projects. One of these projects was awarded a silver medal at the Tan Kah Kee's Young Inventors' Awards in 1992 (Singapore Chinese Chamber of Commerce & Industry 1992, p. 64). On the webpage, Professor Phua Kok Khoo, Chairman of the Inventors' Award Committee, described the award:

> *Launched in 1986, the Tan Kah Kee Young Inventors' Award is perhaps the first annual award given for creativity and innovation in Singapore. It was initiated by Nobel Laureate, Professor C N Yang, who proposed having this Young Inventors' Award for the purpose of encouraging students and young people to be more involved in creativity and invention. They should not just try to achieve good results in their school examinations.*
>
> *We believe that the Award has effectively contributed to the development of an innovative and inventive culture in Singapore. It is an excellent platform for young people to showcase their thinking skills and to gain first-hand experience in applying*

*principles of science and technology to real-life problems. We are pleased that the Award is now quite established and the competition has been gaining much momentum with increasing number of projects submitted each year.*

*Besides the student section and open section, a new category of the Award - Defense Science Award was established in 2001. This marked our first collaboration with the Defense Science & Technology Agency, apart from the Agency for Science, Technology & Research (A*STAR) who has been our co-organizer since 1995. (Tan Kah Kee Foundation 2016)*

Such an inventor award validates the idea that a polytechnic invention has value. Together with a team of staff members, the researcher initiated an inventor development program in the polytechnic in 1993. Over many years, the program has prepared several student and staff inventors. Commercially desirable ideas from this invention pool have been patented, but only a handful have been licensed to SMEs. The challenge faced by IP licensors in transferring inventive ideas recognised at a national level into practical outcomes aroused the researcher's curiosity and encouraged him to better understand IPTC in SMEs, and why technology transfer was not more frequent or effective.

The researcher's indirect involvement in two IP licensing experiences further spurred on investigations. Firstly, in 2005, the researcher's first jointly patented technology (US5771553), a robotic quick fixture affixing system, was licensed to an American company, Intellectual Venture (Ang 2006). Secondly, in 2013, the researcher's most recent jointly patented technology (US8186701), a wheelchair rider transfer system, was licensed to Lifeline Corporation, Singapore (Chia 2014). The first licensing case was transferred with ease, where the American company came looking for the patent independently. In contrast, the recent licensing deal was achieved through the marketing efforts of technology licensing colleagues in the TTO. These experiences reinforce the fact that technology licensing to an SME is different for every product or process, as well as for the individual SME.

**Naked patent license.** The first licensing experience with the American company was a pure *naked patent licensing transaction*. A naked patent license involves only the patent with no associated knowhow (Davis, JL & Harrison 2002). In this case, the licensee, which was a leading IP intermediary in the US (Hagiu, Yoffie & Wagonfeld 2009), saw the value of the patent and decided to take the patent-only license without requesting post-licensing support.

Naked IP licensing fits the out-the-door IPTC concept, whereby the IP is considered successfully transferred when the IP has been simply acquired, or moved out-the-door, regardless of its later commercial success (Bozeman, Rimes & Youtie 2014).

A search using *Patsnap*, a subscription-based online patent search tool (*Patsnap* 2016), returned a fair market valuation of the first US patent (the fixturing patent) at US$30,000. *Patsnap* argues that this fair market valuation methodology is in compliance with a stringent quality assurance system, and is one of the most reliable and tested approaches for establishing fair market evaluation.

The underlying valuation algorithm considered a total of 25 parameters, including the patent's assignee, market attractiveness, claims, technical quality, legal status and history. A similar search was performed on the second patent (the wheelchair patent), and *Patsnap* returned a fair market value of US$260,000.

The patented wheelchair innovation was marketed in the US and was subjected to the scrutiny of the US Food and Drug Administration, and its value has been recognised by the following awards (Winner SG PTE LTD 2018):

- top innovation award in the 14th Australian Association for the Manual Handling of People Conference 2014
- second place in the Tech Challenge Award 2018, Global Conference on Integrated Care 2018
- award finalists in WIPO-IPOS IP Awards 2016 and Ageing Asia Best Innovation Award 2017.

Additionally, the product was further recognised by SilverEco & Ageing Well International 2018 (ONMEDIO 2018) and the Patent for Good Award 2018 (Chew, C 2018; Kan 2018).

**Dressed patent.** The initial IP licensing experience with a local SME involved more than a patent. The patent was bundled with associated knowhow, a *non-naked patent* or *dressed patent*.

Besides the licensed patent and knowhow, this local SME licensee requested the licensor's participation in the following scaling up activities:

- US Food and Drug Administration regulatory approval
- trade exhibitions
- award competitions
- knowhow transfer and production prototyping discussions with factory managers.

As non-product producers, most universities and polytechnics prefer naked patent licensing where the key goal is to transfer the IP from institutions to enhance revenue generated, while few are eager to enforce IP rights in court (Rooksby 2012). Furthermore, IP commercialisation success factors and required resources are beyond the control of polytechnics. The performance of a polytechnic in securing public research funding is usually measured by its capability to generate some straightforward key performance indicators (KPIs) such as number of IP filed or licensed products. It is therefore understandable that polytechnics avoid embroiling themselves with post-licensing support which may interfere with their core teaching and research activity.

In the wheelchair patent licensing case, the polytechnic selectively allowed partial participation in requested post-licensing activities. The rationale for support was that a closer polytechnic-industry relationship is essential to knowledge co-creation, where lessons learnt can be translated into training materials for future entrepreneurial students. In this case, the polytechnic regarded investment in IPTC activities as sunk costs, that is, costs that have already been incurred and cannot be recovered, for staff or student development.

In a situation such as this, where a SME seeks a dressed patent license for IP from a polytechnic, and the organisations enter into IPTC, the question to be asked is whether the cooperation of the two organisations will increase the polytechnic's capacity to perform and use newfound IP commercialisation knowledge. Inherent in Polytechnic-SME cooperation is the danger that the polytechnic will not look beyond the economic or social benefits of IPTC licensing to explore further innovation, because they are challenged by the resource tension engendered by simultaneous teaching, research and commercialisation activities.

A naked-IP licensing approach for both patent and non-patent IP has the effect of distancing the polytechnic from the SME. This reduces the resource tensions but could force SMEs to source IP elsewhere where greater cooperation can be provided. Table 1.3 summarises the features of the two licensing cases discussed. This background provided the stimulus to examine the polytechnic and SME IPTC relationship using Singapore as a case study.

**Table 1.3 Features of the two example licensing cases**

| | US company | Singaporean company |
|---|---|---|
| Licensing transaction | Patent-only | Patent plus knowhow |
| Patent filed date | Oct 3, 1996 | May 6, 2008 |
| Time to the licensing deal (Years) | 9 | 5 |
| Licensing term (years) | 11 | 10 |
| Post-licensing supports | Nil | Yes |
| Due diligence on IP rights | Independently done | Dependent on third party supports |
| Did the IPTC activity allow the polytechnic to increase its capacity to perform and use IP commercialisation knowledge? | Knowledge gained is limited to pre-licensing negotiations of a mutually agreeable licensing contract or a 'naked' patent license. The patent was acquired, moved out of the polytechnic door without further knowhow transfer from the polytechnic. | Unique insights and experiences gained into the full spectrum of IPTC activities provide richer content for student and staff training. |

## 1.2 Research goals

The research reported in this thesis was undertaken to provide insights into the features that characterise IP transfer and commercialisation (IPTC) and make recommendations on how to improve polytechnic-SME engagement in IPTC. In the thesis, IPTC is used as a generic term for activities undertaken to transfer and commercialise all possible forms of IP (not limited to patented technology).

The phrase technology transfer (TT) is commonly used in literature as a universal term to describe both commercial (consultancies, contract research work, licensing and spin-off companies) and non-commercial (quality graduates, education programs, and conferences) transfer of technology from university to industry (Cripps et al. 1999; Rogers, Takegami & Yin 2001). However, in this research context, the word *IP* is used to replace *technology* to emphasise a range of intellectual works (copyrighted materials, designs, recipes, patented and non-patented technology) that an SME can transfer from polytechnics for commercialisation purposes. Whenever possible, the researcher will still retain the word 'technology transfer or

TT' found in cited articles; hence, the phrases TT and IPTC are used interchangeably in this thesis.

## 1.3 Research questions

The general research question (RQ) that guided the research was:

RQ: How do human and structural resources contribute to or impede the intellectual property transfer and commercialisation (IPTC) process in the Singapore polytechnic context?

The RQ was augmented by the following two subsidiary questions (SQ).

SQ1(a&b) was directed at describing the roles and characteristics of IPTC stakeholders and the relevant resources and capabilities, thereby identifying specific influencing factors that could be understood as essential to SMEs as IP recipients and polytechnics as IP translators:

SQ1a) What are the current features of Singapore, SMEs and polytechnics that characterise their development and translation of IP?

SQ1b) What features relating to the development and translation of IP are shared by polytechnics and universities, and what features are not?

In addition, SQ2(a&b) attempted to explore SME managers' perspectives, views, experiences and/or meanings when negotiating the commercialisation of IP, the characteristics of the IPTC process they consider desirable, and the resources and capabilities they look for in the process.

SQ2a) What are the outstanding characteristics of the IPTC negotiations/knowledge transfer/licensing processes involving an SME and a polytechnic?

SQ2b) What type of resources and capabilities are valued and transferred from polytechnics to SMEs by the relevant stakeholders and vice versa?

Using the answers and insights provided, one of the goals of the research was to prepare guidelines to support the management of IPTC from the polytechnics to SMEs, and to develop a new theoretical model for IPTC at the applied R&D level.

## 1.4 Theoretical framework

Contingent on SME needs, a technology transferred out-the-door from a polytechnic could be managed by controlling dependencies on resource and relationship exchanges with the environment, polytechnics included. The theoretical framework of this research was based on Pfeffer and Salancik's *resource dependence theory* (RDT), which focuses on inter-organisational relationship exchanges to reduce resource dependencies in the environment (Pfeffer & Salancik 1978). RDT can be supported by the *resource-based view* (RBV) that looks internally within the organisation for existing strategic resources (Barney 1991) that could be marshalled to avoid resource dependency, which can hamper an organisation's autonomy and strategic decision making. Both the RDT and the RBV are concerned with a business's physical and personal resources, including IP. These resources are, in turn, influenced by the dynamic capabilities (DC) and appropriability regimes (AR) that either agilely manage the resources and operations of the firm (Teece, Pisano & Shuen 1997), or are able to protect those resources by excluding imitation (Teece 1986), leading to competitive advantage (Porter 1985b).

The case research undertaken explored the experiences and perceptions of technology transfer managers in SMEs in order to identify ways in which the engagement of polytechnics with SMEs in IPTC occurs, and how their interactions could be improved.

## 1.5 Overview of research design and methods

The research described in this thesis was qualitative, employing methods such as documentary research and thematic analysis of interview data to develop theory. The conceptual framework is located within the interpretivist paradigm, where data are analysed through experiential qualitative research, emphasising what had been written in primary, as well as secondary documents, or said during the research process (Braun & Clarke 2014).

Based on the fact that the polytechnic sector in Singapore is considered to be a collective group (a sector), and prior research data on IPTC between polytechnics and SMEs are lacking, a single revelatory case design was considered justified for this project (Yin 2003).

The investigation of *SQ1(a&b)* took the form of the collection and analysis of data drawn from publicly available sources, such as documents, records, websites, and literature. Analysis and interpretation of relevant documentary sources resulted in a better understanding of what environmental factors influence IPTC between SMEs and polytechnics in Singapore.

To address *SQ2(a&b),* data in the form of responses to semi-structured interviews were collected from 13 SME case interviews. These SME managers were invited to participate in this research because of their prior experience in attempting to commercialise IP acquired from the polytechnic sector. The interview data analysis was guided by *thematic analysis* (TA), in which patterns in the data are sought, recorded and interpreted, as advocated by Braun and Clarke (2014). The analysis was supported by computer-aided qualitative analysis software, *Atlas.ti*.

## 1.6 Other academic activity during candidature

During the early phase of the candidature, the researcher conducted preliminary research involving five SME managers; the findings were discussed in a conference in 2014 (Sim & O'Connor 2014). After that, the researcher expanded the interviews with an additional eight SME managers. The aggregated findings are discussed in Chapter 4 and 5.

## 1.7 Significance of the research

The contribution of this research is the insight it provides for practising managers in SMEs and polytechnics into relevant processes, resources or guidelines that could improve polytechnic–SME engagement in IPTC. Understanding the resource and relationship exchanges that support the process of IPTC is important since polytechnics are significant public technology translators and consumers. In addition to producing commercially applicable technology and solutions, polytechnics acquire or consume the latest industry or laboratory software and hardware to develop staff competencies (Varaprasad 2016) relevant to IPTC. This research reaffirms the resource dependency theory by adding information about resource and relationship exchanges during the process of IPTC between polytechnics and SMEs

## 1.8 Demarcation and assumptions

One of the features of case study research is the bounding or demarcation of the study area (May & Perry 2011). This section highlights the demarcation of the study area, the assumptions made when conducting the research and analysis, and the limitations of the study.

**Demarcation**. This research investigated polytechnic-SME IPTC processes centred on inter-organisational IP marketing, licensing negotiation and deal-making processes, not other IPTC mechanisms, such intra-organisational IP capturing and protection processes as stated by Bradley, Hayter and Link (2013).

This demarcation was made because the research focuses on resources, roles and relationship exchanges between SME IP recipients (who is also product producers) and polytechnic IP translators, excluding other SME intra- and/or inter-organisational processes. This demarcation was based on the fact that a polytechnic that is a non-product producer would usually consider an IP successfully transferred and commercialised when an SME took an IP licence to develop further and produce new products, processes, services or experiences.

**Assumption.** The recruitment of interview participants was largely achieved through recommendations of different polytechnic technology transfer offices. The assumptions that support this research were that participants were willing to share IPTC personal experience, regardless of the commercial outcome of IP licensing deals. It was expected that the participants had made or could make direct contributions to the decision making process before a licensing deal was signed, and intended to take an IP licence from a polytechnic for commercial purposes. Regarding documentary research on polytechnic innovation characteristics, the five polytechnics were regarded as one sector funded under the MOE.

**Limitation.** As a single case with a clear demarcation of the research boundary, the researcher could only focus on specifically selected IPTC processes when seeking a deep understanding of relevant activities, hence the particularisation of theory development, not generalisation (May & Perry 2011). One case represents the behaviours of only a single member of a broad population of cases. Therefore, generalisation can only encompass similar cases, not the entire array (Stake 1978).

## 1.9 Research contribution

It is anticipated that the results of this research will help Singaporean companies to better understand IP in order to leverage IP as a go-to-market strategy. Using IP as a business strategy is not restricted to high technology start-ups or multinationals with abundant internal resources, and many SMEs could benefit from embracing innovative IP (Yahya 2017). Mr Daren Tang, the chief executive of IPOS, when interviewed by Yahya (2017), suggested that Singapore had established itself in the R&D ecosystem and IP regime in Asia, but required reinforcement in IPTC, as follows:

> *Singapore has done well in the top half of this cycle - we have built an excellent R&D ecosystem in the last 20 years, and we are the top-ranked IP regime in Asia but what we need to focus on going ahead is the latter part of the cycle, dealing with IP commercialisation. How do we translate all this IP into things that can go out to the market and create companies, create jobs and drive the economy? (p.2)*

In a cover story featuring some National University of Singapore (NUS) alumni-entrepreneurs, Professor Ho Teck Hua, Deputy President of NUS's Research and Technology was featured. According to Professor Ho, there are three pathways to follow for IP commercialisation for NUS (Tan, W 2017):

- curiosity-driven pathway
  Researchers create intellectually stimulating IP without prior industry validation.
- industry-driven pathway
  Researchers collaborate with companies to create IP to address industry defined

problems. Examples of industry collaborators cited are large local enterprises (LLEs), such as SemCorp, Keppel and Singtel.

- grand challenge pathway
  Researchers create radical and nontrivial discovery as IP that is high in both intellectual value (very difficult) and translational value (useful for a lot of people).

Of the three pathways, Professor Ho highlighted the fact that NUS will endeavour to increase the pool of efficient and internationally renowned IP creators who could bring radical and nontrivial IPs into the marketplace (Tan, W 2017):

> *My aim is to get more academic researchers to embark on their own grand challenges.*
>
> *NUS used to be a primarily a teaching university, with modest research capabilities. However, in the last 25 years, NUS has revamped up its research productivity.*
>
> *By developing a culture of excellence, we hope to attract and nurture more 'superstars' - researchers with big ideas and international stature - and maybe one of them will become a Nobel Prize winner. (Tan, W 2017, pp. 10-11)*

While NUS focuses on radical discoveries and attracting 'superstar' IP creators, the research for this thesis sought to add to the knowledge base by exploring a space where polytechnics could contribute to SMEs in commercialisation or incremental IP. Investigating IPTC partnerships between polytechnics and SMEs would help the researcher explore ways to help local companies create home-grown products, a process which is currently lacking. Companies that are better resourced, such as MNCs and LLCs, do not depend on polytechnic resources for IP commercialisation.

## 1.10 Research limitations

In this exploratory study, identified IPTC processes and their management guidelines have limited generalisability. However, the findings and conclusions are transferrable to similar cases in other contexts. To improve validity, the researcher compared continuously empirical evidence to evidence from the interview data (Yin 2003).

Only SMEs with prior IPTC experience with polytechnics were invited to explore their experiences and perceptions, and the sample was limited, hence not representative of a general population. According to Teng (2016), three of four polytechnics had delivered not more than two IP licensing deals per year since 2005, which is evidence of a potentially 'developing' phenomenon. The potential for increased IPTC opportunities motivated the researcher to investigate how to better facilitate a bilateral flow of innovative ideas between a polytechnic and SME.

## 1.11 Thesis organisation

This research study explored the experiences and perceptions of managers from 13 SMEs regarding IPTC resource and relationship exchanges to support the process of IPTC in polytechnics in Singapore. The thesis consists of six chapters. **Chapter 1** presents an overview of the research context, states the research problem, and highlights the research question, design, limitations and theoretical framework. **Chapter 2** reviews areas of the literature to support this exploratory study of SME managers' experiences and perceptions on IPTC from polytechnics. **Chapter 3** discusses the research methodology employed. While **Chapter 4** discusses *Case study subunit 1* (the contextual evidence), **Chapter 5** discusses *Case study subunit 2*, the thematic analysis of the data from the in-depth interviews. **Chapter 6** highlights noteworthy findings and presents their implications in relation to thesis objectives and research questions, which is followed by the conclusion and recommendations.

## 1.12 Ethical approval

This research involved information collection through interviews, review of prototypes, public video archives and documents. Regardless of the chosen information collection method, ethical considerations applied. For face-to-face interviews, prior approval from the University of Adelaide Human Research Ethics Committee was obtained on 22 November 2012. The approved project number is H2012-141 (see Appendix 1).

Each suitable participant was first invited to participate in the study either by phone or email. Upon receiving a positive response, the researcher followed up with a formal e-invite embedded with an information pack (participant information sheet, interview protocol, consent form, independent complaint protocol) for the participant's advance knowledge. All participants were required to sign the consent form before the interview began. They were assured of their voluntary participation and informed of their rights to end or withdraw at any time during or after the interview. Numeric codes replaced names when the narratives were recorded to preserve participant anonymity.

## 1.13 Summary

This chapter has introduced the historical background of IPTC, IP regulations, and polytechnics. In addition to working definitions of IPTC, this chapter has provided the personal stimulus for undertaking this research by connecting to intriguing observations gathered while on the IP protection and development job in one of the polytechnics. The chapter has also presented an overview of the research purpose; the problems identified, the research question, the research design with its associated limitations and theoretical framework.

Chapter 2

# Literature review

This chapter reviews literature relevant to this exploratory study of the experiences and perceptions of SME managers regarding resource exchanges and relationships with polytechnics in Singapore. This chapter is organised into the following themes:

1. *Higher Education IPTC processes*

   A literature review on what characterises IPTC in tertiary institutions, such as universities and polytechnics, examining several relevant theories related to IP and other resources necessary to an organisation's competitive success.

2. *Higher Education IPTC ecosystem*

   A literature review of the roles played by the IPTC ecosystem within the tertiary sector, including human, structural and relational assets to guide the development of a case study examining the polytechnic-SME IPTC environment in Singapore.

3. *Competitive strategies with reference to higher education IPTC partnership*

   A literature review on related organisational theories from the perspectives of resources, capabilities and competitive forces for the development of theory, and an explanation of how and why SMEs and polytechnics value those assets to attain their competitive advantages.

In this exploratory research, the researcher approached the review of existing literature in two iterative phases: started with a broad review of relevant concepts and issues and followed by a refinement phase whereby new concepts and issues are added to connect literature to results discussed in Chapter 6. Figure 2.1 shows the literature review framework in which the following three key literature streams were consulted, summarised and synthesised:

- higher education IPTC processes for demarcation of the case research boundaries
- higher education IPTC ecosystem for the development of the descriptive case on SME-polytechnic IPTC environment, and
- competitive strategies regarding IPTC for development of theory and the explanatory case on why and how SME values resources and capabilities to attain the competitive advantage.

Figure 2.1 shows the literature framework graphically.

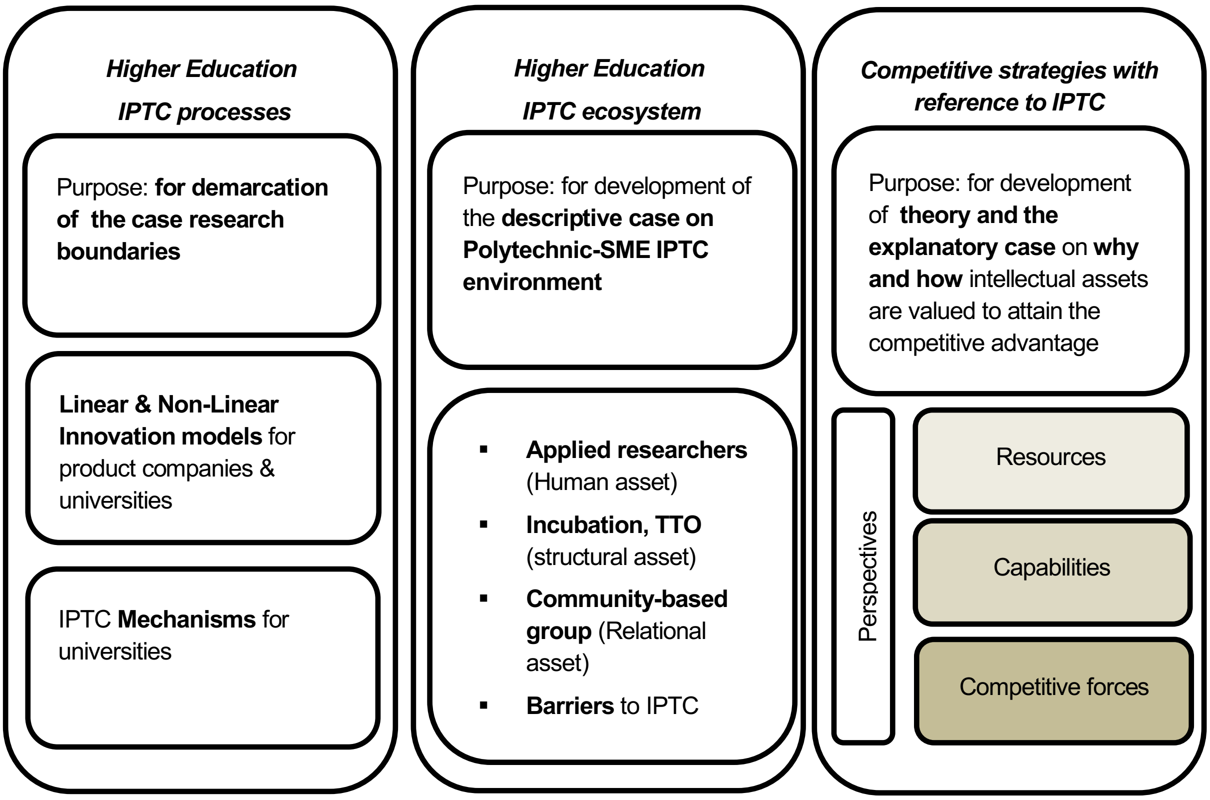



**Figure 2.1 Literature review framework**

## 2.1 Adaptation of university-industry IPTC process literature

Dubickis and Gaile-Sarkane (2015) have found that definitions of innovation and technology transfer used in the literature commonly overlap.

A university's roles in supporting innovation evolved from the simple provision of trained graduates and research outcomes to knowledge/technology transfer and commercialisation (Etzkowitz 2003; Wong, Ho & Singh 2011). The existing IPTC literature shows that most technology transfer studies focus on university IPTC activities, using information available from public survey data compiled by the AUTM (Bozeman, Rimes & Youtie 2014). Given the lack of scholarly literature regarding the polytechnic-industry IPTC space, the university-industry (U-I) IPTC literature was reviewed for this study. Wong (1999), a technology management expert in Singapore, has noted the U-I literature gap in relation to Singapore.

In their literature review, (Bozeman, Rimes & Youtie 2014) identify the three distinct U-I IPTC study strands:

- Early scholars focussed their studies on IPTC from European government laboratories.
- This was followed by a focus swift on transfer agents from government laboratories to universities.
- Recent scholarship has been focussed on non-linear IPTC frameworks, such as open innovation and open source.

The present study focused on IPTC processes, and therefore there was a need to review both linear and non-linear innovation model literature, despite the over-simplicity of the linear model (Bradley, Hayter & Link 2013; Landau & Rosenberg 1986).

### 2.1.1 Linear models of innovation

**Technology push innovation model.** An ideal technology push innovation model takes newly discovered knowledge and searches for a way it might be used. In the opinion of Kline and Rosenberg (1986), innovation should be about applied science, where adequately resourced firms can independently invest in research to create new knowledge, develop ideas through prototyping, and follow through with scaling-up production to meet a certain market need, hence the technology push model. Figure 2.2 depicts such an early linear innovation model featuring the four aspects of knowledge translation – research, development, production and marketing (Landau & Rosenberg 1986) – for product producing companies, SMEs included.

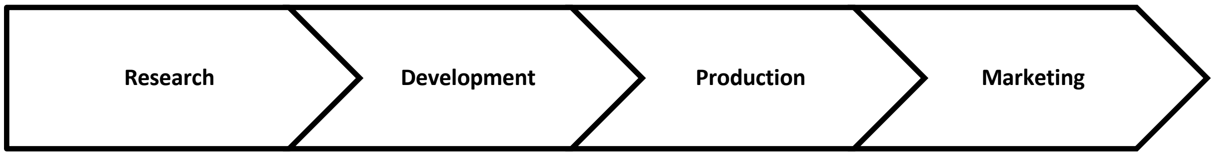



**Figure 2.2 Linear technology-push innovation process model for product producers. Source: Adapted from Kline & Rosenberg 1986, p. 286.**

Agreeing with Kline and Rosenberg (1986), Oslo Manual (OECD & Eurostat 2018) considers R&D to be separate aspects of innovation where research can be divided into two forms:

- **Basic or fundamental research** aims to create new knowledge without any application intended, and the outcome is commonly shared through scientific journals.
- **Applied research** aims to create new knowledge to solve a practical problem by using findings from the basic research or extending available knowledge, and the outcome is usually shared with businesses or industry for potential adoption or exploitation.

Ways of producing innovations are linked to different parameters. Lane and Flagg (2010) map various types of innovation against their respective outcomes in terms of discovery, invention and innovation in relation to the state of knowledge or IP. Table 2.1 shows the mapping.

**Table 2.1 Aspects of innovation creation and their outcomes. Source: Adapted from Lane & Flagg 2010.**

| Innovation processes | Potential outcomes | State of IP | Related explanations |
|---|---|---|---|
| research | discoveries | intangible | Science discovery is defined by Kline and Rosenberg (1986, p. 287) as *the creation, discovery, verification, collation, reorganisation, and dissemination of knowledge about physical, biological, and social nature.* |
| development | Inventions | moderately tangible | An invention can present itself as the first embodiment of the new ideas or discoveries to *demonstrate the design viability* (Rothwell & Gardiner 1985)<br><br>Inventions are often protected as one of the intellectual properties of the organisation (Lane & Flagg 2010) |
| production process | innovations | tangible | The commercial deployment of an invention through iterative prototype design and redesigning is regarded as an innovation (Rothwell & Gardiner 1985) |

The mercantile ecosystem in which new product development thrives involves many players. Rombach and Achatz (2007) map the various innovation processes to the roles played by different innovation players (universities, research institutions, start-up companies, corporate R&D, consulting companies). Based on the researcher's experience and observation, polytechnics arguably will occupy a position between applied research and real-environment prototyping, a position that requires polytechnics to translate ideas or discoveries into invention prototyping.

Engineering and design can be performed independently from basic R&D (OECD & Eurostat 2018). Therefore, SMEs that have product ideas that could be realised through engineering and design could bypass the university basic research process and consider a direct IPTC arrangement with a polytechnic to produce a prototype. Sir James Dyson asserted the significance of iterative prototyping for an everyday product such as a vacuum cleaner during an interview conducted by Forbes (High 2014).

As a non-product making organisation, a polytechnic would not be expected to contribute to the final production or industrial replication of the invention beyond the proof-of-concept stage. According to the Frascati Manual (OECD 2015), the experimental work directed at producing new products or processes en masse requires prior product making experiences, and such experiences are not found in educational institutions. Hence, translating an invention prototype into a large-scale innovative product line is better left to the domain of industrial executives (Lane & Flagg 2010).

**Market-pull innovation model.** While the linear push model produces IP without focussing initially on the market's needs or stakeholder feedback, the market-pull innovation model focuses on users' needs and the demands from the market before an organisation commits itself to develop its IP. One such early model is that introduced by Landau and Rosenberg (1986), a demand-pull innovation model known as the *chain-linked model*, as depicted in Figure 2.3. This model is best suited to firms that compete based on their market knowledge or users' insights, rather than scientific discoveries or technological advantages.

According to Kline and Rosenberg (1986), the chain-linked model can be further enhanced by incorporating cross-functional feedback loops to iteratively source for public and accumulated knowledge, before reaching out for a basic research process. Successful innovative firms tend to attain a balance between processes like research and marketing while ensuring seamless communication and coordination between those processes or functions (Rothwell & Gardiner 1985). The bicycle invention cited by Kline and Rosenberg (1986) is a clear example of an invention arising from market demand, not a scientific discovery. This bicycle invention and many other everyday inventions could be co-developed by polytechnics and SMEs, leveraging on polytechnics' applied research or experimental development capabilities.

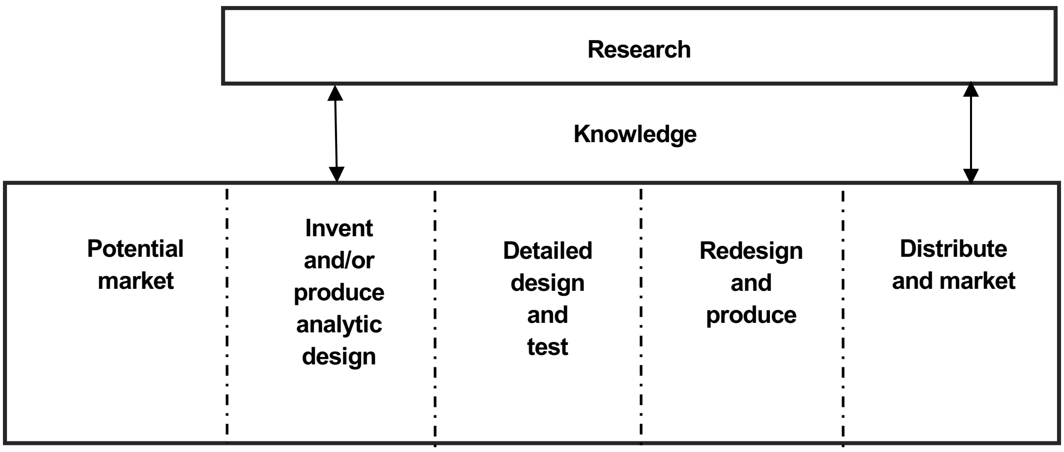



**Figure 2.3 Chain-linked model. Source: Kline & Rosenberg 1986, p. 289.**

**Users' insights are valued in a market pull innovation model**. The market pull innovation model has been echoed by a more recent innovation approach – the *design thinking method*. In a design thinking approach, design thinkers immerse themselves in the experience of users, observing their behaviour and recording what they say about their experience, while iterative idea prototyping and testing to uncover users' unmet needs (Brown & Wyatt 2015). This user-centred design approach has resulted in many radical ideas due to the unrestricted ideation process (Brown & Wyatt 2015).

Acknowledging the importance of incorporating users' insights, Rothwell and Gardiner (1985) have noted that potential users are particularly useful in providing insights when the technical and commercial viability of the invention is clarified with functional or production prototypes. Prove of a concept demonstration of the functional prototype is especially true for high-cost hardware innovations, such as the hovercraft – one of the case examples used in the article to explain this point. Rothwell and Gardiner (1985) found that investing in early-stage or upstream prototyping by a public institution will help to reduce users' resistance and negative feedback emerging from uncertainties related to technical and commercial viability. Polytechnics are expected to provide hands-on innovation capabilities to industry, hence they are well-positioned for this user-centric design approach.

**Model contexts.** The linear model of technology and other IP acquisition and realisation has been adapted over time to suit different contexts. In the university context, where product production is not the core business, the focus of the innovation model is about IP management and commercialisation. Therefore, it is not strange to see a linear IPTC model that excludes the aspects of innovation associated with production and marketing. An example of such an IPTC model is used to describe the flow of university IPTC in an article by Rogers, Takegami and Yin (2001), as depicted in Figure 2.4.

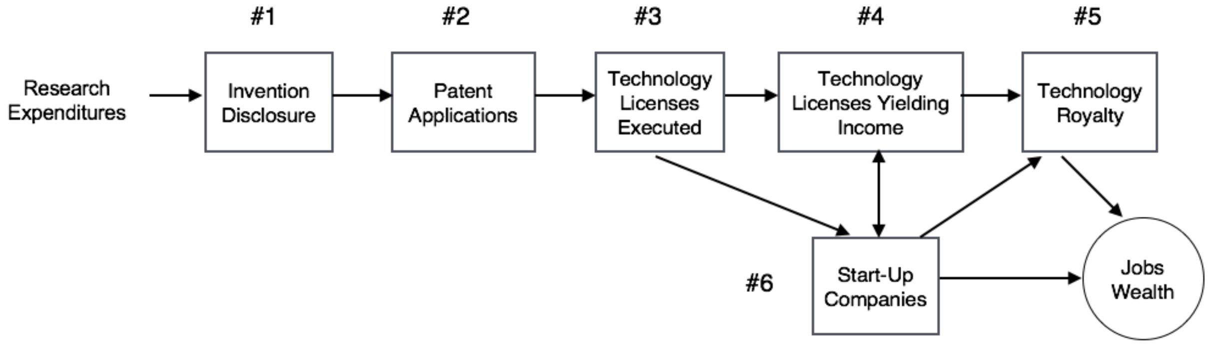



**Figure 2.4 Prior linear IPTC model from a university.**
**Source: Rogers, Takegami & Yin 2001, p. 258.**

The linear IPTC process starts with a translation of research inputs into an invention that is disclosed, patented, and licensed to an organisation or through a start-up company to generate royalty income and job opportunities – an economic perspective. Commercial entities like SMEs, or start-up companies, are expected to complete the innovation cycle by bringing the IP through the production and marketing functions to the marketplace.

In a more recent publication, Bradley, Hayter and Link (2013) present a slightly modified linear IPTC model, as shown in Figure 2.5. This linear IPTC chain starts with a research discovery, which is translated linearly as an invention that is disclosed, patented, marketed, and licensed to an existing organisation or through a spin-off or start-up company. Primarily, a research discovery in its intellectual form must be codified as an invention disclosure to capture it as an intellectual asset, and it can then be recognised as IP protectable under local IP laws.

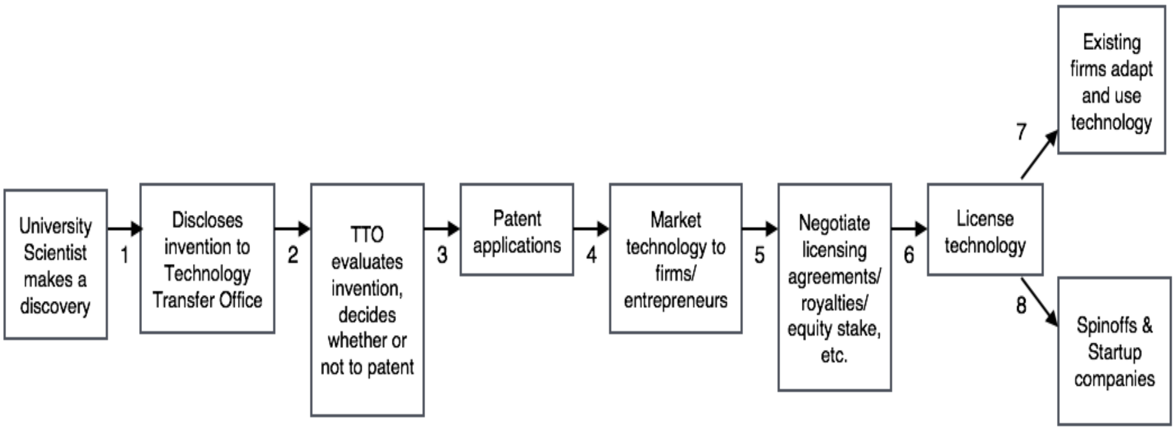



**Figure 2.5 Linear IPTC model from a university. Source: Bradley, Hayter & Link 2013.**

The Association of Universities' Technology Managers (AUTM) regards the U-I IPTC process to be linear, whereby scientific findings are transferred from one organisation to another for further development and commercialisation. The process includes:

- new IP identification
- IP protection through patents and copyrights
- IP development and commercialisation through marketing and licensing to existing organisations or creating new start-up companies (AUTM 2014).

Although linear U-I IPTC models frequently involve patented inventions, not all innovations stem from fundamental scientific research or are backed by patent. For example, the majority of US patents with technological advantages have never been introduced on a commercial basis (Landau & Rosenberg 1986). Concurring, Agrawal and Henderson (2002) found that less than 10% of the Massachusetts Institute of Technology's (MIT) IPTC involved a patent, with the majority of the faculty members preferring publication to patent as the way to convert knowledge to assets.

**Treatment of copyrighted materials.** AUTM, therefore, treats copyrighted materials as an alternative form of commercially relevant knowledge. Copyright is accorded to literary, dramatic, musical and artistic works, such as poems, plays, specific dances, paintings, sculpture and photographs, schematic drawings and computer programs (Ng-Loy 2008). Most of these copyrightable materials are the results of hands-on application of new knowledge – an essential competency of a polytechnic graduate or staff.

Innovation may, therefore, include variants of or modified products and services, as well as the new products and services emerging from R&D or other concepts harvested through various stakeholders' data mining approaches. Rasmussen (2006) introduced an alternative IPTC model, known as the *second generation (2G) model*, which focuses on both patent and non-patent IP, such as copyrighted materials. Based on IPTC case examples referred to in news articles or polytechnic corporate websites, it seems that the *second generation (2G) model* is more representative of the polytechnic-industry IPTC model, in that commercially applicable IP is translated from a variety of materials, both patented and under copyright.

Innovative products or services may not only be new in the market, finding their niche, but can also displace existing ones that may be closely related in function, and further, are substantially altered through incremental variations and changes to be more efficient and cost less to produce or operate (Damanpour 2017; Landau & Rosenberg 1986). A disruptive innovator may introduce new products or services to the industry that not only create a new niche for themselves, but also displace existing services or products by offering so much more benefit to the user or featuring a different and attractive core technology (Chandy & Tellis 2000).

Innovative sharing economy firms, for example, Airbnb accommodation and Uber taxi providers, radically disrupted consumer behaviour, and have surpassed the market valuation of incumbents such as the Hyatt hotel chain and Hertz respectively (Cannon & Summers 2014). Both Airbnb and Uber taxi leveraged on their knowledge about their customers as key competition parameters, not patents. The sharing economy is a new intermediary business model that simply digitises peer-to-peer service ordering and delivery workflows, leveraging on various known mobile platform technologies which may or may not be patented. Many of these known technologies can be acquired off-the-shelf and do not emerge from basic research. The innovation lies in the new ways in which they are used.

Many polytechnics and SMEs should be able to meet the required innovation capabilities for such developments. However, according to Chandy and Tellis (2000), the conventional perception that smaller companies are more radical innovators is not always valid outside the US because of the lack of local venture funding and risk-taking culture. Therefore, there is a need for empirical research based on a cross-section of innovations to determine their source and reasons for their development.

### 2.1.2 Non-linear models

Innovation approaches vary from heavily guarded R&D to open source through IP licensing at mid-level. Twenty-first-century universities view IPTC models as non-linear, involving environmental factors, such as regulatory changes and public funding. Non-linear innovation models discussed in the literature include the *national innovation system* (OECD 1997), *triple helix* (Etzkowitz 2003), *open innovation* (Chesbrough, HW 2003) and *open source* (Lerner & Tirole 2004) models. Most IPTC literature focuses on university TTOs and IPTC mechanisms (Bozeman, Rimes & Youtie 2014); however, the IPTC process remains understudied (Bradley, Hayter & Link 2013).

**National innovation system.** A country's innovative performance goes beyond static snapshots of its innovation inputs and innovation outputs; it also involves the measures of inter-human and inter-institution interactions. The national innovation system places great emphasis on the knowledge flow of how different innovation players (IP producers, government agencies) interact with each other for knowledge development and deployment (Chung 2002). For example, the government agencies manage innovation policies that reinforce the relationship between public IP producers (universities, RIs or polytechnics) and industry.

**Triple helix innovation model.** The triple helix innovation model also echoes the need to bring individuals from U-I-G to interact and collaborate (Etzkowitz 2003). In a study of the contribution of universities to the national innovation system of some Asian countries, Wong, Ho and Singh (2011) state that the Singapore government has played the most vital role in transforming the country from investment to innovation-driven economy. Furthermore, this process has given more prominence to the universities' role in performing IPTC activities, conducting R&D, attracting foreign talent, and providing entrepreneurship training programs.

Acknowledging the importance of spin-off companies and out-licensing to large corporations, the study appears to suggest the following improvements for Asian universities:

- at organisation level
  - SMEs need to elevate their absorptive capacity to internalise sophisticated technologies emerging from universities.
  - Spin-offs need more venture funders, key users, role models, and mentors to improve their success rates.
- at the individual level
  - Student entrepreneurs need to be enabled through entrepreneurship training programs.
  - Alumni entrepreneurs need to be engaged through suitable networking platforms involving industries and investors.
  - Staff inventors need to be incentivised for participating in IP commercialisation in addition to teaching and research (Wong, Ho & Singh 2011).

**Open innovation.** Henry Chesbrough propagated the concept of open innovation. According to Chesbrough, HW (2003), in a closed innovation model large organisations (such as DuPont, IBM, and AT&T) cautiously guard their innovations within their organisations' boundaries by investing heavily in their internal resources**,** a resource-based approach. This closed innovation model allows innovations to be translated quickly and independently within a defined market, rendering it a choice of innovation strategy for organisations that are seeking full control over their IP, benefiting from the first-mover advantage. Organisations in a closed innovation system choose to work defensively with others. Organisations in an open innovation system choose to innovate beyond their organisations' boundaries, leveraging third-party IP or resources as a tool to expand market space (Jeyakodi & Ros 2019).

Open innovation is benefitted by the hyper-connected 21st-century world where ideas and information are publicly accessible, and organisations or individuals who feel that they cannot afford the time or the money to do their R&D can tap into external ideas and resources to stay competitive and creative.

The open innovation model advocates inter-organisation collaboration in which organisations can focus on their strengths and competencies while drawing on outsourcing or in-sourcing opportunities to stay competitive. The degree of openness will influence the ways in which organisations manage their IP and resources.

*Licensing.* In the open innovation model, organisations are more willing to make their IP available for sale or rent through various IPTC mechanisms. For example, an organisation may *license-in* IP from another company or *license-ou*t their IP in return for a fee. This open concept enables companies with little or no complementary R&D capability to commercialise new product ideas and create their IP based on the IP they have licensed-in. The organisation that has licensed-out receives a fee or makes other contractual arrangements so that they can benefit from their IP, along with the licensee.

For example, Samsung acquired Motorola mobile device IPs to strengthen Samsung's IP position before negotiating a *cross-licensing* deal with Apple (Jeyakodi & Ros 2019; Wagner 2015). Through the cross-licensing agreement, IP from both competing firms (Apple and Samsung) became available to each other. Cross-licensing is an advantageous way to avoid litigation for IP infringements when organisations are operating in the same creative space, such as smartphone development. Smartphones contain over 250,000 patented components, leading to what has become known as the 'smartphone patent wars', which have persisted for over a decade (Parker 2014).

Another cross-licensing example is one between Google and Samsung, which enabled them to share both background and foreground IP (Jeyakodi & Ros 2019). In general, cross-licensing of IP is a useful strategy for avoiding expensive patent litigation (Lim, D 2015; Shapiro 2000). Different IP owners can produce their products by sharing a shared pool of IP at a mutually agreed royalty structure without IP infringement. Without making such agreements, infringement of patent or non-patent rights can result in substantial financial penalties and years in court for IP owners trying to protect their IP.

While multinational companies might prefer not to be involved in litigation but have the resources to litigate if they feel it necessary, small businesses are often placed in a dire position when faced with patent or copyright litigation. To defend against a patent infringement costs more than half a million US dollars, whereas to pursue an infringer will cost between US$5 to US$8 million (Lim, D 2015). With such prohibitive IP enforcement costs, polytechnics should be extremely selective in patenting their IP, as it makes little sense to transfer a patent to a SME only to learn that the SME has insufficient financial resources for any future IP enforcement.

*Non-defensive IP strategies.* It is not uncommon for IP owners to share non-core knowledge with all players, whether competitors or complementors. For example, Tesla has decided to grant authentic competitors or complementors free access to Tesla's patented technologies – a non-defensive IP strategy to speed up the development of electric cars and the required ecosystem (Jeyakodi & Ros 2019). A similar IP strategy was adopted by IBM to share 500 pieces of non-core building block IP with industry in 2005 (Jeyakodi & Ros 2019).

*Oversimplified IP licensing approaches.* Licensees' interviews undertaken during this study indicated that Singaporean SMEs tend to look for cost savings by consulting business solicitors who are non-patent agents for the preparation of licensing agreements. The cost of using a licensed patent agent lies in the fact that they offer a vast range of expertise, and can knowledgeably undertake due diligence, draft patents and conduct IP licensing. According to Daryl Lim, D (2015) the cost of conducting due diligence or research into each patent is between US$10,000 and US$15,000, a fee much higher than that required just to pay licensing fees. For example, an SME manager regretted his cost-saving action of engaging a business solicitor instead of an IP professional to review and prepare the IP licensing contract; he shared the disappointment after learning that the licensed IP taken from a polytechnic had limited freedom to operate in the US market. This oversimplified IP licensing approach invites unexpected IP infringement threats at a later stage when the product incorporating the licensed IP has gained full consumer acceptance.

*Open innovation for Singapore.* Open innovation platforms need to win the hearts and minds of Singapore SMEs. In early 2000, the open innovation model went into cyberspace to connect the *solvers* (solution proposers, including individuals, universities, and polytechnics), *seekers* (organisations seeking solutions to their challenges) and *brokers* (intermediaries) through online collaborative communities or platforms (Antikainen & Vaataja 2010; Cardoso, Carvalho & Ramos 2009). Corporation seekers, such as Procter & Gamble and Eli Lilly, have chosen to bypass intermediaries, connecting to solvers directly using self-established online open innovation portals, *Nine-Sigma* and *InnoCentive*, respectively (Cardoso, Carvalho & Ramos 2009).

Seekers digitise their challenges into a request-for-idea or technological summary without the disclosure of confidential information and share ideas with solvers. Battistella and Nonino (2012) conducted a study of 20 open innovation platforms to examine their motivations and motivational drivers. The researchers found that one of the most frequent and high impact drivers was issues and challenges proposed from outside and entrusted to the members of the community.

Trusting relationships and commitment are two crucial factors in building online open and collaborative communities (Antikainen & Vaataja 2010). This research indicates that not all technology seekers are trusting or keen to share their challenges openly through online platforms. Untimely disclosure of the challenges encountered may unintentionally reveal the company's weaknesses or pass information to the competition. However, the researcher anticipates that more Singapore SMEs will use online innovation platforms in future once the trust level has improved.

Instead of turning to cyberspace, Unilever launched its corporate-start-up co-working spaces, *Dogpatch Lab* in Ireland and *Level 3* in Singapore, to bring global start-up entrepreneurs closer to Unilever for open and collaborative innovations (*Business Wire* 2017; The Unilever Foundry 2017). These physical co-working spaces have witnessed over 100 pilot projects with start-ups and Unilever brands under the Unilever Foundry Initiative (*Business Wire* 2017). Unlike online open and collaborative innovation communities, Unilever Foundry's unique pitch-pilot-partner program (*Business Wire* 2017; The Unilever Foundry 2017) provides a more trusting environment where face-to-face interactions thrive. One of the ways polytechnics introduce their innovative ideas to the public is through international tradeshows, such as the *IP Week* (C2 Creative Communications 2019), or *TechInnovation* (IPI-Singapore 2019).

At individual innovator levels, another online open innovation known as *Kickstarter* has successfully connected 5.7 million investors to 57,000 projects to attain financial support, making their ideas a reality (London Business School 2014). According to London Business School (2014), about 44% of fund seekers raise their target amount.

Innovation productivity and speed improve through open-source IP exchanges without financial consideration. Open-source programmers allow public and free access to their original IP under specific rules, including sharing of foreground IP arising from the use of background IP (Lerner & Tirole 2004). Social platform giant *Facebook* is a classic example of an open-source beneficiary (Jeyakodi & Ros 2019). In another example, different robot hardware manufacturers, *Care-O-bot 3*, *iRobot Create*, and *Aldebaran Nao*, are sharing codes developed under the *Robot Operating System*, an open-source robotics common. Sharing code without restricting access to it helps the global robotics community to quickly locate, develop and integrate software required for rapid deployment (Cousins et al. 2010).

Another emerging sharing economy, the circular economy, a popular sustainable product development concept promoted in Europe, will potentially change how future IPTC operates. Traditionally, products are made, used and disposed of. With the circular economy, products and materials are circulated, reused, remanufactured, and recycled. Hence, product IP will likely be co-owned by an inter-related community, and IPTC partnerships will be more integrated throughout the sharing economy (Korhonen, Honkasalo & Seppälä 2018)

With the current wider acceptance of open innovation concepts, polytechnics, which have little interest in product making, could focus on producing commercially applicable IP for acquisition or licensure to benefit society and SMEs.

### 2.1.3 IPTC mechanisms

IPTC mechanisms are identifiable by their intended purpose. Australian universities transfer their technologies to the industry through mechanisms such as the supply of quality graduates, continuous education programs, conferences, consultancies, contract research work, licensing of IP and spin-off companies (Cripps et al. 1999; Rogers, Takegami & Yin 2001). For this study, the IPTC mechanisms were grouped as:

- knowledge transfer mechanisms
- knowledge development mechanisms
- knowledge deployment mechanisms.

Figure 2.6 provides the graphical representation of the classification of IPTC mechanisms by purpose.

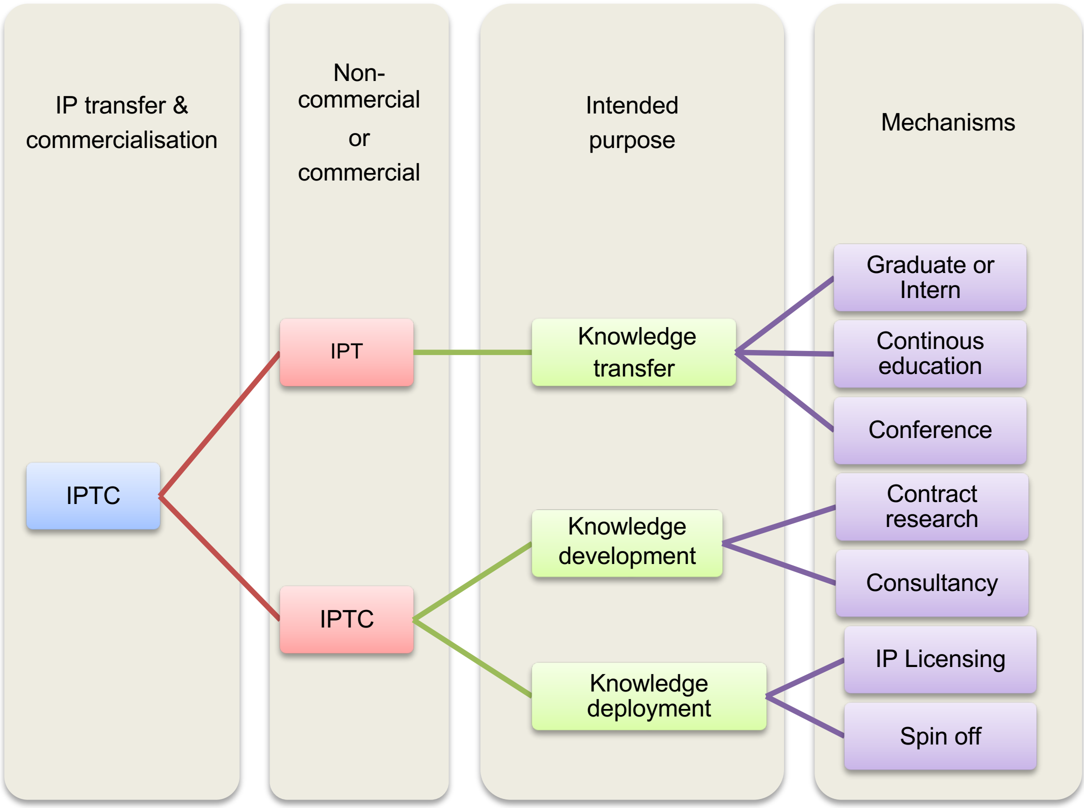



**Figure 2.6 Researcher's interpretation of IPTC mechanisms by purpose**

The supply of graduates and interns, continuous education training and conferences, and publications were viewed as non-commercial mechanisms suited for knowledge transfer. In contrast, research contracts and consultancy work were considered to be commercially applicable mechanisms for knowledge development.

Finally, other commercial mechanisms, including licensing of IP and spin-off companies, are commonly used for knowledge deployment in the new product or process deployments. Licensing of IP is the most common mechanism in product innovation for the biomedical and information technology sectors (Cripps et al. 1999). In agreement, Edvinsson and Sullivan (1996) highlight several value-to-cash technology conversion mechanisms:

- sale or assignment
- out-licensing
- joint ventures (strategic alliances)
- tax-deductible donations
- new venture creation.

Although there are both non-commercial and commercial IPTC mechanisms through which a polytechnic can contribute to the society or industry, IP licensing was chosen for this research because it is the sharpest edge in an IPTC mechanism; a relationship in which a SME licensee is expected to commit a substantial financial investment to convert the licensed IP into an innovation available in the market

Besides categorising IPTC mechanisms by their purposes, it is also possible to categorise them into the following categories by adding the dimension of time:

- short-term transactional IPTC mechanisms
- It is normal for consultancy, contract research, and IPTC licensing projects to be completed in a shorter timeframe. In these types of projects, partners consider managing their relationship via a mutually agreed transactional agreement. The relationship usually ends when the contract is fulfilled. Besides a licensing mechanism, IP with no strategic value can be sold or assigned for a more substantial financial return (Cripps et al. 1999).
- *mid-term risk-taking IPTC organisations*
  Some R&D IP embeds early-stage technologies, and may not be immediately ready for commercialisation. A separate venture can be created to transfer and commercialise the early-stage IP through a spin-off or university start-up to test the business ideas while strengthening the economic value creation (Cripps et al. 1999; Ndonzuau, Pirnay & Surlemont 2002).
- *long-term IPTC alliance*
  Besides mergers, organisations can form alliances or joint ventures to gain more control and balance in terms of power in the relationship (Davis, GF & Adam Cobb

2010). For example, an SME retailer can create a supplier-manufacturer agreement, whereby the retailer supplies the end-users who need that technology.

## 2.2 Technology transfer ecosystem in the tertiary sector

The success of university IPTC is largely determined by university-specific assets and organisational capabilities in the management of both internal and external environments. Firms in a specific industry – start-ups, SMEs, large local enterprises (LLEs), or multinational corporations (MNCs) – seek different IPs with different market distances to maximise their benefits. Public tertiary institutions, such as research universities, teaching universities, institutes of technology, or polytechnics, are providing IPs at different technology readiness levels for public benefits. Tertiary institutions that focus on applied R&D tend to provide problem-solving technologies to benefit private organisations, but publicly funded basic R&D provides longer-term public good (Cripps et al. 1999; Geiger 2006).

### 2.2.1 Applied researchers, the university IP translators

Applied R&D is essential to translate university basic R&D outcomes to a readiness level that is acceptable to interested industries. Applied research promotes university-industry technology transfer (Powers 2003). In the UK, for example, government has promoted the following top-down changes to promote university and industry collaboration (Lockett, Wright & Wild 2013):

- focusing more on vocational skills by ending the binary divide between polytechnics and universities, viewed by many as levelling the playing field by moving closer to industry
- limiting the provision of public funding to encourage universities to seek alternative funding support from industry.

As a result, many post-1992 universities (former polytechnics) that collaborated with local industry in applied research were disadvantaged when attempting to access public funding. Decter (2009) cited Cranfield University as an exemplary applied research university that managed to raise more funding from industry or business than from public sources. However, until 1996 the performance of UK universities in basic research was the key indicator measured by the Research Assessment Exercise conducted by public funding agencies (Decter 2009; Lockett, Wright & Wild 2013). In 1996, the Research Assessment Exercise recognised the value of university-industry interaction by introducing applied research as one of the performance indicators.

In 1998, new public funding schemes (University Challenge, Science Enterprise Challenge) focusing on encouraging university-industry collaborative problem solving through applied research were introduced in a competitiveness white paper produced by the Department of Trade and Industry (Salter et al. 2000). Unlike the UK, many universities across North America had embraced applied research to translate basic research outcomes after the *Bayh Dole Act* (Sharma, Kumar & Lalande 2006).

Applied researchers who aggregate contemporary technologies (not scientific discoveries) into incremental innovations can enjoy private benefits. Claudio Ballard invented a patented method that aggregated known contemporary technologies to process digital copies of checks and earned hundreds of millions of US dollars from banks (Wyatt 2011). As discussed in an interview in the *New York Times*:

> *I didn't invent the scanner; I didn't invent networking, or computers or software,' he said. 'But I am an expert at systems integration, and I created this complete end-to-end solution' for digital check processing. (Wyatt 2011, p. B1)*

In polytechnics, there are talent who are like Claudio Ballard, able to innovate based on today's technologies because of their prior industrial working experience. These talents could be tapped by an SME in their innovation journey.

### 2.2.2 Technology incubation, the IP commercialisation facilitator

Start-up or spin-off companies are commercial vehicles through which risks associated with the commercialisation of early-stage technology-reliant IP can be mitigated. According to Geiger (2006), small firms are less likely to benefit from university research because university research outcomes are usually lab-based and require further development to translate them nearer to the marketplace. Two-thirds of university IPs are licensed and translated by start-up companies into near-market inventions or prototypes, although many such start-up companies fail to attain commercial success (Geiger 2006).

The Massachusetts Institute of Technology pioneered the use of start-ups as an IP commercialisation mechanism in the 1980s (Bray & Lee 2000). In this century, universities, governments, and private corporations worldwide are trying to replicate the success of Silicon Valley as technology incubators who can provide effective incubation or accelerator programs, funding schemes and resources to promising start-up companies to commercialise their IP (Isabelle 2013). One venture company in the Netherlands, the Zernike Group, focusing on the IP commercialisation incubation process, has been particularly successful in their transformation of start-up companies (Milton-Smith 2001).

Isabelle (2013) suggests that an incubator's performance is a challenge to measure due to the inconsistency of the criteria applied by different incubators to incubatees, access to data and local political influence; finding that there was contradictory evidence linking the commercial success of start-ups to incubation.

In Singapore, IPTC infrastructure is made accessible to SMEs through the Centre of Innovation (COI), incubators, technology and science parks, and technology transfer offices (OECD/ERIA 2018). Most of the COIs are set up in partnership with selected polytechnics as the one-stop centres for SMEs to develop their innovation projects through the provision of prototyping facilities, consultancy, and knowledge transfer.

### 2.2.3 Technology transfer offices (TTOs), the university commercial arm

Technology transfer offices (TTO) are considered the commercial arms of tertiary institutions. TTOs are expected to understand the IP-market fit of the institution's research and interface with the business world (Geiger 2006), thereby allowing faculties to focus on teaching and research. Dos Santos and Torkomian (2013) describe a TTO's proactive role in the innovation process as one that covers activities, such as industry outreach, IP auditing, protecting, and marketing, and IP commercialisation through licensing, spin-offs, or incubation. In the process of technology transfer, a university is expected to engage in complex interaction with third-parties, including licensees, patent agents or private investors.

IPTC competency and resources influence TTO's decision making. Sharma, Kumar and Lalande (2006) argue that universities accord TTOs sufficient financial and managerial autonomy to meet industry or business demands. To reduce costs, TTOs generally prefer to sign a licensing deal rather than seeking patent protection. In this way, patent protection costs can be transferred to the licensees (Geiger 2006). According to Pazos et al. (2012), TTOs in developing countries need to gain a better understanding of business demand if they want to improve IPTC outcomes.

Patent protection impedes knowledge advancement – a notion that influenced the behaviour of early IP creators. Before the *Bayh-Dole Act*, universities or individuals engaged third-party independent organisations or foundations, such as the Research Corporation, to manage their IP (Mowery et al. 1999; Sampat 2006). According to Sampat (2006), Berkeley chemist Frederick Gardner Cottrell pioneered the use of the Research Corporation to manage his electrostatic precipitator, a pollution control device, in order to avoid direct involvement in IPTC activities while upholding his commitments to open science and knowledge advancement.

In the UK, a TTO is also known as a knowledge transfer office, and the first wave of TTOs saw 11 universities formally establish a TTO between 1984 and 1985 (Lockett, Wright & Wild 2013). Today, many research universities have begun to establish comprehensive TTOs, co-locating all different IPTC related skills and resources in one location (Geiger 2006).

In three short decades, TTOs or their equivalents were being established in Singapore to facilitate IPTC from universities, and polytechnics (WIPO n.d.):

- In 1992, NUS established the Industry and Technology Relations Office.
- In 2000, Nanyang Technological University (NTU) established the Innovation and Technology Transfer Office.
- In 1990, Singapore polytechnic founded the first TTO in the polytechnic sector, two years ahead of the university sector.

Exploit Technologies Pte Ltd was set up in 2002 as the TTO of the A*STAR research institutions (C2 Creative Communications 2019). Today, all five polytechnics are offering

IPTC services through their TTOs. At a global level, the Ministry of Trade and Industry set up Intellectual Property Intermediary (IPI) to connect registered IP producers and seekers to collaborate in an international context (IPI-Singapore 2018).

### 2.2.4 Community-based organisation, the technology transfer catalyst

In the IPTC ecosystem, community-based organisations bring together like-minded people to share best practice and knowledge, a national initiative to promote relational capital. The AUTM, based in the US, Réseau Curie (France) and Praxis-Unico (United Kingdom), are among the better-known technology transfer community-based organisations (Dos Santos & Torkomian 2013). In addition to the dissemination of IPTC best practices, and carrying out training and development programs, one of the key contributions of such community-based organisations is the publication of benchmarking surveys for scholars who are studying the effectiveness of university technology transfer (Phan & Siegel 2006).

Technology transfer happens at the transnational partnership level too. Technologies are also transferred from developed to developing countries through the establishment of transnational institutions to conduct hands-on skill training using the latest technologies. In the late 1970s, Singapore collaborated with the Japanese, German, and French governments to transfer technical knowledge via the Japan-Singapore Institute, German-Singapore Institute and French-

Singapore Institute (Lin, CT 2002; Mok 2015; Varaprasad 2016). These three institutes now form the foundation of Nanyang Polytechnic (Lin, CT 2002).

The literature suggests that universities are stepping up applied R&D, establishing more technology incubation spaces and engaging proactively with the professional community to improve IPTC competencies and resources.

### 2.2.5 Overcoming barriers to technology transfer

Kumar, Luthra and Haleem (2015) and Keller and Chinta (1990) have established that the following barriers can hinder transnational technology transfer:

- external threats (political, socio-cultural, and technological)
- internal weaknesses (managerial, economic, supply chain, socio-cultural, and technological).

Regardless of the source of the barrier, they are mostly the result of people's attitudes and behaviour.

Studies show that university-industry people engagements could be enhanced if organisational culture or performance measurement were aligned (Collier, Gray & Ahn 2011; Cripps et al. 1999; Razak & White 2015). Markman et al. (2005) found faculty-inventor disengagement to be a substantial barrier to the IPTC process and speed, attributing their indifference to IP producers' preference for scholarly work rather than IPTC activities, and the importance of academic work to their chances for tenure and promotion.

From the resource-based perspective, the IPTC process can also be impeded by a limited TTO budget, bad TTO reputation, incompetent TTO managers, or TTO bureaucracy (Markman et al. 2005). In a study of what promotes or hinders collaborative relationships between universities, industries and government, Razak and White (2015) grouped most of the barriers highlighted by Markman et al. into three overlapping categories – relationships, universities, and policies –

as collectively illustrated in Table 2.2, incorporating similar findings by Cripps et al. (1999), and Collier, Gray and Ahn (2011).

**Table 2.2 Categories of barriers to technology transfer.**
**Source:(Collier, Gray & Ahn 2011; Cripps et al. 1999; Razak & White 2015).**

| Category | Consolidated barriers |
|---|---|
| **Relationship** | ▪ Conflicting organisational culture<br>▪ Conflicting value and risk perception (Performance indicators, financial return or public good)<br>▪ Conflicting decision-making process (Bureaucratic and slow)<br>▪ Weak university-industry relationship and communication<br>▪ Lack of local partner. For example, an under-resourced SME who licensed IP from the polytechnic would seek local partnership support in prototype testing, regulatory approval, marketing, and scaling-up development. |
| **University** | ▪ Limited access to the required human capital (credible basic researchers, applied R&D enablers, and IPTC champions)<br>▪ Limited infrastructure<br>▪ Unclear in the direction of knowledge creation and dissemination (Applied or basic R&D)<br>▪ Lack of interest to perform applied R&D due to time and shortage of reward system<br>▪ Conservative academic attitude<br>▪ Bureaucratic and slow decision-making process (Large companies) |
| **Policy** | ▪ Unfriendly' or unsuitable policies lack government funding gap between research policies and the strategy adopted by industry |

**Relationships**. A university is fundamentally a different world compared to industry where there are SMEs, LLEs or MNCs. A university must be prepared to allocate considerable time and resources to continually engage, re-engage, follow-up and value-add to the technology transferees (Schroer et al. 1995), overcoming marketing and credential deficiency issues.

Traditionally, universities value teaching and publications as the means of knowledge dissemination, and create new knowledge through long-term strategic basic research; conversely, industry is primarily driven by financial returns to commercialise IP transferred from universities, preferring to take business risks through short-term development activities (Cripps et al. 1999; Parker & Kirkland 1996 in Jasinski 2009)

In addition to financial returns, universities are motivated by other non-financial secondary drivers, including productive use of discovery IP and long-term social or public good when considering IPTC (Campbell 2005; Cripps et al. 1999). Unlike organisations that are quick in decision making, university bureaucratic procedures imposed by TTOs are likely to be slow and frustrating (Collier, Gray & Ahn 2011; Siegel et al. 2004).

Strong, personal relationships (Collier, Gray & Ahn 2011) and inter-organisational relationships (Razak & White 2015) are vital to ensuring effective technology transfer. For Collier, Gray and Ahn (2011), effective communication enhances university-industry relationships in technology transfer. Limited accessibility to required human capital is more pertinent for poorly resourced SMEs. In the case of a micro-enterprise, the founder can also be the innovator who favours incremental innovations and is continuously seeking ways to overcome (Jones et al. 2014):

- costly and inflexible new product legislation and regulation
- the limitation of skills and knowledge for new product development.

**Universities**. According to Cripps et al. (1999), universities' IP is sought by industry if they can offer state-of-the-art infrastructure (specialised equipment and plants) and human capital (credible researchers, IPTC project managers, practical enablers) who can translate needs to solutions.

For Cripps et al. (1999), the lack of interest among university researchers in performing applied R&D can be attributed to a weak reward system and time constraints; university researchers being more inclined to conduct academic research to meet their key performance indicators, such as the number of high impact publications and R&D grants. Issues grounded in academic and university administration staffing, coupled with remuneration incentives curtail faculty involvement, resulting in academics seeking to circumvent the university technology transfer office and process (Siegel et al. 2004). It remains arguable that most university researchers are inclined to research and publish. The researcher has noticed that there has been an increase in applied R&D grants from both universities and polytechnics for projects involving qualified industry partners.

However, universities have come to value IPTC in terms of long-term gains, such as sustained partnerships, cultural change, and job creation (Campbell 2005). For Razak and White (2015), findings on barriers that hinder a university (technology producer) and an SME (technology seeker) are not mutually exclusive and overlap with one another.

One barrier not discussed above is the exorbitant cost of scaling up. It is easy to invent, but the cost of scaling up is 10,000 times more than the worth of academic invention or discovery (*The Economist* 2002).

In summary, most scholars have found that IPTC would thrive if the university administration were less bureaucratic, the university staff more equipped with the desired skills and mindsets, and the university well-resourced with IPTC friendly infrastructure and resources.

## 2.3 Technology transfer to attain competitive advantage

The business world today is more interconnected and businesses more vulnerable to social or economic change, which impacts organisational competitiveness. Organisations can respond to those changes by either generating or adopting the following innovation typologies (Damanpour 2017):

- *product or process innovation*:
  Product innovation is defined as the introduction of a new product or service, while a process innovation is about how that product or service could be produced.
- *technical or managerial innovation*:
  Technical innovation involves new ideas that change a product, process, and service, while managerial innovation involves new ideas that alter a human resource policy, resource allocations, and social structures.
- *radical or incremental innovation*:
  A radical innovator can generate innovations that displace incumbents at the industry level or destroy jobs or competences at an organisational level, while an incremental innovator introduces minor changes to existing activities, products, processes, and practices.
- *intra- or inter-organisational innovations*:
  Intra-organisational innovations are developed entirely in-house, while inter-

organisational innovations are created and developed through a partnership with external partners, both individuals and organisations.

Damanpour (2017) suggests that future organisational innovation research will look at the intersection between various innovation types, guided by environmental demands and managerial aspiration.

Organisational theories are being studied to understand both intra- and inter-organisation knowledge and technology transfers and IPTC can be found in organisational theories as part of a competitive strategy. For example, organisational learning (Dodgson 1993) and the conventional resource-based view (Wernerfelt 1984), and the dynamic capabilities perspective (Teece, Pisano & Shuen 1997) are applicable when studying intra-organisational knowledge acquisition, accumulation, and transfer processes. Whereas the resource dependence theory (Pfeffer & Salancik 1978) and network organisations theory (Powell 1990) are applicable when studying inter-organisational processes, including knowledge and technology transfer. Accordingly, competitive strategies literature, concentrating on resources, capabilities, and competitive forces, was investigated.

### 2.3.1 Resource-based view (RBV)

The resource-based view (RBV) is a model used to help explain the continuum of success experienced by businesses, from very successful to abject failure and all the possibilities in between. The RBV argues that an organisation can outperform another due to the possession and deployment of resources that are valuable (create demand to neutralise threats), rare (scarcity), inimitable (hard-to or imperfectly imitable), or non-substitutable (hard to replace); that is, they are *valuable, rare, inimitable, and non-substitutable* (VRIN) (Barney 1991). These four elements form the resource attribute test model with which to assess an organisation's competitiveness. Generally, the resources can be broadly categorised into:

- tangible physical capital resources (plants, materials)
- human capital resources (individual employee's knowledge, insights, knowhow, experience, skills, and relationships)
- organisational capital resources (structure, processes, routines, coordinating systems) that either strengthen or weaken a firm semi-permanently against its competitors (Barney 1991; Wernerfelt 1984).

In addition to the VRIN resource attribute test model, Collis and Montgomery (1995) add another competitive advantage test to ensure that a resource has a genuine competitive advantage and durability (slow in depreciation); appropriability (an immobile resource that sticks within the firm); and competitive superiority (better than competitors).

Even if all the tests of resource attributes for a firm are met, it is almost inevitable that even valuable resources will depreciate and profits will be temporary. Firms must constantly monitor and nurture their resources, continuously reviewing, investing, developing, and repositioning them against competitors (Collis & Montgomery 1995) who will want to challenge them in the marketplace.

Since infrastructure and equipment – tangible, physical capital resources – can easily be imitated or substituted by competitors, the influence of such replicable assets on the IPTC partnership was not considered in this research, which investigated the sharing of intellectual property between its originators and those who want to acquire the IP. For organisations with limited valuable resources, IPTC is one of the popular strategies by which to attain competitive advantage (Somsuk 2010).

Similarly, based on an RBV, a university competes by leveraging its unique internal resources that may include the capabilities of the IP creators, and accessible organisational processes, infrastructure, and financial support (Powers 2003).

RBV has been used to assess the success of university settings, technology transfer, and university spinoffs, to understand those barriers to the commercialisation of innovations, and determine how TTOs affect outcomes (Ahn & York 2010; Pazos et al. 2012; Somsuk 2010). However, while conventional RBV has been used with great success, it has inherent drawbacks in terms of its applicability to technology transfer**.** It is an inwardly focused approach to understanding resources and fails to consider the market or externally accessible resources (Mathews, JA 2003). Although owning and controlling internal resources is one way to attain a competitive advantage, the capability to manage and use these resources is another source of competitive advantage (Akio 2005).

Lacking in product development capability, a conventional university will take a non-product producer role by focusing on knowledge/technology generation to secure more quality students and R&D grants. In contrast, a more entrepreneurial university can spin off a company to undertake innovative entrepreneurship endeavours in order to translate its technologies into new consumer products and compete in the market. In this spinoff context, there is little RBV literature relating to the role of entrepreneurship as a source of competitive advantage (Akio 2005).

### 2.3.2 Human and structural resources

Under RBV, an organisation's resources can be broadly grouped into tangible physical resources, human resources, organisational resources (Barney 1991; Wernerfelt 1984). Human resources are intrinsic to the operation of any organisation. Whether it is a sole trader or a corporate giant, it is the people and what they bring to an organisation that makes a business operate. Human resources do the work and have the ideas; it may be the most valuable asset a firm possesses, from the CEO to the janitor. Examples of intangible assets created by human resources within the firm include knowledge, insights, know-how, experience, skills, and relationship - collectively known as HC (Barney 1991).

However, for success, strong organisational resources are required to support the employees – this is also commonly known as structural resources. With strong structural resources, the intangible HC can then be developed, tested and codified into another intangible resource category known as structural capital (SC), where IP, structures, processes, routines and management systems are possible outcomes (Barney 1991).

Human and structural capitals operate in dynamic interaction, and their successful combination can give a firm its competitive advantage. According to Pike, Roos and Marr (2005), the dynamic interaction of intangible resources is the value driver in a firm's research and development process. Relying on its human and structural resources, organisations reach out to customers, other businesses, regulators, and potential collaborators to build networks, which create another intangible resource category, *relational capital* or RC. Pike, Roos and Marr (2005) have grouped HC, SC and RC under the term *intellectual capital* (IC). There are, of course, tangible physical resources, such as land, building, and equipment and monetary resources, including cash and financial assets.

In spite of all these resources, it must be kept in mind that not all the necessary resources required by an organisation to achieve its goals actually exist within the organisation itself.

**Human capabilities.** The human resources of an organisation include all internal (employer and employees) or external (contractors or suppliers) people who collectively generate and develop new or improved knowledge and knowhow that can be translated into devices, methods, compositions, or process inventions. Human resources include individual cognitive abilities, behavioural norms, or qualifications, experience, judgement, as well as knowledge and knowhow (Pike, Roos & Marr 2005).

Knowledge, a human capital (Mazloomi Khamseh & Jolly 2008; Newell 2005; Wernerfelt 1984) can be represented in two forms: information, which is factually orientated data (inventory list); and knowhow, which is action-oriented data (inventory reordering manual) (Kogut & Zander 1993) and deeply idiosyncratic and unrecorded. Over time, individuals in an organisation will accumulate knowledge and deepen their skills, thereby improving the organisation's competitiveness with both universal (shared and codified) and tacit (personal and uncodified knowhow) knowledge.

Being 'distributed, ambiguous and disruptive', tacit knowledge is difficult to transfer (Newell 2005, p. 275) without experience, teaching and practice. Explicit or codified knowledge can be transferred through documents and books. Tacit knowledge is the result of specific knowledge, interpretation and experience not readily captured by documentation. It is the knowledge that resides in the human capital of the organisation.

Tacit knowledge transfer can be considered problematic and limited in terms of its learning cycle, as it often requires individual learning and shared experiences to improve organisational outcomes and create best practice (Newell 2005). According to Edvinsson and Sullivan (1996), tacit knowledge can be traded, transferred or commercialised through knowledge transfer mechanisms, including hands-on training and demonstrations. Alternatively, organisations can consider a costlier IPTC mechanism by hiring or transferring the appropriate people.

While tacit knowledge is difficult to transfer, routines or technologies related to the firm's knowledge can be further developed, codified and embodied into a non-human knowledge system as organisational knowledge/assets (structural and relational capitals) for technology transfer purposes. Technology in this form is readily transferable, codified explicit knowledge (hardware, software specifications, patent documents) that can be codified in words, numbers or figures.

*Networks of knowledge.* The repeated interactions of individuals and workgroups over time create a shared understanding that enables knowledge transfer in the form of ideas. According to Argote and Ingram (2000), knowledge can be embedded in the various networks formed through the interactions among people, tasks or tools underpinning a firm, and the resultant knowledge can be shared, moved and modified within and beyond a firm's boundaries. Thus, knowledge transfer occurs within the organisation. This research focussed on dynamic interactions between individuals who were networking as part of their role within their structural resources.

**Structural resources.** Human resources, supported by appropriate structural resources, create and develop innovative works (Edvinsson & Sullivan 1996). The structural resources of an organisation are both tangible (equipment, buildings, machines, and financial assets) and intangible (customer databases, workflows and marketing plans, culture, reputation, strategy and intellectual assets).

*Sharing and preservation of IP.* An IP is an important structural resource, which Ng-Loy (2008) has defined by reference to the World Trade Organisation's agreement on Trade-Related Aspects of IP Rights OR TRIPS as:

- copyrights and related rights
- trademarks
- geographical indications
- industrial designs
- patents
- layout designs (topographies) of integrated circuits
- protection of undisclosed information, more commonly known as 'trade secrets'.

Except for trade secrecy, most IP rights are mobile, codified, and can be readily transferrable via appropriate legal contracts. Legally, all IP is regarded as personal and mobile property and may be assigned, licensed or mortgaged (Ng-Loy 2008); hence many jurisdictions obligate a patent holder to codify and publish all enabling intellectual knowledge in exchange for statute rights in order to exclude unlawful copying. This full disclosure allows future collaborators to replicate and validate the claimed IP before negotiating future technology transfer activities. Codified explicit knowledge can be readily imitable (Gunsel 2015; Lin, BW 2003; Teece 1986), and the transferee is unable to sustain its first-mover competitive advantage if the transferred IP is not accorded legal rights to exclude competitors (Porter 1985b).

*Patents*. Not all patents are useful transfer objects. Many process patents, except some new chemical products and simple mechanical inventions, can be redesigned to benefit followers in the market (Teece 1986), hence making patenting a hard decision for many organisations. Agreeing with Teece (1986), Bettis and Hitt (1995) note that chemical and pharmaceutical technologies are worth patenting, but electronics firms avoid patenting ideas that are readily imitable and duplicable within weeks.

Not only must organisations struggle to decide what technologies to protect from unlawful imitation, but they are also confronted with unlawful leakage of enabling information through the movement of people or interactions between organisations (Bettis & Hitt 1995). Therefore, while patenting gives the right to exclude competitors, it is sometimes challenging to ring-fence IP. On the other hand, putting IP into the market by licensing the technology to competitors offers the benefit of early adoption of industry technical standards, while sharing pioneering technology costs (Lichtenthaler, Ernst & Conley 2011; Porter 1985b).

While most innovations will involve some form of technology, not all technology-infused innovations are patentable. In recent years, differentiated business model owners, such as Uber taxi service and Airbnb accommodation providers, have generated unexpected market valuation and local regulatory attention in the United States (Rauch & Schleicher 2015). Susan and Serena (2014 ) report that Uber is still trying to overcome initial objections of the US Patent and Trademark Office about 'non-obviousness' or a 'lack of inventive step' for 10 of 13 patents filed. The following two points were raised:

- A business method invention is harder to secure a patent grant. The difficulty in obtaining a business method patent is reflected in a recent US court's decision to invalidate patents that simply digitise established business concepts.
- Proper due diligence on 'freedom to operate' (FTO) is necessary. Before they were publicly listed, companies such as Twitter and Alibaba ensured that relevant background patents were licensed in order to fulfil the FTO requirements of their in-house foreground patents. If proper due diligence is not upheld, Uber runs the risk of infringing relevant patents owned by IBM on mobile payments and by Nokia on mapping technology.

This Uber case example clearly shows that established business methods may not be a patentable subject matter or non-patent IP, even though the market valuation of Uber remains strong. In the Singapore context, the economic values of non-patent IP should not be underestimated. One-quarter of non-patent IP-owning forms earn positive revenue from licensing non-patent IP to third parties, which is higher than the 7.9% from licensing-out patents, according to a survey conducted by Wong, Ho and Singh (2006).

*Appropriability regimes*. On the use of protected IP as a competitive resource, Teece (1986) uses the innovation model called *appropriability regimes* to describe how a company can exclude others from quickly copying its innovation by retaining enabling knowledge within its organisation for competitive advantage. A company technology asset can be protected from imitations by strengthening its 'appropriability regime' through both legal mechanisms (e.g., patents, registered designs, trade secrets, and copyrights) and 'natural' barriers (e.g., difficult to replicate, and immobile tacit knowledge) that make imitation difficult (Chesbrough, H 2008; Pisano & Teece 2007). This model implies that a company with products protected with different tacit knowhow and capability and multiple legal appropriability mechanisms (patents, non-patent IP) will have a strong appropriability regime.

For example, Pisano and Teece (2007) explained that software technology enjoys a relatively strong appropriability regime in IP advanced countries because both patents and copyrights can protect the underlying concepts and codes. The appropriability regime of software technology can be further strengthened by the natural barrier with a non-reversible source code compilation or conversion. In contrast, mechanical technologies enjoy a relatively weaker appropriability regime; unethical imitators can convert the patented technology to non-infringing alternatives by observing the physical product (Pisano & Teece 2007), or by reviewing the public accessible patent documents in collaboration with IP professionals.

Armed with vast IP commercialisation business experiences, the product developer WorkTools asserts that, although patents are complicated, annoying and expensive, they will still be beneficial if a product will sell for many years (Invention City Inc 2021a). For example, WorkTools shared a success story of a patented mechanical fastener driver known as Gator-Grip Universal Socket that drives various types of fasteners, attributing its commercial success to the robust US patent regime (Invention City Inc 2021a).

To demonstrate that not everyone needs a patent to make or sell a product, however, WorkTools has shared a failure story in which an earlier patented mechanical fastener driver, SqueezeDrive, failed commercially due to lack of business knowledge about small markets and high production costs, as well a lack of insight into customers' interests, although the tool offered some fantastic, inventive features (Invention City Inc 2021b).

In Singapore, the legal rights to IP usually belong to the human creator, but it is not uncommon for organisations to own the legal right to deploy the IP created by their employees (Singapore Academy of Law 2017). This arrangement allows the organisation the freedom to trade, transfer, or commercialise based on known and mutually agreed IPTC mechanisms, including IP licensing or assignment. The effect on employees capable of producing innovations while working within such a firm-centric IP policy is worth a separate investigation.

In essence, it is tacit knowledge accumulated over time that is the best example of difficult-to-imitate resources. They are regarded as firm-specific assets that make competition pointless (Teece, Pisano & Shuen 1997). On the other hand, IP that is well-protected by the law and supported by organisations able to defend its integrity will also be able to fend off competition.

Although the appropriability regimes model highlights the influence of imitability, the imitability test of the IP's strength and the replicability can be subjective without scientific measurement methods. However, it is clear that a firm will decline if the firm ignores appropriability regimes. Besides appropriability regimes, a firm must know how to manage the innovation processes to bring its products to the market with the right position and timing.

*Dynamic capabilities perspective*. A firm's ability to manage (coordinate and deploy) its resources to meet the needs of a changing business environment is another feature of exercising competitive advantage. Teece, Pisano and Shuen (1997) extended the RBV theory by looking beyond merely tangible resources and considering a particular resource that was intangible – management capability. They referred to the management of resources in the organisation as the *dynamic capabilities perspective* (Teece, Pisano & Shuen 1997). Dynamic Capability scholars argue that as ordinary capabilities are the best practices for doing things right, SMEs can, therefore, outsource some of these ordinary capabilities at competitive prices to selected specialised contractors (Leih & Teece 2016; Schoemaker, Heaton & Teece 2018). Nevertheless, dynamic capabilities are about doing the right things, developed through sensing, seizing and transforming framework to allow an SME to flexibly manage (deploy, reconfigure and coordinate) its resources, competences and intellectual assets in a coherent way (Leih & Teece 2016; Schoemaker, Heaton & Teece 2018).

The concept of dynamic capabilities describes the rapidity with which capabilities can be engaged to successfully undertake management processes, such as how to adapt, integrate, transform, protect and use internal and external organisational, functional and technological skills. In a polytechnic and SME IPTC context, although SMEs can rapidly react to its dynamic environment, the polytechnics, due to their hierarchical structures, may have difficulty coordinating and re-deploying resources rapidly.

These are capabilities that rely on the quality of the managers and their tacit knowledge of management processes and routines that are usually developed in-house and are difficult to imitate, transfer or trade (Nonaka 1994; Schoemaker, Heaton & Teece 2018; Teece, Pisano & Shuen 1997). Mowery, Oxley and Silverman (1996) found that dynamic or complex capabilities are both difficult to imitate and difficult to transfer. They argue that they are more effectively transferred through equity joint ventures than contract-based alliances (licensing agreements) because capable managers possessing intangible knowledge will be able to participate in developing and bringing a product or service to market.

The RBV has been extended to incorporate networks of external organisations, non-competitors, and their interactions (Arya & Lin 2007). Arya and Lin (2007) showed that both internal and external resources allow non-profit organisations to collaborate in a networked environment to advance their capabilities in seeking clients, funds and government support. Here we can see a similarity between this and Porter's (1985b) view of awarding licenses to non-competitors to stimulate broad market appeal.

Lavie (2006) examined the competitive advantage of interconnected organisations' alliances using extended RBV and found that the relationships between organisations held more considerable significance than the resources held by the alliance organisations. John A

Mathews, JA (2003) extended the conventional RBV that took a firm-level perspective of resources to a larger scale and called that *competitive concept dynamics and economic learning*.

The economic learning perspective has organisations considering a broad array of external resources derived from the market or exchange of resources, including the development and leveraging of relationships that increase the value proposition (Mathews, JA 2003). In this context, it could be argued that SMEs would benefit from accessing the resources and the capabilities of non-competing partners, such as universities or polytechnics, to increase their competitive advantage.

### 2.3.3 Resource dependence theory (RDT)

Besides internal resources and capabilities, external interdependencies management is another aspect relevant to IPTC literature. Scholars of RDT, argue that the fundamental units for understanding inter-firm relations in an open innovation environment are organisation.

Thompson (1967) contingency theory posits that a firm's behaviour or structure is contingent on internal and external situations that reflect variations in technologies, coordination problems, and environmental pressures. Thompson suggests that managers isolate their organisations from internal and external disruptions by buffering and protecting their technical core (long-linked technology deployed in mass production, mediating technology used by banks, intensive technology deployed in hospitals), a closed component within the firm, closely aligning contingency theory to a closed innovation system.

In the late 1970s (Aldrich & Pfeffer 1976; Pfeffer & Salancik 1978), organisation scholars began to regard contingency differently and shifted focus to the organisation's interdependency with the environment (Scott 1981). Organisations in an open system are not autonomous, but were seen to depend on each other to survive or gain competitive advantage (Hillman, Withers & Collins 2009).

In open innovation, interdependence occurs when there is ambiguity relating to the control of the firm's resources and capabilities for survival and competitive advantage. Therefore, firms or universities take actions to reduce external interdependencies (Hillman, Withers & Collins 2009; Pfeffer & Salancik 1978). For example, IPTC partners could source critical external resources to innovate. In RDT, organisations or universities attempt to understand the environment while looking for alternative relationships, or to become less vulnerable to any threat to the supply of critical resources. For example, a university might reduce its dependence on traditional sources of financial income by increasing commercial technology transfer activities (Powers 2003), whereas, an organisation that embraces an RBV will tend to eschew alternative funding from technology transfer due to its interest in protecting unique and imperfectly imitable resources. Differences of opinion among university leaders may create tension in this situation, since some may wish to be in complete control of their resources. In contrast, others may believe that the open transfer of technology or knowledge will result in public good through the university's relationships with multiple organisations (Collier, Gray & Ahn 2011).

Both outlooks have their validity, and RDT mostly looks at the power balance, while also considering the sources of that power and the resulting consequences for inter-organisational relationships. Organisations attain control by building knowledge as a resource, seeking enforceable resource ownership, access, allocation, and utilisation (Pfeffer & Salancik 1978), allowing for mergers, joint ventures and co-optation while maintaining all possible autonomy (Davis, GF & Adam Cobb 2010; Hillman, Withers & Collins 2009). RDT is highly geared toward understanding the concept of power through relationship management, as opposed to management of resources like RBV (Davis, GF & Adam Cobb 2010). The three main concepts within RDT are:

- The social situation is essential.
- Organisational strategies must be geared toward autonomy/independence.
- Power and its influence within the firm and externally are more important than efficiency and rationality (Davis, GF & Adam Cobb 2010).

RDT examines the interdependence of organisations and is well suited for looking at the interdependency of joint ventures, which include strategic alliances, R&D agreements, research consortia, joint-marketing agreements and buyer-supplier relationships (Hillman, Withers & Collins 2009). Just like any inter-organisational relationship, in a university IPTC, universities (IP providers and non-product making organisation) are typically seeking the freedom to use the funds received from their resources (knowledge, technology or IP), exchanged or transferred. In contrast, as IP recipients, SMEs would seek autonomy to translate the exchanged

IP with in-house R&D capability or external partnerships. The external IPTC partnership can include polytechnic licensor, another polytechnic, or other private IP translators.

This university-SME relationship is most effectively defined through an IP licensing agreement, a contract-based alliance (Mowery, Oxley & Silverman 1996). According to Mowery, Oxley and Silverman (1996), IP licensing is less effective if the SME requires the IP to be transferred with the associated complex capabilities and tacit knowledge, which will require the two parties to consider an equity-based joint venture alliance.

Hillman, Withers and Collins (2009) reviewed and summarised ways on how RDT can be used to reduce resource dependency on others while promoting innovation capabilities by:

- creating mergers or integrating vertically to reduce the dependency completely
- creating a joint venture to partially reduce dependency through formal long-term contracts
- co-opting a board member
- undertaking political action
- planning executive succession.

RDT is also well suited to examine the power accorded by political action. A case in point includes the *Bayh Dole Act* that allows universities and colleges to seek new revenue streams through technology transfer activities. However, IPTC has a broader application across society than merely an economic one. Drees and Heugens (2013) used RDT to explain why some resource providers looked beyond economic performance to work with organisations with high societal acceptance or legitimacy. In summary, both RDT actions – political action or non-contract alliance – whether they be for economic gain or not, unquestionably provide a latitude for RDT scholars to explore how to manage relationships in a university-industry IPTC.

Casciaro and Piskorski (2005) expanded the RDT with two distinct theoretical dimensions, power imbalance and mutual dependence, which were incorporated in the original construct of interdependence. Power imbalance and mutual dependence should be considered bilaterally between the two collaborating partners. The power imbalance can be defined as the difference in each partner's power over the other, whereas mutual dependence captures the presence of bilateral dependencies. For example, a merger could be achieved with ease if both collaborating parties have strong mutual dependence, thereby nullifying any power imbalance.

RDT has been used to understand technology transfer, with Wayne (2003) employing RDT as a useful framework to define the relationship between external stimuli and university technology transfer performance. RDT perspective has contributed to appreciating how universities adapt to external environments. In the study, Wayne (2003) measures how accessing external public and private research or venture funding can influence university IPTC outcomes in terms of licensing revenue, number of licenses and number of start-ups formed.

Metzger (2000) showed that RDT could be used to analyse the influence of university policy and university structure on the economic performance of technology transfer. In the study, Metzger (2000) conducted mixed-mode research into both the internal and environmental factors that influenced IPTC. Common RDT themes were cited in the qualitative case interviews with four university TTO directors, which included representatives from start-ups or spinoffs (external firms). These interviewees preferred licensing IPTC of IP for life science but would take equity in IP for physical science. Knowledge of such IPTC practices could influence university IP policies.

Markman et al. (2005) affirm that RDT will influence the management of a TTO's work when the office is pressured by resource constraint, to speed up a university IPTC process, deal with IP disclosure evaluation, IP protection, IP licensing, and finalising the transfer with clients. Markman et al. (2005) found that:

- IP creators in the universities generally have a mentality of publication first, IP protection second.
  In the IP discovery and disclosure stage, faculty disengagement (resistance to disclosure for patenting, indifference to licensing opportunities, and poor-quality IP discoveries) will slow the IPTC process more than resource limitations (limited budget, time, capital and administrative support).
- IP creators in the universities are motivated by their projects, and the university's performance is somewhat secondary. In the final commercialisation stage, university

faculty will be more motivated and engaged either as faculty-inventors or faculty founders of a spinoff company. This engagement accelerates the IPTC process.

- Competent IPTC talents are rare. IPTC executives are expected to possess complex and context-dependent competencies. To attain a higher degree of effectiveness, TTOs may recruit the appropriate people, diversify relevant networks, develop better organisational routines, or outsource specialised services to external fee-based patent agents or technology consultants.

### 2.3.4 Explaining IPTC using RDT

In this section, relevant RDT concepts are mapped onto polytechnic IPTC practices based on the researcher's observations and interactions with other polytechnics' TTO managers.

During this study, SMEs were considered to be the focal organisations for taking IP from polytechnics (external organisations) to commercialise it. A polytechnic licensor will usually relinquish control of the IP rights to the SME licensee via a mutually agreed licensing contract in exchange for financial return, such as upfront and running royalties. Pfeffer and Salancik (1978) found RDT to appropriately describe the behaviour of SME managers involved in IP licensing activities, and RDT argues that an organisation will leverage its advantageous resource position to exchange financial, physical, information or social resources with external organisations.

**Types and value of resources.** IPTC managers and relevant IP creators conduct IP audits at a polytechnic to jointly review the polytechnic's R&D outcomes (e.g., drawings, computer programs, data, and findings). Such IP audits will determine if there are inventions that create value located in the institution, and whether they are sufficient to provide a buffer that allows further development of the resources (Thompson 1967, p. 20) in the polytechnic–SME IPTC context. Sufficient resources allow for the creation of innovative applications, materials, methods, products, or services, increasing an organisation's IP buffer.

The commercial value of such resources can be measured against Barney's VRIN competitive measurement model, and subsequently converted to IP in the form of patents, designs, trademarks, trade secrets or copyrighted materials to exclude competition. For example, a polytechnic that can patent some of its RIE outcomes generally possesses a cache of valuable

IP that SMEs want to access, especially if it is perceived as rare and inventive, imperfectly imitable (costly to copy), and non-substitutable (hard to replace or design around).

**The value of a resource increases with higher innovation maturity.** Various technological development frameworks, such as the *technology readiness level* or TRL and *system readiness level* or SRL, can be a risk assessment checklist for individual technology development and system maturity respectively (Lee, M-C, Chang & Chien 2011). Existing literature on TRL and SRL has largely ignored the role of the management of innovation throughout the evolution to market. Therefore, a recent study incorporated TRL and SRL into a newer framework referred to as *innovation readiness level* or IRL (Evans & Johnson 2013; Lee, M-C, Chang & Chien 2011) to review and assess the firm's management capabilities with regards to innovation processes and activities. Integrated with a market dimension, Innovation Readiness Level (IRL) can be used as an innovation management framework for innovating SMEs.

As an IP producer, a polytechnic could use the TRL to assess the costs of IP creation and development. The TRL proposes a nine scale instrument: starting from basic principles observed and reported (level 1), and finishing at system testing at appropriate actual environments (levels 8-9), passing through technology and/or component prototyping and validation in a laboratory environment (levels 2-4), and through component and/or subsystem prototyping and validation in various relevant environments (levels 5-7) (Lee, M-C, Chang & Chien 2011; Mankins 1995). According to Mankins, as the technology matures through the nine levels, level 8 (system testing at the actual environment) has the highest 'unique' cost (Mankins 1995).

It is commonly expected that university research will cease at prototyping in a laboratory environment, whereas polytechnics are recognised for their practical application of IP where prototyping will usually cease at higher TRL levels. It is worth investigating whether polytechnics could and should charge a higher IP commercialisation fee when their TRL is higher.

The high level of TRL achieved by a polytechnic provides the institution with greater certainty and better control over their IP – a common practice in IP management. Polytechnics' access to public and private R&D funding may fluctuate over time; thus, to buffer against uncertainty, polytechnics need to calibrate R&D efforts according to current national technology policies. However, this reactive approach may limit the scope and variety of technology offered to the public, SMEs included.

A similar buffering effort applies to an SME. For example, an SME retailer may wish to buffer and protect its market knowledge and users' insights as a valuable resource and outsource non-core product development and manufacturing to external companies. A classic buffering example is Apple Computer's decision to focus on its internal resources (Apple Disk Operating System and the supporting macro software) and outsource non-core manufacturing (Quinn & Hilmer 1994).

Hillman, Withers and Collins (2009) discuss external sourcing strategies, such as co-opting and joint ventures (strategic alliance and R&D agreements), to minimise dependence and to complement internal resource shortfalls. Such concepts are relevant to SMEs, as not all SMEs are self-sufficient. Ideally, SMEs that have the rarest resources, most significant control over resources, and least dependence on third parties are the most autonomous and able to forge certain types of relationships with other organisations in the environment. Generally, organisations either manage the environment by avoiding resource interdependencies or by acquiring and developing the dependency (Aldrich & Pfeffer 1976).

Generally, the RDT model accurately captures the nature of inter-organisation general relationships, their environments, and their interdependencies (Hillman, Withers & Collins 2009). Hillman, Withers and Collins (2009) have integrated RDT with a variety of other theoretical perspectives to describe better specific inter-organisation relationships, including network theory (merger), game theory and organisational learning (partner power), transaction cost (partner choice), and resource-based view (partner complementarity).

The current research was undertaken with the view that it would be possible to integrate RDT with other relevant theories to explain how an SME could obtain a competitive advantage by licensing the required IP from a polytechnic (complementary partners) to reduce interdependencies.

**Management approaches to reducing resource dependency.** Managers of independent organisations who recognise their resource dependency will naturally make attempts to reduce their dependency or to be strategic in selecting the required resources and partners. Casciaro and Piskorski (2005) suggest that being flexible about the desired resource or developing alternative resource suppliers are options for avoiding being constrained by a troubled partner relationship characterised by potentially harmful dependency. RDT recognises that managers may seek a merger to fully negate IC resource constraints, or a joint venture (strategic alliance) (Casciaro & Piskorski 2005; Hillman, Withers & Collins 2009).

Based on the RDT view, Table 2.3 proposes how a polytechnic can control and exchange its resources within its particular network of institutions and organisations. The table connects the various resource types to key questions regarding their availability, importance, and control instruments. In a short-term IPTC project, a polytechnic will consider attaching its invaluable innovative and capable staff resources to the industry via a short-term attachment contract. By contrast, in a longer-term IPTC project, the polytechnic will not hesitate to release IP and inventions that are by-products of its R&D activities to SMEs for commercialisation through IP licensing agreements. In the case of a patent licensing deal, the SME licensee can expect up to 20 years of freedom to control the transferred IP. This longer duration allows the licensee to recover the product development costs for financial gains.

**Table 2.3 Accessible resources in a polytechnic**

<table>
<tr><th>Types</th><th colspan="2">What resource is accessible for exchange?</th><th>Is the resource critical to the organisation?</th><th colspan="4">What contract controls the dependencies?</th></tr>
<tr><td rowspan="3">Intellectual assets</td><td>HC</td><td>Individual creativity, experience and knowledge</td><td rowspan="5">RBV<br>• valuable<br>• rare<br>• imperfectly inimitable<br>• non-substitutable</td><td colspan="4">Employment, attachment, internship enrolment contracts</td></tr>
<tr><td>SC</td><td>IP, Poly reputation, IPTC processes</td><td>NDA</td><td>LA</td><td>RCA</td><td>MTA</td></tr>
<tr><td>RC</td><td>Partnering agreements with external parties</td><td>NDA</td><td>LA</td><td>RCA</td><td>MTA</td></tr>
<tr><td rowspan="2">Physical assets</td><td>Infrastructure</td><td>Laboratory equipment, machines and facilities</td><td colspan="4">Consultancy/service contract</td></tr>
<tr><td>Inventions</td><td>Prototypes and samples</td><td>NDA</td><td>LA</td><td>RCA</td><td>MTA</td></tr>
<tr><td>Legend</td><td colspan="7">NDA: non-disclosure agreement, LA: licensing agreement, RCA: research collaboration agreement, MTA: material transfer agreement</td></tr>
</table>

**Dependencies acquisition and adaptation approach**. Other inter-organisational theories describe how resource dependency is addressed by pooling or integrating an organisation's resources and activities with those belonging to another organisation. Resources pooling can be achieved by one organisation acquiring or merging with another. According to Todeva and Knoke (2005), out of 13 forms of inter-organisational relations, acquisition ranks at the top in market interaction. The result will be bureaucratic integration where one organisation takes full control over the partnering organisation's resources and capabilities as a single entity. IP licensing is placed in ninth position, closer to the end of the spectrum where transactions are done at arm's length.

Through the researcher's observation of past involvement as a manager in the TTO and a secretariat member of the Technology-Innovation-Enterprise Management Committee of the Ministry of Education (MOE): as an education institution, a polytechnic cannot merge with an SME or other commercial entity, but in the SME IPTC context, both can use contractual relationships with similar organisations to themselves to enhance their resources and activities. The following forms of the merger are ideal and attractive:

- *Vertical merger.* A polytechnic can vertically merge with a university to provide a complete spectrum of RIE activities, both upstream and downstream. On the other hand, an SME licensee may acquire a manufacturer to gain control and create a certainty of supply quantity and quality.

- *Horizontal merger*. All polytechnics can come together to pool their resources, often duplicated, to provide a first-stop mega IPTC centre for SMEs. Besides, organisations can also perform horizontal mergers by acquiring a competitor organisation that produces or sells an identical or similar product.

If equity holding is used as the IPTC mechanism through spinoff formation, it is not uncommon to co-opt a polytechnic/university member as a director to the organisations, with prior approval, to provide the needed advisory and information channels, preferential access to resources and legitimacy (Hillman, Withers & Collins 2009; Wong, Ho & Singh 2011).

Organisations could also consider the following inter-organisational relations motivated by economic and strategic factors (Todeva & Knoke 2005):

- *Joint venture*. Pooling resources across organisations can also be accomplished by a joint venture, whereby two or more organisations create a new organisation in order to pursue an R&D or marketing project in a predetermined period.
- *R&D consortia*. Through agreements, organisations can also consider temporary strategic alliances as another means of pooling and sharing resources between two or more organisations.

In the context of IPTC, a research and collaboration agreement could become a joint venture, whereby resources, including human resources, are exchanged between polytechnics and SMEs for a short time, which can be extended if there is uncertainty and further need for dependency.

### 2.3.5 Value-added activities and resources

Michael Porter defines the term 'value' in his 1985 book Competitive advantage: Creating and sustaining superior performance as:

> *In competitive terms, value is the amount buyers are willing to pay for what a firm provides them. Value is measured by total revenue, a reflection of the price a firm's product commands and the units it can sell. A firm is profitable if the value it commands exceeds the costs involved in creating the product. Creating value for buyers that exceeds the cost of doing so is the goal of any generic strategy. Value, instead of cost, must be used in analysing competitive position since firms often*

*deliberately raise their cost to command a premium price via differentiation. (Porter 1985a, p. 38)*

For Peteraf and Barney (2003) economic value is derived by an organisation that provides a product or service and is the difference between what is a perceived benefit for which the customer is willing to pay, compared to the cost which the producer has paid to produce that product or service. Creating economic value for universities in the US was a way to generate revenues to offset decreases in traditional funding by commercialising research through IPTC, thereby giving economic value to that research (Andes 2016). However, most IPTC is deemed to be a 'failure' since most universities generate minimal licensing fees and the cost of operating a technology transfer office far exceeds the revenue derived from the licensing (Andes 2016). Therefore, this begs the question of how to value technology transfer.

The Stanford Office of Technology looks at value as the potential to create change and have an impact, besides creating public good and making revenue. They point out that in many cases the potential is not always known until later, and that in some cases, like the *Bayh-Dole Act*, legislation has proven to be invaluable since it stimulated an entrepreneurial drive for universities to collaborate to bring about outcomes that could be brought to the private sector (Stanford Office of Technology 2009).

For Stanford, value also means valuing the inventors and the relationships with stakeholders, and licensees. Stanford has a broad and more holistic view of value beyond simple dollars and cents and argues that there is a level of social responsibility in how value is perceived. The value of an invention is both practical, particularly where there is clinical value, as well as financial (Stanford Office of Technology 2009).

Licensing is only one means of generating revenue. The establishment of new start-ups or spinoffs, designing curricula directed at specific industries, increasing the relationship between academia and industry to extend to industry-related research, and providing technology consulting to the industry, are other ways in which to generate revenues (Andes 2016). There are limitations to patents and licensing, given the limited number of technology categories; thus opportunities to generate revenue and achieve economic value are restricted (Andes 2016).

Merriam Webster defines value as 'fair return' but defining 'fair' creates problems, given the subjective nature of what is fair (Stanford Office of Technology 2009).

In the context of this research, an exorbitantly priced IP licensing deal would, therefore, create little or no value for the licensee if the licensed IP fails to be transformed into to a successful commercial product.

**Value.** When discussing value, it is worth remembering that value will have a different meaning to the end-users, organisations (product manufacturer, or the service provider), ecosystem and society (Den Ouden 2011). According to Den Ouden (2011), value overlaps, the values flow from the end-user to the society, passing through organisations and ecosystem. For example, a product end-user would regard a more economical and better-performing product as valuable (Stabell & Fjeldstad 1998).

For a product manufacturer, value resides in activities performed within and around an organisation to improve its competitive advantage (Porter 1985a). According to Porter, a good understanding of a value chain model is that an organisation's primary product manufacturing activities (logistics, operations, marketing and sales, and service) and support activities (procurement, technology development, human resources or capabilities, and infrastructure) are the building blocks that put the value in the chain.

Upon analysis, these discrete activities and their linkages determine the level of success of an organisation, and the quality of their performance is directly related to the organisation's competitive advantage. Managing the elements of the chain effectively and the relations between them will have an economic impact, including cost reduction advantages (Porter 1985a).

For a service provider that supplies expertise and IP to solve a client's problem, Stabell and Fjeldstad (1998) have introduced a model for value-adding analysis for a professional service organisation (medicine, law, architecture, and engineering). On the other hand, Porter's value chain analysis, which is designed for manufacturing firms, considers a five-activity chain (problem-finding/acquisition, problem-solving, choice, execution, and control/evaluation).

Generally, resources are required, transformed, and interact throughout a product or service development. Pike, Roos and Marr (2005) argue that value is created if resources are transformed through intellectual capital (IC), physical, and monetary means. Without a solid understanding of required resources, their interaction and how they rely on each other to create value, it is difficult to manage and allocate resources in an IPTC process strategically.

This thematic analysis of SME managers' experiences and perceptions on IPTC activities would help both polytechnic and SMEs to identify and perform valuable activities as professional IPs, and manage their relationship.

### 2.3.6 Competitive forces perspective

Motivations to share IP differ, depending on perspective. Ideas, knowledge and IP are owned, used, developed and distributed by competitors or non-competitors within an industry, but most technology licensors are motivated by financial gain (Lichtenthaler, Ernst & Conley 2011). Porter (1985b) states that the value of technology in achieving a competitive advantage is realised when that technology improves the firm's cost position or differentiates the firm, product or service from others.

According to Bou-Wen Lin, BW (2003), high-value technology manufacturers in countries like China, Taiwan and Korea attempt to attain competitive advantage by learning and accumulating, adapting and transferring acquired background technology, codified or tacit.

Porter (1985b) notes that many technology leaders deliberately slow technology diffusion by how they transfer the technology, either directly or indirectly, in order to protect their investment. The organisation introduces its innovation through resource buyers, equipment suppliers, vendors or personnel rather than licensing it to eager licensees anxious to enhance and distribute the technology. This strategy allows the IP owner to maintain control of the IP and retain the profits.

Technology transfer can be a risk to long-term profitability if not carefully planned, so other organisations often pursue extensive technology patenting and aggressive enforcement or retain enabling information to slow down the rate of diffusion.

To prevent copying through technology acquisition in countries where IP enforcement is a complex issue, organisations can opt to keep competitive advantage knowledge (technical or non-technical) tacit and confidential. This undisclosed information is known as a trade secret (Ng-Loy 2008) that is commonly used by beverage firms, such as Coca Cola, to sustain the first-mover advantage. While patenting gives the right to exclude competitors, licensing the technology to competitors drives early adoption of industry technical standards while sharing pioneering technology costs (Lichtenthaler, Ernst & Conley 2011; Porter 1985b).

Mapping the interest of two parties may lead to a win-win situation overall. Under the competitive force's approach, an SME could simply acquire or license the desired IP owned by a polytechnic to attain cost and product differentiation. A polytechnic or university is a publicly funded educational provider, and a non-product producer is expected to supply non-core IP to SME IP recipients who produce products for the public good. Without having an interest in converting the IP product, a polytechnic could play a complementary role.

Michael Porter's five-forces framework (the entry of new competitors, the threat of substitutes, the bargaining power of buyers, the bargaining power of suppliers, and the rivalry among the existing competitors) provides a useful way of thinking in interpreting the positioning of an SME IP-buyer when licensing IP from a polytechnic IP-supplier in the innovation ecosystem of Singapore.

Figure 2.7 maps the relationship between a university (or polytechnic) and an SME in terms of Michael Porter's five-forces competition framework. Clearly shown in the figure, a university (or polytechnic) is situated in the supplier category in the structure, where they seek to provide SMEs with commercially applicable IP or technologies.

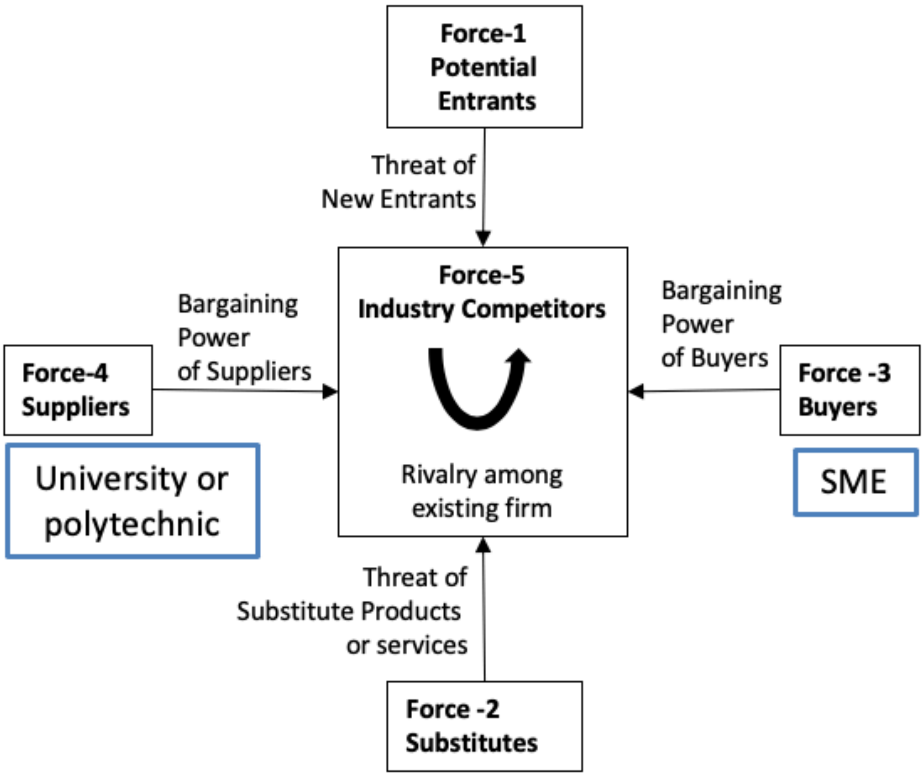



**Figure 2.7 Adapted by the researcher from Michael Porter's *The five competitive forces.* Source: Porter (1985a, p. 5).**

Using a simplified direct buyer-to-supplier (SME-to-polytechnic) relationship, the IPTC industry seems to be less profitable for the polytechnic IP-supplier. The SME IP-buyer can bargain for a cost-effective IP since there are many polytechnic IP-suppliers who have no intention of commercialising the IP themselves. Besides, most polytechnics (rivalry among existing firms) and other IP-suppliers (new competitions or substitutes) are not obliged to produce IP to meet a specific SME's need but tend to a create a wide range of invention IP enabled by a diverse range of different technologies – equivalent to the concept of an IP 'supermarket'.

This five-forces framework was used to inform the research about the decision-making factors influencing the SME IP-buyer that include: threats of new or substitution products, the need to be cost-effective, and the influence of a polytechnic's reputation. Since organisations need time to develop resources that they lack (Teece, Pisano & Shuen 1997), and product making is not the polytechnics' core business, SMEs could save both time and resource investment by developing the IP licensed from scratch.

In addition to Porter's five-forces, organisations may consider four alternative strategies – increased market penetration, market development, product development or product diversification (Ansoff 1957). Reflecting on the need to achieve a competitive advantage, both Porter's and Andoff's work helped this study to understand the reason why an SME (product-producing firm) would depend on IP produced by a polytechnic (public IP supplier that does not produce products) to lower product development costs.  While Porter's views on competition strategies are more a deliberate strategy planning, Mintzberg's 10 strategic management strategies are more relevant in today dynamic world where new technologies emerge, and old technologies are constantly updated (Mintzberg, Lampel & Ahlstrand 2017). For instance, IPTC partners could consider Mintzberg's *The Design school* thinking to create a competitive strategy to match the firm's internal capabilities and external environment; or adopting Mintzberg's *The positioning school* approach when analysing the content and results of the winning market positioning strategies (Mintzberg, Lampel & Ahlstrand 2017).

### 2.3.7 Competitive advantage and the tertiary sector

In a competitive funding environment, universities are seeking new revenue streams from the commercialisation of academic research or third stream activities (Leih & Teece 2016; Lockett, Wright & Wild 2013). For this reason, educational institutions attempt to strengthen their intermediary resources to facilitate IPTC processes.

Not surprisingly, many research universities began to develop a one-stop IPTC complex, co-locating all different skills and resources in one location (Geiger 2006). Such technology transfer complexes typically house a range of offices (industry liaison, IP transfer and commercialisation, entrepreneurship, venture and public funding, research park and business incubator) staffed by highly trained professionals. They work to build relationships with the private sector or funding agencies. The groups specifically look to link academic expertise with the research needs of organisations. These TTOs work to promote and market technology licensing and manage academic proposals that may require patenting, as well as work to establish start-ups.

Tertiary institutions pursue IPTC, not for profit, but alternative values and a better public image. While the intent is to create a competitive advantage for each institution and generate revenue to sustain operational costs, Mowery, Sampat and Ziedonis (2004) found few institutions were achieving profit through patent commercialisation. This observation is supported by (Geiger 2006), who found that only 34 institutions generated US$5M in revenue from licensing, and it was contended that those that were making less were probably losing money.

Typically, an IP is licensed in return for an up-front issue fee and a royalty on the product sales. Most upfront fees fall between US$10,000 and US$50,000, while most royalty rates range from 2% to 5% (Bray & Lee 2000). A commercially successful product will return the licensor a better royalty income. The struggle is to establish a middle ground between profit maximising through multinational licensees who are both skilful and resourceful in commercialisation and delivering public goods through local SME licensees to create jobs (Cripps et al. 1999).

These studies (Geiger 2006; Mowery, Sampat & Ziedonis 2004), when taken solely from an institutional perspective, suggest that there is limited economic value to the seller, that is, the university. They also suggest that further research is necessary in order to understand the long-term value of the patent or license from the buyer's perspective; that is, who purchases the patent or license, and what is the broader, more macro effect that patents or licenses have across society in the long term? The definition of value is a function of the financial limitations of what it costs to operate a TTO and the value of the patent or license at the time it is sold, not what it can bring in the future. Measuring the value of a TTO and the cost to operate it, along with the money generated from licenses and patents, could be misleading when looking at it solely from a financial point of view.

For institutions to create a competitive advantage under Porter's (1985b) maxim of IP differentiation or cost leadership, it appears that despite having any IP differentiation, the cost of developing and protecting the IP, whether through patenting or not, is, in fact, operationally prohibitive when universities are under siege from governmental funding reductions. Cripps et al. (1999) found that institutions involved in IPTC are primarily motivated by money that can be used to support the shortfall in government funding, and supplement academic salaries. Thus, the institution's management must decide the value of sustaining a TTO that continues to lose money. Chapter 4 provides an overview of the characteristics of funding agencies, polytechnics, and SMEs contextualised in the Singapore triple helix innovation model.

Since IPTC is considered an unsustainable model in business, it is intriguing to find out why some universities still strive to generate patents and licenses regardless of whether they are making a profit. The question is whether the IP differentiation provides a competitive advantage for the institution sufficient enough to justify the losses in bringing the IP to market. The problem raises the question of university (or polytechnic) values. However, they are public institutions, and for them sustaining such a costly technology transfer business to either deliver public good or to enhance the perceived value of the university and university-industry ties means they can attract more students.

### 2.3.8 Competitive advantage and small-medium-enterprises (SMEs)

Organisations acquire strategic resources to complement internal skills and resources. To achieve long-term economic success, a firm can gain competitive advantage through a near-perfect estimation of the future value created by its strategic resources, or leave it to luck from an incorrect estimation by its competitors (Barney 1986). Ong, Ismail and Goh (2010) affirm the importance of both entrepreneurial attributes and luck (endogenous or exogenous) in sustaining a competitive advantage for SMEs. Such an affirmation suggests that SMEs must compete through the careful formation of strategic partnerships to access complementary resources and by conducting in-house experimentation to promote endogenous luck since exogenous luck is less predictable.

Barney (1986) stresses that entrepreneurs place greater emphasis on future products, and that universities in the technology transfer market are meeting this need, but that SMEs appear not to have sufficient drive. Often, they lack or have a limited technological infrastructure for knowledge storing and processing, and depend on a partnership with other organisations to transfer codified technology to remain competitive (Gunsel 2015; Lee, J & Win 2004). SMEs in the electronics industry in Australia, for example, appear to value incremental innovation of existing products and ideas with proven market potential rather than competition in an uncharted market, which requires more abundant resources to pursue (Collier, Gray & Ahn 2011). While SMEs can create strategic alliances or partnerships through which to forge mutually beneficial cooperative ties that share or delineate specific responsibilities, there must exist legally binding contracts to prevent IP theft.

## 2.4 Research gap

The literature review highlights the fact that there is virtually no knowledge base specific to the understanding of IPTC between polytechnics and SMEs in Singapore. However, the three key literature themes that relate to university-industry IPTC were reviewed to inform the development of the general research questions for this research. The knowledge gap relating to the polytechnic's role as an IP translator and the influential factors at work in its business environment were answered by a descriptive case study using secondary data sources. Scholars' concerns, including the value of patent, the motivations, and the desired controls from the buyers' perspective, were established using a descriptive case study based on thematic analysis of the interview data.

## 2.5 Summary

This chapter reviewed the literature, categorised according to three relevant IPTC themes that relate to university-industry IPTC. The themes were: university IPTC processes, university IPTC ecosystem, and competitive strategies concerning IPTC. The literature review identified the research gaps in direct research related to IPTC between polytechnics and SMEs in Singapore. Since universities and polytechnics share space in the educational and knowledge transfer environment, the three themes related to university-industry IPTC were used to inform the development of the general research question for the present research. The chapter reviewed relevant organisational theories and provided the rationale for selecting the RDT as the dominant theoretical framework, and the use of intellectual capital (IC) perspective to analyse the IPTC activities and resource transformation. The next chapter will provide background on the study methods.

Chapter 3

# Research methodology

## 3.1 Introduction

This chapter explains the research method adopted to determine what environmental factors influence IPTC between SMEs and polytechnics in Singapore, and considers the related IPTC relationships from the SME's manager's perspective. Chapter 2 discussed and analysed the literature, while this chapter will layout the methods employed to address the research questions, provide an in-depth discussion of the research design, and explain data collection and analysis.

## 3.2 Conceptual framework

The research sought to understand the phenomenon of commercialisation of IP acquired by SMEs from the polytechnic sector in Singapore. Although the creation and commercialisation of IP are central to Singapore's development, there has been little or no research into the activities and relationships of Singaporean polytechnics and SMEs. Understanding the factors that influence the IPTC relationships between these two sectors, and the attitudes and behaviours of SMEs towards IPTC, is a critical first step to making the most of Singapore's creative and human capital. This research was qualitative and interpretive.

Basically, there are five major types of approaches available for qualitative researchers: narrative research, phenomenology, grounded theory, ethnography, and case study (Creswell 2007). Qualitative researchers collect and analyse *words as data* in all sort of ways, flexibly, while quantitative researchers collect and analyse *numbers as data* using a singular statistical method (Braun & Clarke 2013; Cassell et al. 2006). Using a statistical method, a quantitative researcher can generalise findings using broad data obtained from a large pool of participants in order to test a theory objectively (Braun & Clarke 2013). Because the sample pool in this study was tiny due to the limited number of participants with appropriate experience in Polytechnic-SME IPTC, a qualitative paradigm was preferred.

Based on a study conducted by Teng (2016), four out of the five polytechnics in Singapore collectively licensed out 91 separate pieces of IP to industry between 2005 and 2016. This collective performance indicates that IP licensing in the polytechnic sector is merely an emerging phenomenon, and the number of cases is too small for a large quantitative study.

Quantitative means of objective or unbiased validation are valued and more highly regarded by most top management journals (Cassell et al. 2006; Gummesson 2006), and quantitative methods are popular in publication driven research. Generating the data for a qualitative study may involve hours of interviews, thematic analysis, documentary research and analysis or researcher participation, among other data collection methods. The sample pool is often too small to realistically generalise the analyses (Braun & Clarke 2013).

However, although qualitative research may take longer and cost more, while lacking generalisability, the thicker descriptions of the study phenomenon contained in the data allow a qualitative researcher to investigate data offering more rich detail, and gain a better understanding of the nuances of a particularly complex event or state (Gray, Micheli & Pavlov 2015; Gummesson 2006). Focusing on particularity helps researchers unravel complexity, providing a deeper understanding of relevant activities (May & Perry 2011).

According to Braun and Clarke (2013), qualitative research aims to explore and make meaning of a particular phenomenon through language laden data collected from small samples within a specific context, and a theory is developed inductively with the researcher's involvement encouraged.

Tufford and Newman (2012) discuss how a researcher could use bracketing methods, including memo taking, bracketing journals, or bracketing interviews with trusted colleagues, to set aside personal preconceptions (assumptions, values, interests, emotions and theories) on a research topic. A researcher's awareness of their preconceptions before and throughout the research process aids in the collection of data, its interpretation and presentation, and self-awareness is one of the most challenging aspects of qualitative research.

Charmaz (2006) emphasises the point that researchers who code interview data are expected to grapple with their worldview, standpoint and situation when interacting with language laden data. The world is constructed by language, and prior knowledge of the language, or jargon, used in the research space helps the researcher better understand the data. According to

Charmaz (2006), through iterative line-by-line coding, researchers define and refine codes by studying participant actions and statements, which helps overcome preconceived notions of the data.

Braun and Clarke (2013) highlight how a qualitative researcher can use spoken or written language (words) to discover the meaning of a phenomenon by focusing on:

- *what is said at its face value*
  Based on the theory that language reflects reality, the researcher will try to understand a participant's perspectives, views, experiences and/or meanings. This is referred to as *experiential qualitative research*. Experiential qualitative research is commonly used to analyse spoken language where the focus is on the words uttered by the participants (*not* how it was said). An interview transcript that records incomplete dialogue, excluding such nonverbal language cues as non-semantic sounds, hesitations, repetitions, and pauses, can still be used as the data source for experiential qualitative research.
- *what and how it is said*
  Based on the theory that language creates reality, meaning can be constructed through pattern-based discourse approaches and texts deconstructed to interrogate the associated hidden or dominant assumptions. This is called *critical qualitative research*. A thorough transcription that captures details of *how* something was said is better suited for the critical analytic method.

The aim of this research was to give a voice to selected SME managers who had prior IPTC experience with polytechnics. Experiential qualitative research was therefore adopted.

## 3.3 General research question

The guiding research question was developed in line with the idea that a written or spoken language reflects reality, forming the framework through which people make sense of their world. To reiterate, the RQ was: *How do human and structural resources contribute to or impede the intellectual property transfer and commercialisation (IPTC) process in the Singapore polytechnic context?*

Subsidiary question SQ1(a&b) was directed at describing the roles and characteristics of relevant IPTC stakeholders, along with relevant resources and capabilities. The objective was to determine the specific factors that were essential to SMEs as product firms and polytechnics as IP translators.

SQ1a) What are the current features of Singapore, SMEs and polytechnics that characterise their development and translation of IP?

SQ1b) What features relating to the development and translation of IP are shared by polytechnics and universities, and what features are not?

Subsidiary question SQ2(a&b) sought to understand the SME managers' perspectives on the phenomenon of IPTC, capturing their views and the meaning the managers assigned to their experiences.

SQ2a) What are the outstanding characteristics of the IPTC negotiations/knowledge transfer/licensing processes involving an SME and a polytechnic?

SQ2b) What type of resources and capabilities are valued and transferred from polytechnics to SMEs by the relevant stakeholders and vice versa?

## 3.4 Research design

A research design is 'a logical plan' that guides the researcher to collect, analyse and draw conclusions about the RQ (Yin 2003, p. 21). The RQ is about the polytechnic IPTC context, and polytechnic-SME IPTC process. The question and its subsidiary queries were answered by firstly collecting and examining publicly available information about the innovation characteristics of polytechnics and their IPTC stakeholders, followed by interviewing SME managers to identify and analyse their unique IPTC experiences and determine their decision making processes. A case study approach was considered appropriate for this research because a case study investigates a contemporary phenomenon; in this instance, the IPTC process in a real-life polytechnic-SME context (Yin 2003).

The RQ was divided into subunits, as shown in Figure 3.1 to address the goals of the research study.

### 3.4.1 Case study research

The case study method is used in a variety of fields: psychology, anthropology, sociology, history, political science, education, economics, management, biology, and medical science (Flyvbjerg 2011; Yin 2003). It is a common method used to explain the causal link, describe an intervention, a process or a real-life context, illustrate specific topics, explore unique situations and conduct a meta-evaluation of complex interventions (Flyvbjerg 2011; Yin 2003). Case study research can be sub-categorised into exploratory, descriptive, or explanatory types (Yin 2003). A case, or a unit of analysis, is related to the way the initial research questions are structured, and the analysis can pertain to individuals, entities, experiences, processes or events (Baxter & Jack 2008; Yin 2003).

Case study research can be differentiated from other qualitative techniques by case demarcation, small samples, and in-depth analysis. While the research processes or methods (interviews, participant observations and documentary analysis) used in the case study are generic across qualitative research, the uniqueness of the case study lies in the case boundaries and the small samples to provide relatively in-depth data for particularisation of theory development (May & Perry 2011).

| **RQ: How do human and structural resources contribute to or impede the intellectual property transfer and commercialisation process in the Singapore polytechnic context?** | |
|---|---|
| **Research subunit 1** | |
| ***Subsidiary question SQ1(a&b)*** | ***Purpose of subunit investigation*** |
| a<br>What are the current features of Singapore, SMEs and polytechnics that characterise their development and translation of intellectual property? | To describe and characterise the roles played by the IPTC stakeholders located in Singapore, focused solely on the city-state, IHLs and SMEs |
| b<br>What features relating to the development and translation of intellectual property are shared by polytechnics and universities, and what features are not? | |
| ***Documentary research and analysis***<br>Took the form of the collection and analysis of relevant data sets drawn from publicly available sources, such as documentation, reports, survey data, websites, and literature.<br>Analysis and interpretation of relevant documentary sources resulted in a better understanding of what environmental factors influenced IPTC between SMEs. | |
| **Research subunit 2** | |
| ***Subsidiary question SQ2(a&b)*** | ***Purpose of subunit investigation*** |
| a<br>What are the outstanding characteristics of the IPTC negotiations/knowledge transfer/licensing processes involving an SME and a polytechnic? | To explain the decision on whether or not to commercialise an IP taken from a polytechnic, based on the experiences and perceptions of SME managers. |
| b<br>What type of resources and capabilities are valued and transferred from polytechnics to SMEs by the relevant stakeholders and vice versa? | |
| ***Thematic analysis***<br>Data for this second embedded case was collected mainly in the form of responses to semi-structured interviews and analysed using thematic analysis (TA), a method for identifying and analysing patterns or themes in qualitative data advocated by Braun and Clarke (2006). A theme reflects something significant and meaningful in the data (Braun & Clarke 2006).<br>Wherever possible, the understanding of issues was enhanced by examining relevant data sources, such as product web pages and prototype review. | |

**Figure 3.1 The research question structure and methodology**

A case is just a constituent member of a population of cases, and generalisation based on the analysis is about a particular case or a similar case, not on a population of cases (Stake 1978). Stake argues that while generalisation may assist readers to understand general conditions revealed by the data, they may see the phenomena somewhat simplistically. However, case researchers have the tools to assist readers to develop appropriate generalisations. By presenting an analysis of the research participants' tacit knowledge of 'how' and 'why' things are, and how things are perceived or felt by participants, the case study provides details that can be readily and naturally applied to a reader's situation or comparable situations (Creswell 2007, p. 163; Melrose 2009; Stake 1978).

**Qualitative case study research in IPTC research.** Cunningham, Menter and Young (2017) conducted a systematic literature review on the themes and trends of qualitative case study methods in technology transfer research based on top journals like the *Journal of Technology Transfer, Research Policy, R&D Management, Science and Public Policy,* as well as *Technovation*, from 1996 to 2015. Their review yielded 107 unique articles that applied case study methods in the context of technology transfer. The key findings from the review were (Cunningham, Menter & Young 2017):

- A range of qualitative research is used to seek insights into different factors that influence TT processes. The following is the percentage distribution of research methods reported: a form of case study research (42%); a form qualitative analysis (22%); data triangulation (14%); literature analysis (10%); miscellaneous, including ethnographic analysis, explorative analysis, grounded theory and thematic analysis (14%).
- Top TT journals publish the outcome of qualitative case study research with a range of sample sizes. About 40% of the articles used small samples (less than four individuals), while 37% used a higher number of cases (more than 25).
- The most frequently used primary data collection methods were semi-structured interviews, telephone interviews and questionnaires. Data reports, websites and newspapers were the most used secondary data collection methods.
- Only a minority (about 13%) used a form of data analysis software. *N-Vivo* and *Atlas.ti* were the more common analytic tools used.

This recent systematic literature review of Cunningham, Menter and Young (2017) revealed that case study research, semi-structured interview, and documentary analysis are gaining traction in TT research. Such findings provide further support for the choice of this research design.

Another reason why qualitative research was preferred for this research was the current lack of studies relating to polytechnic and SME IPTC, as highlighted by the literature review. Case study research is best suited for exploratory research where theory could be developed through case boundaries demarcation, and in-depth data analysis of small samples (May & Perry 2011). According to Yin (2003), a case that was previously inaccessible to the scientific community will justify documenting and analysing as a single revelatory case – a design that was adopted for this research.

**Single-case design.** In Singapore, 'polytechnic' is an education sector consisting of five institutions (polytechnics or polys) that provide tertiary education separately from the university education sector. Polytechnic education sector allows the transfer of knowledge to SMEs through the development of skilled graduates, and the provision of opportunities for SMEs to seek and transfer commercially applicable IP (Chew, C 2009; Liaw 2009; Teng 2016). This research sought to extend inter-organisational theories to develop guidelines that support the management of IPTC from polytechnics to SMEs. This research extends the discourse on IPTC with a particular focus on interactions in Singapore's SME and polytechnic sectors.

When designing case study research, selecting a single case to investigate rather than multiple cases is desirable when the single case represents the critical case, extreme case, typical case, revelatory case, or longitudinal case (Yin 2003). According to Yin (2003), most single-case designs involve only one unit of analysis, which is abstract and holistic. However, certain single-case designs embed a few subunits of analysis to enhance the insights gained from that single-case.

Research data on IPTC between polytechnics and SMEs is virtually non-existent, and a single-case design involving simultaneous investigations (subunits) into the nature and environment of polytechnics, SMEs and their relationships during IPTC in Singapore was considered appropriate for this project (Yin 2003).

### 3.4.2 Demarcation of case study research

One of the distinctive features of case study research is that of the boundary demarcation of the area of study. IP licensing and the processes and structures associated with it are innovative strategies that have been embraced by product-firms. Polytechnics, which are non-product producers, consider their IP successfully commercialised when an SME takes a license to further translate the licensed IP into new products, processes, services or experiences.

The case selected for this research encompassed the roles and relationships between SMEs (the product firms) and the polytechnics (the IP producers).

Figure 3.2 encapsulates typical polytechnic-SME IP licensing deal-making processes and highlights the bounds of the areas of study (shown in white). Besides licensing as a general feature of the process, the study areas were:

- IP marketing processes
- IP licensing negotiation processes
- IP licensing deal finalising.

Other SME intra- and/or inter-organisational areas (black) were not considered.

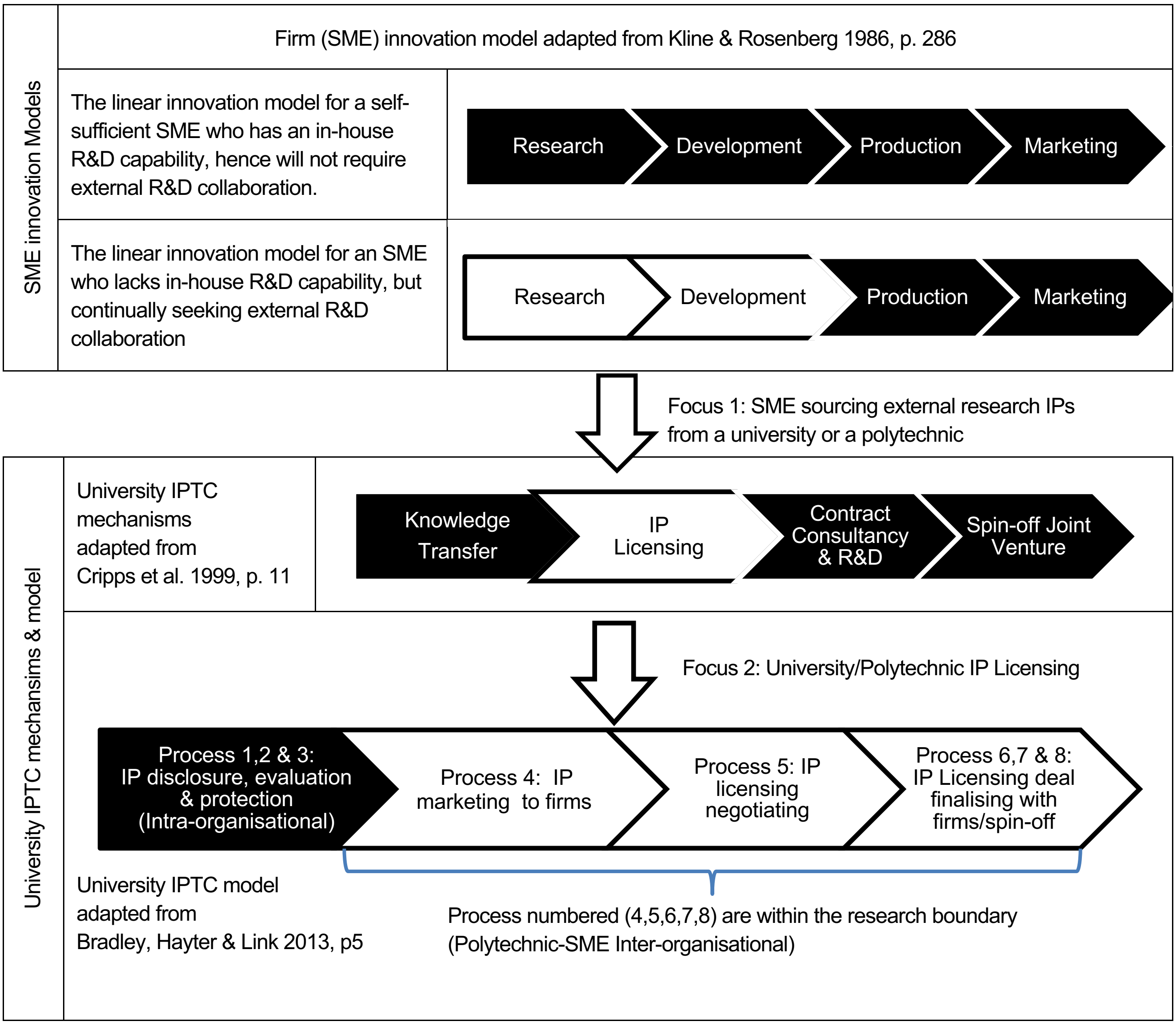



**Figure 3.2 Study boundary in an IPTC value chain. Adapted by the researcher by correlating a university IPTC model by Bradley, Hayter & Link (2013, p. 5) to a selected university IPTC mechanisms and an SME innovation model.**

For SME product-firms (top of Figure 3.2), two likely SME innovation models were adapted from Kline and Rosenberg (1986) to exhibit a sufficiently-resourced and an insufficiently-resourced SMEs graphically. This research excludes those SMEs who are well-resourced to complete the entire innovation process independently without seeking any external collaborations. Although the SME model begins with *research,* research IP is rarely the product of SME activity who are lacking in R&D capability and often acquired from other firms (competitors or complementors) or public IP producers, including universities or polytechnics (non-competitors).

The current research focused on IP sourcing from public IP-producers (university or polytechnic). The university IPTC mechanisms discussed by Cripps et al. (1999) have been adapted in Figure 3.2 to graphically illustrate the focus on the IP licensing process, and the exclusion of other IPTC mechanisms, such as knowledge transfer, consultancy, R&D and a spinoff (rarely found in the polytechnic sector).

All activities but those associated with IP licensing were excluded from this research. Based on the university IPTC model adapted from Bradley, Hayter and Link (2013), IP licensing activities were subdivided into intra- and inter-organisational processes related to the promotion and securing of the license. The initial capturing and protection of the IP were excluded in this research as an intra-organisational process within the polytechnic.

According to Teng (2016), on average the top-performing polytechnic in Singapore commercialises less than eight IPs per year, with most producing only two. Based on available data of NYP, RP and TP, there were a total of 258 patents filed and 79 IP licensed. It can be assumed that all 79 licensed IP were drawn from the collective pool of 258 patent applications leading to almost 31% conversion rate. However, the actual conversion rate could be lower than 31% as other non-patent IPs, although not explicitly reported, were likely to contribute to the collective pool of licensing deals too. Such an average conversion rate seems to suggest that not all patents filed arising from polytechnics' IP capturing and protection processes will be converted into IP licensing deals.

Also excluded from the research were investigations into processes, roles, relationships, and factors needed to develop and produce products, processes, services or experiences involving other stakeholders, such as product manufacturers, regulators, resource suppliers and go-to-market consultants. In summary, the research focussed on understanding IP marketing, IP licensing negotiation, and IP licensing deal finalising processes that are part of the interaction between SMEs seeking innovation and polytechnics seeking to provide it.

### 3.4.3 Recruiting participants

The researcher chose to use purposive sampling to address sampling for the selection of the participants for the case study. Typically, a qualitative researcher will prefer purposive sampling to probability sampling (used by quantitative researchers), but some mixed method researchers would adopt an integrated purposive-mixed-probability method instead (Teddlie & Yu 2007).

**Purposive sampling.** Purposive sampling is commonly used in qualitative research to generate information-rich cases, events, or behaviours to reveal an in-depth understanding of the phenomenon under study (Ishak & Bakar 2014; Maxwell 1997; Palinkas et al. 2015; Teddlie & Yu 2007). According to Ishak and Bakar (2014), qualitative researchers tend to use an expert's judgement to select cases that can meet a specific purpose progressively, not limiting the number of selected participants, until the data reaches a saturation point – a point when participants can no longer offer new substantive information. Intention to take an IP from the polytechnic sector for commercialisation purposes was the critical common criterion for participant recruitment, as the emphasis was on understanding similarities or commonalities among the SME managers.

A select group of SME managers was recruited through typical case sampling strategy (Palinkas et al. 2015) to provide the primary data source for this research to answer the 'how' and the 'why' (Baxter & Jack 2008) of the research question. The goal was to collect data that would highlight what was typical, regular or average (similarities) for those unfamiliar with the Polytechnic-SME IP licensing deal marketing, negotiation and making processes, and to make particularised statements (Palinkas et al. 2015).

The most important criterion of this typical case sampling was that the potential SME manager must have an authentic intention to take an IP license from a polytechnic for commercialisation purposes. The ultimate IPTC negotiation outcome was of secondary importance, and the commercial success of the licensed IP was also outside of the study boundary.

Figure 3.3 shows the participant recruitment process.

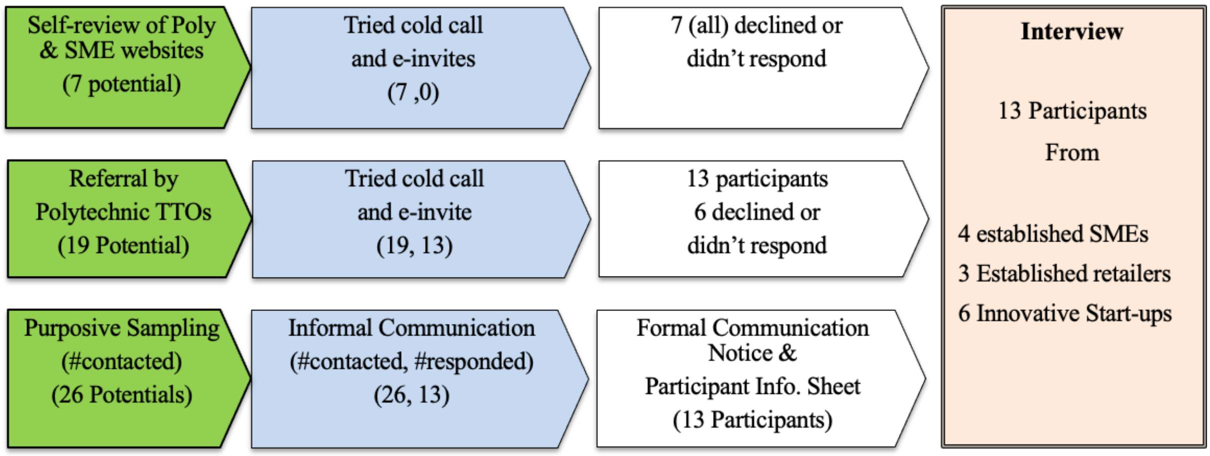



**Figure 3.3 Participant selection and recruitment**

The purposive sampling identified 19 SME managers with prior IPTC experience as potential participants. Sampling involved getting recommendations from different polytechnic technology transfer offices.

In an attempt to enlarge the prospective sample pool, the researcher identified seven other potential SMEs through personal review of IPTC stories published in polytechnic and related SME websites. With a total of 26 SMEs identified, the researcher made contact through cold calling or e-invites supported with a project advertisement (containing the scope, practical and ethical elements of the research) in a Project Notice.

Out of 26 potential participants, only 13 responded positively. More than half of those who did not respond to emails or phone calls had either left the company or were legally obligated not to discuss such topics due to the existence of non-disclosure agreements. Noticeably, most of the polytechnics' referrals (70%) produced positive responses. However, none of the identified

SMEs through website review accepted the interview request, and the majority of them were established SMEs.

Positive responses to interview requests were followed up with a formal e-invite accompanied by a participant information pack which contained:

- information on the research scope and ethical approval
- interview guide or protocol
- a consent form and independent complaint protocol, for the participant's advance knowledge and preparation.

To some degree, the information pack enabled participants to reflect on their experiences before the interview. All participants were assured of their voluntary participation and required to sign the consent form before the interview began. Participants were informed of their rights to end or withdraw during or after the interview. To preserve participant anonymity, numeric codes were used to record their narratives.

In preparation for recruitment, a contact list of potential SMEs was drafted but is not included in this thesis in order to protect participants' privacy. Using the appropriate government website, the researcher determined the *Unique Entity Number* (UEN) of organisations represented by the manager participants. The UEN is a single identification number issued by the Accounting and Corporate Regulatory Authority to ease interactions between all government agencies (Government of Singapore 2017b). From data associated with the UEN, the researcher was able to record the type of entity the participant manager worked for, the address, the organisation's present and previous names, UEN status, and any previous UEN. The UEN is updated over time, so the researcher triangulated the data (e.g. year of registration, address, and industry) with the SME corporate websites, as well as the Business Filing Portal website (Accounting and Corporate Regulatory Authority 2018).

Table 3.1 lists the profile of the 13 participating SMEs. Collectively, these companies offered the researcher a range of different business experiences:

- More than half (seven) were companies established more than five years before the interview, of which three had more than 18 years of retailing or distributing healthcare products.
- Six were innovative start-up companies established less than five years before the interview. Three had just been founded to bring the licensed IP to the marketplace.
- IP licenses were separately deployed to six different healthcare, three electronic, two chemical and two software products.
- All participants were directly involved in the IPTC process, and most of them held decision making positions (Managing Director).

The assumptions made to support an interview as the data collection method were that all SME managers recruited were willing to share their personal IPTC experiences regardless of the resulting commercial outcomes.

Table 3.1 List of participants by interview sequence

| SME | Interview Date | Year established | Years to interview date | Type of firm | Job Title* | Product embedded with a polytechnic IP |
|---|---|---|---|---|---|---|
| C1 | 28-Jan-13 | 2003 | 10 | Established company | GM | Software product |
| C2 | 28-Mar-13 | 1994 | 19 | Established retailer | M | Healthcare product |
| C3 | 02-Apr-13 | 1995 | 18 | Established retailer | MD | Healthcare product |
| C4 | 03-Apr-13 | 2002 | 11 | Established company | MD | Electronic product |
| C5 | 07-Jun-13 | 1991 | 22 | Established retailer | MD | Healthcare product |
| C6 | 22-Aug-14 | 1994 | 20 | Established company | MD | Software product |
| C7 | 10-Sep-14 | 2014 | 0 | Innovative Start-up | MD | Chemical product |
| C8 | 18-Sep-14 | 2011 | 3 | Innovative Start-up | GM | Electronic product |
| C9 | 24-Sep-14 | 2011 | 3 | Innovative Start-up | CEO | Chemical product |
| C10 | 25-Sep-14 | 2014 | 0 | Innovative Start-up | MD | Healthcare product |
| C11 | 06-Nov-14 | 2003 | 11 | Established company | M | Healthcare product |
| C12 | 21-Oct-15 | 2015 | 0 | Innovative Start-up | CEO | Medical product |
| C13 | 30-Oct-15 | 2012 | 3 | Innovative Start-up | MD | Healthcare product |
| * M: Manager, MD: Managing Director; GM: General Manager; CEO: Chief Executive Officer | | | | | | |

## 3.5 Methods of data collection

Flexibility in processes or methods is a unique feature of case study research. Case researchers can use qualitative and/or quantitative methods. Evidence of research can be drawn from multiple sources, including fieldwork, archival records, documents, interviews, verbal reports, physical artefacts, direct observations, surveys, participant observations or a combination of these, allowing case researchers to analyse and correlate data in a holistic or aggregated fashion, providing a multitude of perspectives to attain robust case outcomes (Baxter & Jack 2008; Yin 1981). Figure 3.4 shows the methods used in this study: direct observations, literature review, documentary research and interview. Data sources are also outlined.

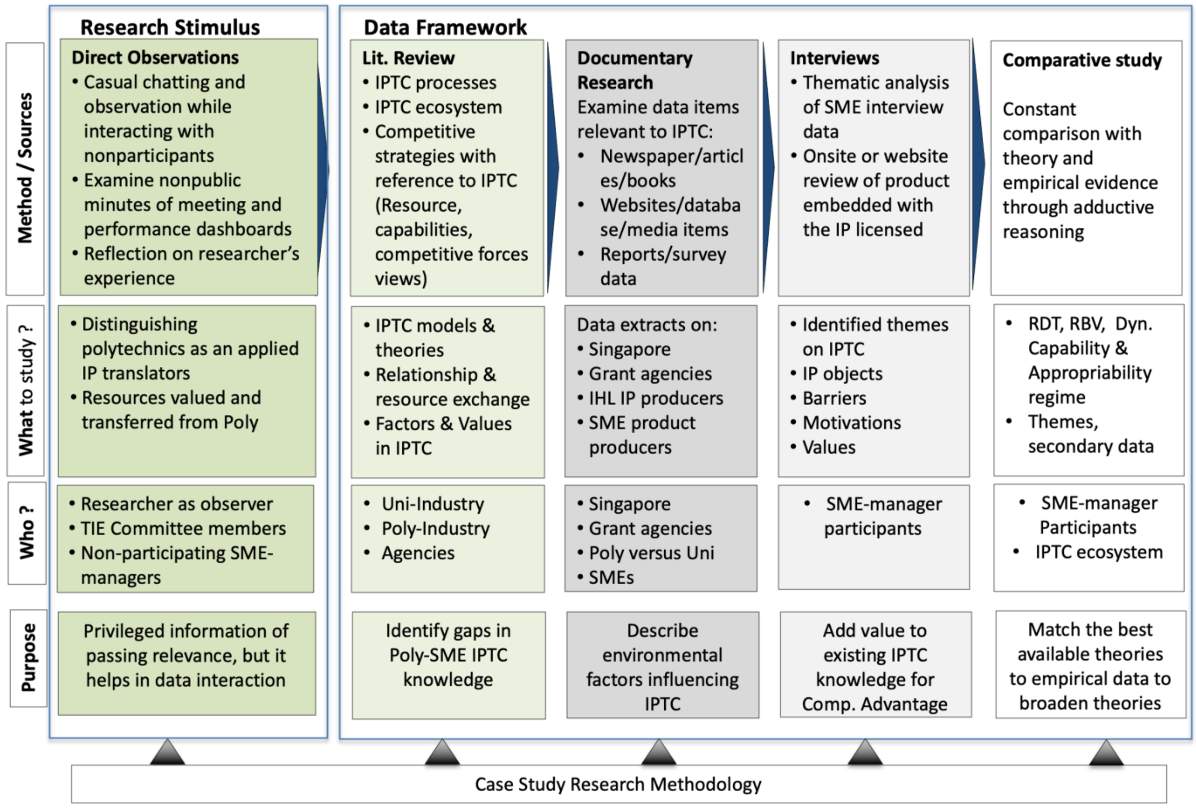



**Figure 3.4 Case study research methodology: Documentary research and interview**

### 3.5.1 Direct observation

The researcher began investigations with direct observations (primary research) through formal or casual interactions with people from MOE, polytechnics and SMEs to understand the research context. Innovation-related survey data and grant information were made available during formal meetings with MOE Technology-Innovation-Enterprise Management Committee members. The information was considered informative, but not particularly important in the context of the study, and was also confidential. Similarly, some evidence on SME needs and wants emerged during many informal interactions with SME managers in public conferences and IPTC exhibitions the researcher attended, but proved to be of little significance to the study.

This background knowledge provided a stimulus for the researcher to conduct documentary research of publicly accessible data (documents, web pages or databases, *YouTube* interviews, survey data) on polytechnics, universities, industry and funding agencies in Singapore.

### 3.5.2 Documentary research

Documentary research covers a range of pre-existing empirical materials, such as written texts (publications, reports, newspapers, minutes of meetings, websites, blogs), statistics (surveys), audio-visual recordings (*YouTube* interviews, television talk shows) and photographs. Collectively these sources can be subdivided into (May 2011):

- *primary* (written and personally witnessed by the authors), secondary (written, but not personally witnessed by the author) or tertiary (document such as abstracts and reference manuals written to help us locate other references) types
- *public or private, and solicited or unsolicited*
  Material information related to decision making may exist as a company's confidential information, hence not accessible to the research.

**Access to secondary data can be relatively quick and easy.** According to Braun and Clarke (2013), secondary sources can be reviewed in fragments to answer a variety of research questions. For example, some secondary sources like online forums and interviews, are suited to explore people's experience, while other secondary sources like magazines can be used to understand socio-cultural meanings about a particular context. As a data collection method, documentary research on secondary sources offers less depth and flexibility than that accorded by the face-to-face interview method (Braun & Clarke 2013). Hence the need to complement the documentary research adopted in this research with face-to-face interviews.

In undertaking documentary research, the researcher was aware of potential bias and selective recording of the secondary sources (May 2011). To minimise these influences, the researcher conscientiously selected the following sources of documents:

- polytechnic and university websites to extract evidence of IPTC stories and related information by reviewing the polytechnic missions, visions and annual reports. Whenever possible, findings were triangulated by scholarly articles, newspaper articles, and book chapters published by former principals of polytechnics.
- Science, Technology & Enterprise Plans published by A*STAR or Ministry of Trade & Industry for relevant IPTC stories, and funding programs.
- IPTC performances of various players were carefully examined to predict and describe the innovation characteristics of Singapore, the universities and polytechnics. Table 3.2 links the various databases or survey reports to the respective publishers, which are either government agencies, universities or reputable commercial entities. The reliability of entities is less questionable, as they are commonly held accountable by their boards of governors, that contain both internal and external high-ranking executives.

**Table 3.2 Examples of sources used for documentary research in relation to IPTC performance**

| IPTC player performance | Databases or survey reports | Publishers | Entity type |
|---|---|---|---|
| SME | Survey of Innovation, IP Creation & Usage among Singapore Firms | IP Academy | Government agency |
| Singapore | The Global Innovation Index | Cornell University, INSEAD & WIPO | Universities and government agencies |
| Singapore | Creative Productivity Index | The Economist Intelligence Unit Ltd & Asian Development Bank | Reputable commercial entities |
| University | World University Rankings | Times Higher Education | Reputable commercial entities |
| Singapore | Report of The Economic Strategies Committee | Economic Strategies Committee of Singapore | Government agency |
| Polytechnic vs university | Patenting performance | IPOS, WIPO and Innography Inc | Reputable commercial entities and government agencies |
| University | Highly cited researchers | Thomson Reuters | Reputable commercial entities |

The extant literature explored in Chapter 2 affirms that most U-I technology transfer research literature centres around Europe or the US (Bozeman, Rimes & Youtie 2014). A gap in knowledge was found in the newly industrialised economies of East Asia, including Singapore (Wong 1999). Given the lack of scholarly literature regarding the U-I technology transfer space in the Singapore context, this research used qualitative documentary research to explore, characterise and describe the innovation capabilities of the government agencies, along with the polytechnic and SME sectors in Singapore.

Similar to ethnography, grounded theory and phenomenology, qualitative content analysis can be used as one of the methods in documentary research to analyse textual data, focusing on the content and contextual meaning (Hsieh & Shannon 2005). The text can be deconstructed, examined and interpreted to provide knowledge and understanding of the phenomenon in question, in this case, the IPTC.

For example, to understand the public expectation of what a polytechnic is supposed to do, a qualitative content analysis was conducted of the mission statements of each polytechnic. The patterns of appearances of particular phrases (research and knowledge creation, for example) were examined and interpreted as a means of identifying common IPTC characteristics.

Chapter 4 describes and characterises 'what' roles were played by IPTC stakeholders (government agencies, polytechnics, universities or SMEs) located in Singapore. Newspapers, data/survey reports, annual/yearbooks, *YouTube* interviews, web sources, innovation reports, books, databases, and research articles were all used for this analysis. A good understanding of the characteristics of government agencies, polytechnics, universities or SMEs provided useful insight into the environmental factors that influence technology transfer or innovation capability for SMEs in Singapore.

Innovation capability was investigated because the word 'innovation' is widely understood to overlap the phrase 'technology transfer' (Dubickis & Gaile-Sarkane 2015). Dubickis and Gaile-Sarkane (2015) found that most focus group participants considered 'innovation' and ‘technology transfer’ overlap when they are presented with various definitions of ‘innovation’ and ‘technology transfer’ obtained from a systematic literature review.

The documentary research was purposefully completed by targeting public sources using keyword searches for terms associated with technology transfer, IP licensing or commercialisation within the population of polytechnics in Singapore.

For example, the research investigated the following public sources to compare the innovation capabilities between the polytechnic and university education sectors in Singapore:

- individual mission statements obtained from webpages to understand the nature of their core activities (teaching and learning, R&D, or IPTC)
- level of patenting activities by accessing the national patent database hosted by IPOS to understand the importance of patenting
- patent strengths through a fee-paying database (Innography) to measure the value of patents filed
- level of article publication through the Ex Libris group library database to understand the importance of fundamental knowledge production.

In addition, annual reports published on the Internet (in the format of either a PDF or in HTML), were used to look for IPTC stories which could be indicators of innovation activities that leveraged intellectual capital (IC). Figure 3.5 shows the steps and keywords (license, licensing, R&D, commercial, commercialised, industry, industry partner) used in the searches.

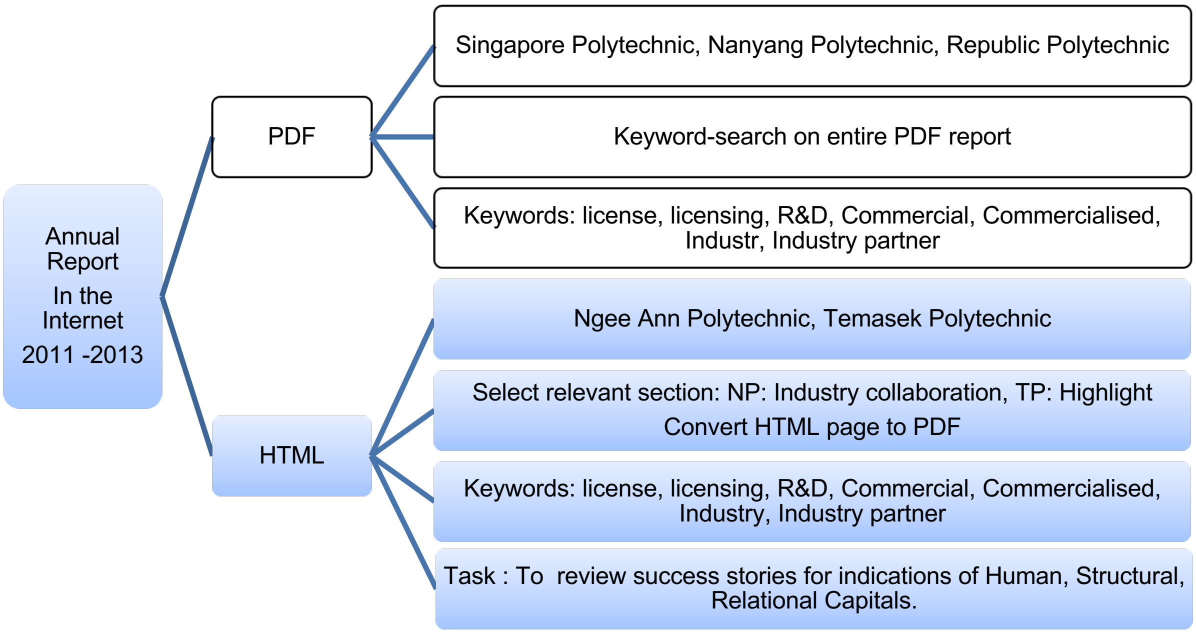



**Figure 3.5 Study of polytechnic annual reports from 2011- 2013**

### 3.5.3 Semi-structured interviews

Semi-structured interviews were used in this research as a means to interactively collect data on experience-type research questions for participants who have some kind of personal stake in the topic (Braun & Clarke 2013). Semi-structured interviews were used in this research to provide a voice for the SME managers who had individual accounts of their IPTC experiences, knowledge and attitude that would otherwise remain inaccessible (Peräkylä & Ruusuvuori 2011). In preparing a semi-structured interview, a researcher will use a pre-prepared interview guide to structure interview questions, and the wording and sequencing of the interview questions can be flexibly changed in response to the interviewee's replies (Braun & Clarke 2013).

The main research question was *How do human and structural resources contribute to or impede the Intellectual Property Transfer and Commercialisation (IPTC) process in the Singapore polytechnic context?* and the subsidiary question targeted for SME managers was For SME managers negotiating the commercialisation of IP, what characteristics of the IPTC process do they consider desirable, and what resources and capabilities do they look for? The researcher did not pose these exact main and subsidiary research questions to participants, but instead rephrased them into main, probing and rapport-building interview questions which were more focused and concrete (Bernard 2006; Braun & Clarke 2013), clustered and ordered into research topics as shown in Table 3.3.

**Conducting the interview.** Thirteen face-to-face, semi-structured interviews were conducted at the participants' offices for their convenience. Each participant was greeted and thanked before the interview, and reminded of the scope, purpose, practical and ethical elements of the research. Permission was sought to audio-record the interview. During the actual interview, the questions were guided by the pre-prepared interview guide, and the answers recorded. Recordings were later transcribed verbatim by reproducing all spoken words and other sounds and pauses. Quick and brief notes were also made on the spot during the interview if new questions were required. Field notes were also made after each interview to record details of the SME workplace, detailed features of the IP licensed, and personal reactions to the participant.

**Table 3.3 Pre-prepared guide that frames the interview topics and questions**

| Topics | Essential interview questions | Question type |
|---|---|---|
| Basic understanding of the poly-SME TT mechanisms. | What is your understanding about poly-SME technology transfer (TT)? | Rapport-building (Opening) |
| An account of your personal poly-SME TT experience with focus on the TT processes. | Could you please share your experience in a poly-SME TT project?<br><br>Reflecting on the whole TT process, what were the benefits gained from your perspective? | Main |
| Motivating factors for SMEs to source technologies or technical applications from the polytechnics | In your view or experience: What other competencies or resources can create lasting value, and how they are utilised? | Probing |
| Perceived barriers or risks to poly-SME collaboration in value co-creation | In your view or experience: What prevents SME (or poly) from leveraging on polytechnic (or SME) resources and competencies?<br><br>What are the other TT barriers? How can such barriers be addressed? | Probing |
| Poly-SME relationship | What are your firm's (or poly's) criteria in identifying and selecting an SME as the technology collaborator?<br><br>What is problematic about the working relationship between poly-SME in TT? How can progress be made?<br><br>What more could be done to enhance poly-SME relationship? | Probing (Closing) |

**Observation of IP types.** Wherever possible, an onsite review of the product incorporating the licensed IP was undertaken to understand the nature of the IP, and the value of applied R&D in IPTC. In the absence of onsite demonstrations, product reviews were conducted online using the SME's website.

**Preparing audio data for analysis.** Unlike written language, after being transcribed spoken language is without punctuation and is embedded with naturally occurring non-semantic sounds and silences, such as pauses, laughter, sighs and so on (Braun & Clarke 2013). A professional service provider transcribed the 13 audio recordings, which were converted to word documents interlaced with standard notations. For example, a comma indicated a short pause. A full-stop indicated a long pause. The word ‘speaker’ represented the participant, and the word ‘interviewer’ represented the researcher. An underlining indicated unclear speech or sounds.

Figure 3.6 illustrates and explains some examples of notations used in the original transcription. Each transcript was reviewed and edited multiple times to ensure it contained enough details for subsequent analysis. The edit included removing and changing any sensitive information that could lead to the identification of the participants. Such information included the participant’s name, and the names of other people, entities, or polytechnics mentioned in the interview.

For example, the name of first participating SME was removed and the number C1 assigned. Similarly, the name of the participant from C1 was removed and replaced by Pax 1. According to Braun and Clarke (2013), this anonymity protects the participants, but can also remove their voice. It is crucial, therefore, to offer participants a choice about whether to be anonymous or not. Less than half of the participants opted to be named, but will not be identified in this thesis to provide uniformity of the entire analysis.

However, the researcher will consider naming those identifiable participants in future paper publications when the scope of the writing is much more targeted. Participants’ informed consent was obtained, and their right to withdraw from the research was discussed based on the points listed on the consent form designed by the Human Research Ethics Committee.

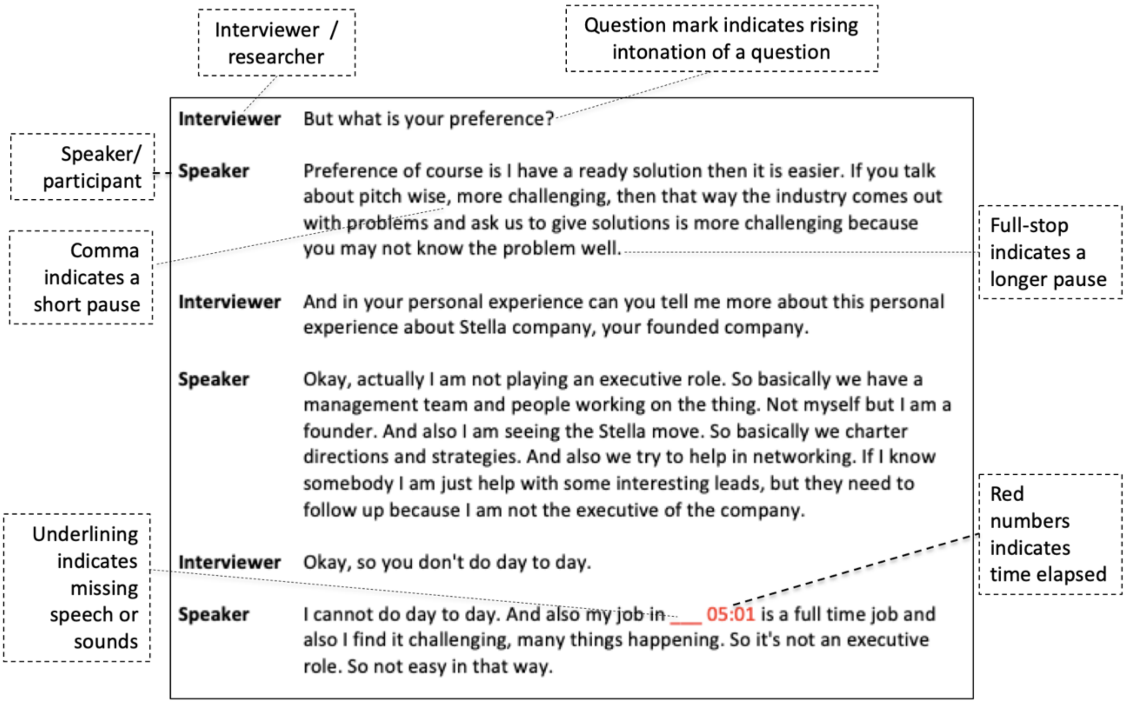



**Figure 3.6 Annotated examples notations used in the original transcription**

## 3.6 Analysis of the interview data

Thematic analysis (TA) was used to analyse the interview data. TA is regarded as an analysis method that can be flexibly applied to answer a wide range of research questions and does not require strict adherence to established theoretical frameworks or methodologies, such as grounded theory and interpretative phenomenological analysis (Braun & Clarke 2006). TA is extensively used as a foundational qualitative method within a realist framework to search, identify and interpret patterns (themes) of meaning across qualitative interview data using a bottom-up approach (Aronson 1995; Braun & Clarke 2006). In 2006, Braun and Clarke (2006) documented a widely adopted TA approach that simply reports what is manifested in the data in relation to the research question, involving a repeatable six-phase process:

1 Familiarising yourself with the data and identifying items of potential interest

2 Generating initial codes

3 Searching for themes

4 Reviewing potential themes

5 Defining and naming themes

6 Producing the report.

### 3.6.1 Familiarising

Familiarisation with the data requires the researcher to read and re-read every transcribed interview in order to identify and note potentially interesting data features that are relevant to the research question. Examples of relevant data features that can be coded include data segments that are recurring or surprising; are related to the supporting literature; and are specifically emphasised by the interviewees.

### 3.6.2 Initial coding

Coding happens at the early stage of analysis when the researcher reads and re-reads the words actively, analytically, and critically line by line to make sense of the data. This process involves two categories of coding, where data are segmented or fragmented across the documents:

- *Semantic coding.* The codes are inductively created through a bottom-up approach where codes are affixed to select data segments that capture and represent something meaningful at the surface or manifest level.
- *Latent coding.* Codes are deductively created through a top-down approach to dig deeper into the data to identify hidden meanings. This phase ends with a list of the potential meaningful codes and their corresponding data segments. Recoding is often required to refine the initial codes, and the entire coding process can be

manually completed or managed through a *Computer-Aided Qualitative Data Analysis Software* (CAQDAS).

### 3.6.3 Themes searching

Themes are sought after the initial coding, although in reality, researchers will be thinking of themes as they code (Joffe 2012). Themes are the most salient meanings found in the data and can be categorised using the initial codes. Depending on the researcher's analytic judgement about what is meaningful and essential for answering the research question, similar codes are clustered together to form themes and sub-themes. Gradually a thematic map emerges that can graphically show all main- and sub-themes and their relationships. As a rule-of-thumb, the coherence of a 10,000-word report could be typically attained with six to seven themes (Braun & Clarke 2012).

Thematic coding is an iterative process, and as the themes are gradually identified and integrated, the researcher must ensure that each theme is linked coherently and substantially to the individual coded data and the entire data set. Themes must be identified by names that are informative and engaging in order for the researcher to remain coherent and consistent while integrating the data into a cogent whole as effectively as possible. When no further patterns of information or links can be found, a final set of themes is produced that encapsulates the meaning of the data, and a report can be prepared on the significance of the analysis.

### 3.6.4 Producing the report

The final phase of the thematic analysis is to produce a report, the content and style of which will depend on the purpose of the research. In this case study, Chapter 5 presents the case interview analysis reporting key themes and their relationships, the profile of SME managers and critical review of their experiences.

Meaning drawn from the thematic analysis forms the foundational empirical evidence can be studied in combination with relevant literature to develop and formulate a richer story (Kovács & Spens 2005). According to Eriksson and Lindström (1997); (Kovács & Spens 2005), such an approach is known as abductive reasoning, an alternative to inductive and deductive approaches, used to establish the best available explanations matching theories to empirical observations with particularities of specific situations.

Similar to the induction approach, the abductive reasoning starts with a real-life observation and iteratively moves between empirical and theoretical spaces in an attempt to search for the best matching theory to explain the observed evidence, hence leading to theory development (Eriksson & Lindström 1997).

Figure 3.7 shows graphically how the adductive research process combines both empirical pieces of evidence (interview and documentary data) with existing conceptual or theoretical insights (literature) to broaden the understanding of IPTC phenomenon in the Singapore polys context. Chapter 6 discusses this iterative process and the resulting theory-empirical relationships to develop theory for answering the RQ.

**Computer-aided text analysis.** In the coding process, interview data are fragmented and represented with codes; while in the writing process, those fragmented codes are integrated into a coherent piece of narrative. This research followed the recommendation made by Bernard (2006); Smit (2002) on the use of *Atlas.ti* as the CAQDAS, designed to process large amounts of data, affix codes to data segments, develop thematic maps, and facilitate data searches, ordering, retrieval and visualising functionalities. There are other similar CAQDAS, such as *NUD.IST*, *NVivo*, or *Hypersoft* available for qualitative researchers (Smit 2002).

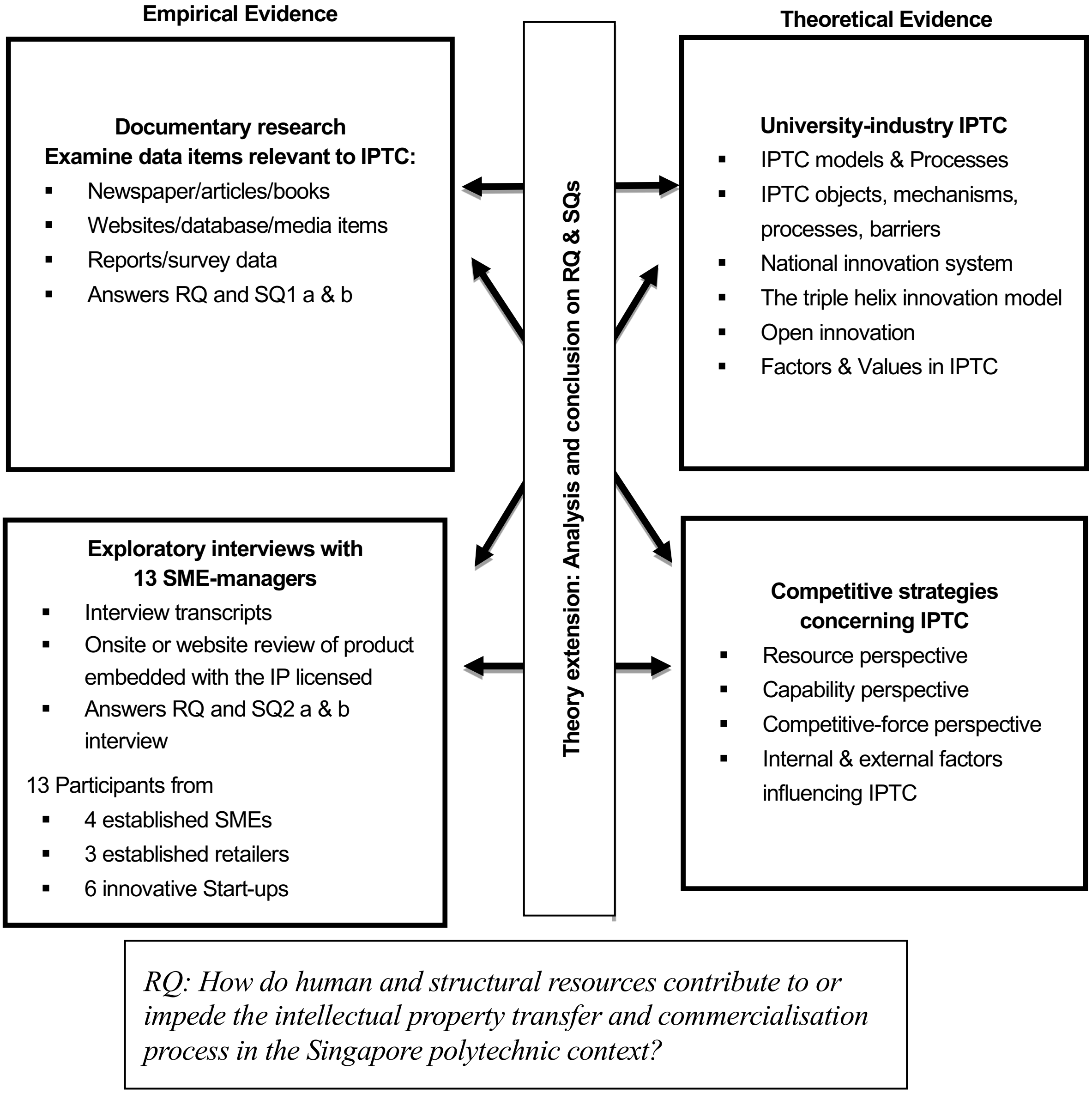



**Figure 3.7 The best available explanations between empirical and theoretical evidence. Source: Adapted from Kovács & Spens 2005, p. 139.**

Using *Atlas.ti*, the researcher uploaded all interview transcripts into the system where interview data were analysed and interpreted using coding and thematic mapping activities based on TA. Before using *Atlas.ti*, the researcher attempted to use Microsoft *Excel* to automate the code affixing using the '=Concatenate (text1,text2,…textn)' function. An example of such an application is shown in Table 3.4 below, where the function '=Concatenate (B1, C1, D1)' was inserted in the E1-field. The *Excel* function joins texts pre-populated in the B1-field (central theme), C1- and D1-fields (sub-themes) and returns a string of phrases in field-E1 (Challenging issues: Multitasking: Conflicting priority). All main themes could then be collated into separate worksheets for further thematic grouping and mapping.

**Table 3.4 Example of the *Excel* 'concatenate' function joining main themes and sub-themes together**

| A1:<br>Data segment | B1:<br>Main theme | C1:<br>Sub-theme 1 | D1:<br>Sub-theme 2 | E1:<br>Combined themes |
|---|---|---|---|---|
| It's always the time because the lecturer is all -- they have many projects developed at the same time. | Challenging issues | Multitasking | Conflicting priority | =Concatenate (B1,C1,D1) |

- The *Excel* approach was time-consuming, involving switching from one worksheet to another to compare, refine codes, and search for themes with concept similarities. *Atlas.ti* was preferred over *Excel* because a competent *Atlas.ti* user can perform data ordering, structuring, retrieving and visualising more efficiently. In addition, *Atlas.ti* can be used to construct and develop thematic maps, a necessary step for theory building or development (Smit 2002). Although the use of such CAQDAS tools helps the researcher to organise, manage and visualise data based on a chosen data analytic method, but not the actual intellectual work of data interpretation which is human-centric (Braun & Clarke 2013).
- Figure 3.8 illustrates an example of an *Atlas.ti* conceptual map showing various ways that a SME could manage a patented technology asset by integrating six codes, two clusters with all connected quotation segments added. In this example, relevant quotation segments extracted from the transcript of Pax 1,2, 3, 5, 7, 8, 9, 10, 11, 12 and 13 were integrated into a concept map to justify why SMEs prefer patented technology to strengthen their long-term competitive advantage.

SME managers interviewed were hoping to leverage patent to prevent unauthorised copying, as well as to improve their company's fundraising position. The latter is an exciting concept shared by Pax 12, a medical technology start-up founder, who had worked in an established medical technology company before the start-up venture. This justification suggests that the public confidence in a patent as a valuable technological asset is still strong, especially from the perspective of financial entities, such as banks or venture funders.

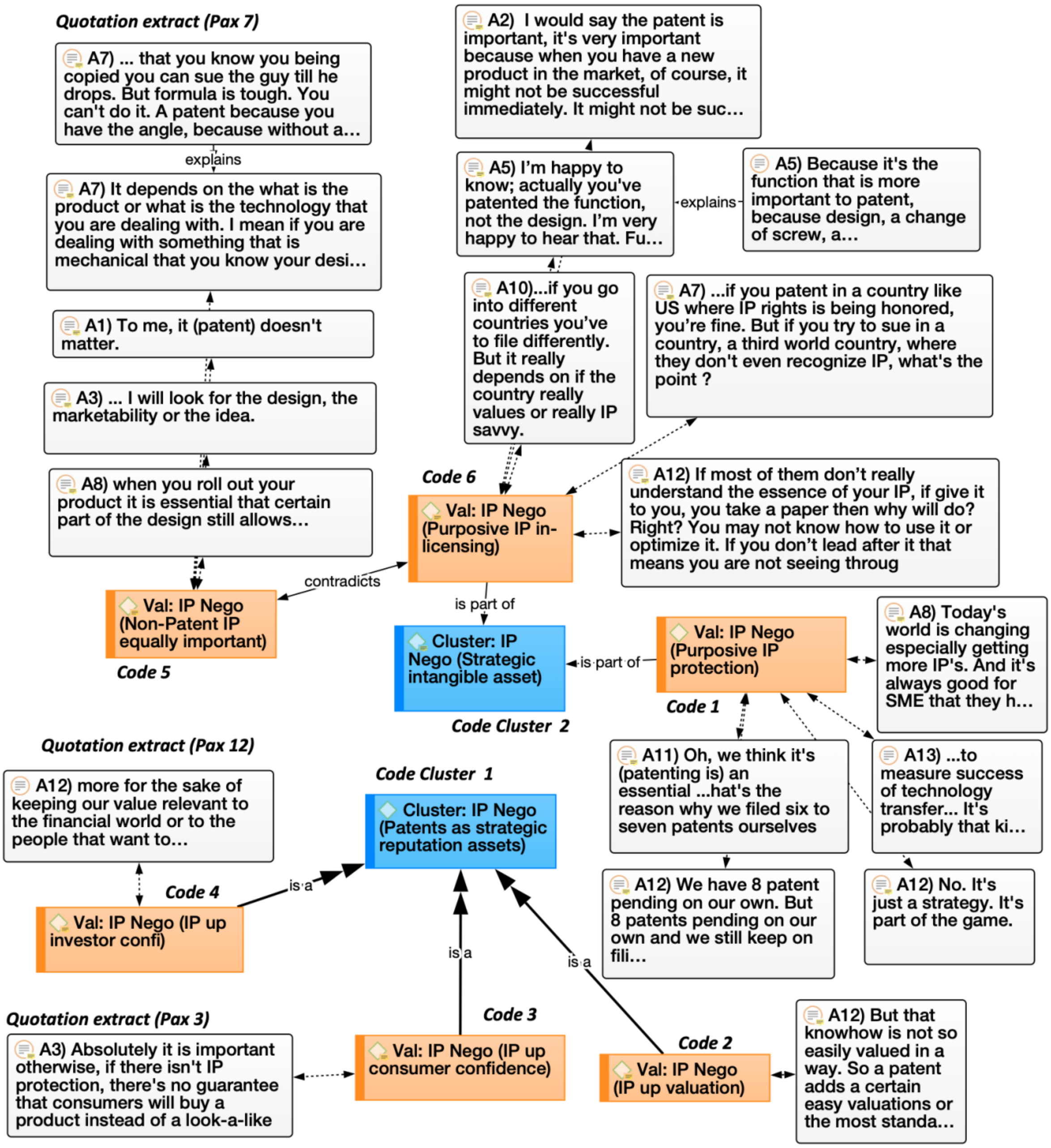



**Figure 3.8 A conceptual map of ways a patented technology is leveraged**

## 3.7 Ethical considerations and trustworthiness

This research was conducted according to the guidelines published by the Human Research Ethics Committee of the University of Adelaide. The application for ethics permission was approved by the Human Research Ethics Committee in November 2012. A copy of the approval letter is attached as Appendix 1. This thesis will not identify the participating SMEs or individuals, although out of 13 participants, seven opted to be named while six others chose to remain anonymous.

### 3.7.1 Validity versus transferability

Unlike quantitative research, this research sought transferability, instead of generalisability. Most qualitative researchers emphasise appropriate use of the tools, processes, and data to attain validity (Leung 2015), while case study research often investigates a particular phenomenon in a particular sample of a particular context; hence generalisability is usually not an expected quality (Stake 1978).

Qualitative researchers should, therefore 'propose new versions of the generalisability concept, e.g., 'transferability', which relies on the context-dependent judgement of 'fit' between two or more case instances made by a researcher' (Hellström 2008, p. 321). Transferability means that the findings and conclusions of a study are transferable to other contexts or populations. Or in Stake's words, 'generalisation about that particular case or generalisation to a similar case rather than generalisation to a population of cases' (Stake 1978, p. 7).

### 3.7.2 The trustworthiness of the data and conclusions

In this research, trustworthiness was influenced by:

- ensuring characteristics of the contexts, case participants and the transfer objects were sufficiently described to allow a fair comparison with other samples.
  For the study of the polytechnic context, multiple data from reliable sources were used to allow readers to gain a better understanding of the nuances or thick descriptions.
- the purposeful sampling that ensured data richness for readers to assess the potential transferability and appropriateness for their contexts.

Data were collected from different SME managers, different types of SMEs who had transferred different types of IP to provide readers with more data richness.

- the clear demarcation of a research boundary to allow readers to focus on the particularity of selected IPTC processes, hence providing a deeper understanding of relevant activities of interest to them
- inclusion of data from two negative cases in which licensing deals were not completed.

## 3.8 Summary

This chapter provided an overview of the conceptual framework used in the research; reintroduced the research question; presented the single-case study design; discussed how to prepare for and conduct the chosen methods of data collection and analysis. The analyses are discussed in the next two chapters.

Chapter 4

# Embedded case study subunit 1: Contextual evidence

This chapter describes the characteristics of Singapore as an innovative nation, public agencies as innovation catalysts, polytechnics as IP translators, and SMEs as product and service producers by exploring publicly accessible documentation and research articles, an un-obstructive method. For example, to an extent, the level of human, structural and relational resources (collectively referred to as intellectual capital [IC]) that reside in a particular polytechnic can be obtained through corporate web resources, or by referring to secondary sources of data, such as national R&D surveys.

## 4.1 Innovation development in Singapore

Without natural resources, Singapore has to compete in human capital development through knowledge and technology transfer (Lin, CT 2002; Yeo 2011). Since independence in 1965, Singapore has experienced rapid economic and technological development, leveraging MNCs to transfer and diffuse advanced technology to local SMEs and workers (Edquist & Hommen 2008; Mok 2015; Wong & Singh 2008). Pioneering MNCs include National Semiconductor, Texas Instruments, Fairchild, Hewlett-Packard and Philips (Chua 2002).

Wong and Singh (2008) argue that Singapore has transformed from a technology adopter to a technology creator through the following phases:

- *The initial industrial phase* (1965-1975) when MNCs transfer knowledge and technology to support their labour-intensive manufacturing.
- *Local technological deepening phase* (1975 to late 1980s) when MNCs transfer knowledge and technology to support their automated or upgraded manufacturing operations. This period witnessed the rapid growth of local process technological capabilities and the emergence of a critical base of local supporting industries in precision engineering and components assembly. This shift of knowledge transfer from skills-intensive to technology-intensive was observed in EDB training institutions where courses in advanced manufacturing technology, process control, and industrial robotics were introduced (Lin, CT 2002).
- *Applied R&D expansion phase* (the 1980s to late 1990s) when more MNCs transfer knowledge and technology through their applied R&D activities located in

Singapore, instead of the parent country. This period saw the growth of newly public R&D institutions established to support MNC product and process innovation activities.

- *High-tech entrepreneurship and basic R&D phase* (from the late 1990s onwards) when there was a government push for a more vibrant technology-entrepreneurial community, shifting from an MNC-reliant innovation strategy to a balanced one to enhance indigenous technological innovations through the formation of local high-tech start-up companies and the intensification of basic R&D in life sciences and advanced materials.

In the 1970s Singapore lagged behind other Asian countries because low labour productivity and real productivity growth were less than half that of Taiwan, South Korea, and Hong Kong. By the 1980s and through the 1990s, Singapore still had issues to address, such as:

- the lack of local expertise because of a 'brain drain'
- a lack of governmental policy for science and technology
- the lack of an indigenous R&D and innovation capability
- overdependence on multinationals to transfer and diffuse technology.

These issues retarded Singapore's capability to develop the skills and attitudes required to embrace innovation, creativity and entrepreneurship (Edquist & Hommen 2008; Lee, SK et al. 2008). According to the EDB chairman, Yeo (2011), Singapore did experience success in the high-technology industries of computer hard disk drives (in the mid-1980s), semiconductor wafer fabrication (late 1980s), aerospace components (early 1990s) and petrochemicals (late 1990s).

Singapore's MNC-reliant innovation strategy deprived the local SME sector of the opportunity to conduct its R&D, disregarding the sector's innovation capability (Edquist & Hommen 2008; Mok 2015). In their book chapter, Edquist and Hommen (2008) cited a different approach embraced by the Danish economy, where a SME-reliant policy facilitated healthy innovations while working in tandem with only a few MNCs. Most Singaporean SMEs have been content to support MNCs with parts or services, regarding the MNCs as non-competitors who mainly produce products for export purposes (Chua 2002). Supporting MNCs to manufacture products without the creation of upstream innovation activities was akin to operating in a *technology* *colony* whereby Singapore was dependent on foreign MNCs to provide relevant high technology and the host country to conduct relevant high value-adding R&D (De Wet, Gideon 1999).

Singapore, a city-state, invests heavily in innovation input to encourage innovation output. Two international surveys, one published in 2014 another in 2019, highlight the fact that Singapore has an environment that is conducive to innovation, yet is somewhat lacking in terms of innovation outcomes. The 2019 Global Innovation Index (GII) (Cornell University, INSEAD & WIPO 2019) positioned Singapore first of 129 countries in innovation input, yet fifteenth in innovation output. The 2014 Creativity Productivity Index (CPI) (The Economist Intelligence Unit Ltd & Asian Development Bank 2014) ranked Singapore first of 22 Asian countries in creative input, yet sixth in creative output. Overall, these surveys emphasised the need for Singapore to transform into an innovation producing nation.

Singapore is a high-income nation, and it is interesting to compare the city-state's innovation performance against Switzerland, another high-income nation, and China, a medium-income nation. Switzerland consistently ranks first or highly in the GII, while China scores highly in the innovation output sub-index.

In the 2019 GII (Cornell University, INSEAD & WIPO 2019), the GII score is computed as the average of its input and output sub-indices. Table 4.1 shows three GII score computations based on the two numerators: Innovation Input Sub-index (A) and Innovation Output Sub-index (B). Since a GII score is an average derived value (A+B)/2, a high input or output sub-indices score will improve GII ranking. Singapore was placed eighth of 129 countries with a GII score of 58.37, derived from the average of the input sub-index score (A=72.15) and output sub-index score (B=44.59). In this case, Singapore maintains a high GII ranking by focusing more on innovation inputs.

**Table 4.1 Innovation performance of Switzerland, Singapore and China. Source: Adapted from the 2019 GII Report**

| GII 2019 | Global Innovation Index | | Innovation input sub-index | | Innovation output sub-index | |
|---|---|---|---|---|---|---|
| | *Rank* | *Score (A+B)/2* | *Rank* | *Score (A)* | *Rank* | *Score (B)* |
| Switzerland | 1 | 67.24 | 2 | 71.02 | 1 | 63.45 |
| Singapore | 8 | 58.37 | 1 | 72.15 | 15 | 44.59 |
| China | 14 | 54.82 | 26 | 56.88 | 5 | 52.75 |

**Investing in innovation.** Examining the sub-indicators level, Figure 4.1 lists the scores of five input sub-indicators (business sophistication, market sophistication, infrastructure, human capital and research, and institutions) of Singapore in relation to Switzerland and China. By taking a simple average of the five indicators, Singapore (with an average of 72.15) outperforms Switzerland and China – evidence of an environment that is conducive to innovation.

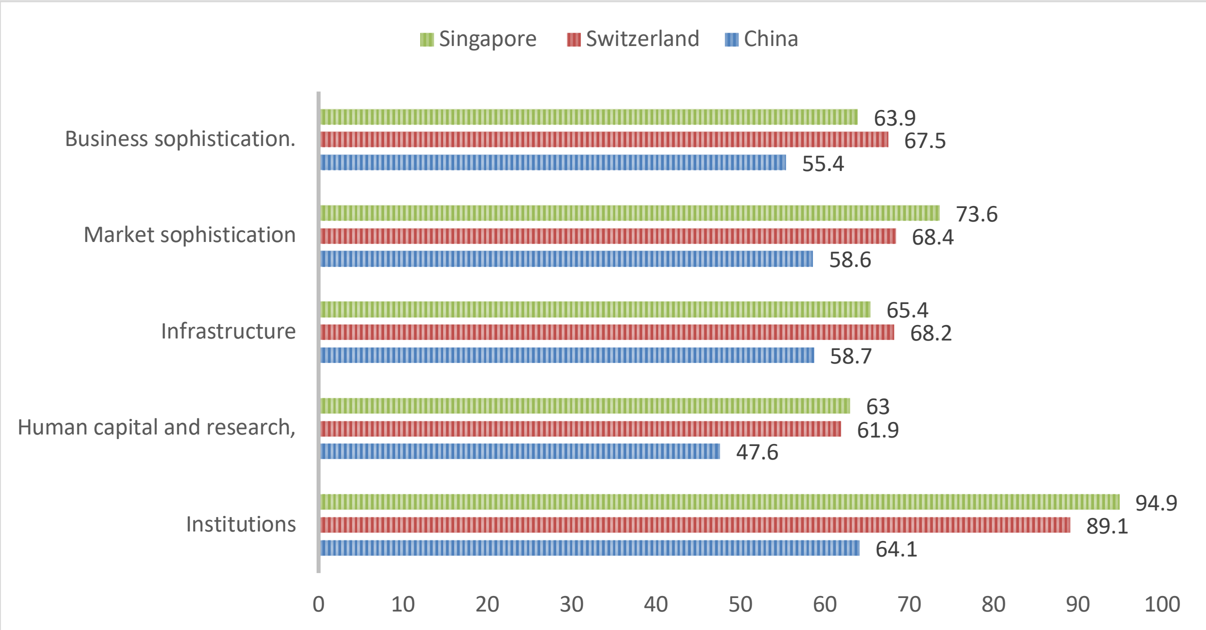



**Figure 4.1 Innovation input sub-indices. Source: Adapted from 2019 GII report.**

Most high-income economies, including Singapore, perform better in the GII than do low-or medium-income countries. This finding seems to suggest that wealthier countries can invest heavily in innovation to stay ahead of their competition. Table 4.2 lists the ten best-ranked economies by the high-income group in the GII and their respective ranking in the innovation input and output sub-indices. Although Singapore occupies the top position in the Innovation Input Sub-index, it has underperformed in the Innovation Output Sub-index ranking, hence only attaining the eighth position in the overall GII ranking. On the contrary, with lower innovation inputs but higher innovation outputs, the US could still outperform Singapore in the overall GII ranking. In the researcher's opinion, the US's way of sustaining innovation outputs with a smaller innovation input is a desirable strategy that Singapore may consider in the future.

**Table 4.2 List of the 10 best-ranked GII countries. Source: Adapted from the 2019 GII report.**

| Global Innovation Index (GII) | Innovation Input Sub-index | Innovation Output Sub-index |
|---|---|---|
| Switzerland(1) | Singapore(1) | Switzerland(1) |
| Sweden(2) | Switzerland(2) | Netherlands(2) |
| United States of America(3) | Sweden(3) | Sweden(3) |
| Netherlands(4) | Denmark(4) | United Kingdom(4) |
| United Kingdom(5) | Finland(5) | United States of America(6) |
| Finland(6) | Netherlands(6) | Finland(7) |
| Denmark(7) | Germany(7) | Israel(8) |
| Singapore(8) | United States of America(8) | Germany(9) |
| Germany(9) | United Kingdom(9) | Denmark(12) |
| Israel(10) | Israel(10) | Singapore(15) |

**Achieving innovation.** In terms of output from investment in innovation, as shown previously in Table 4.1, Singapore ranks fifteenth, below Switzerland (first) and China (fifth). Examining the sub-indicators level, Figure 4.2 shows that Singapore must work to catch up to Switzerland and China in terms of knowledge and technology output and creative output.

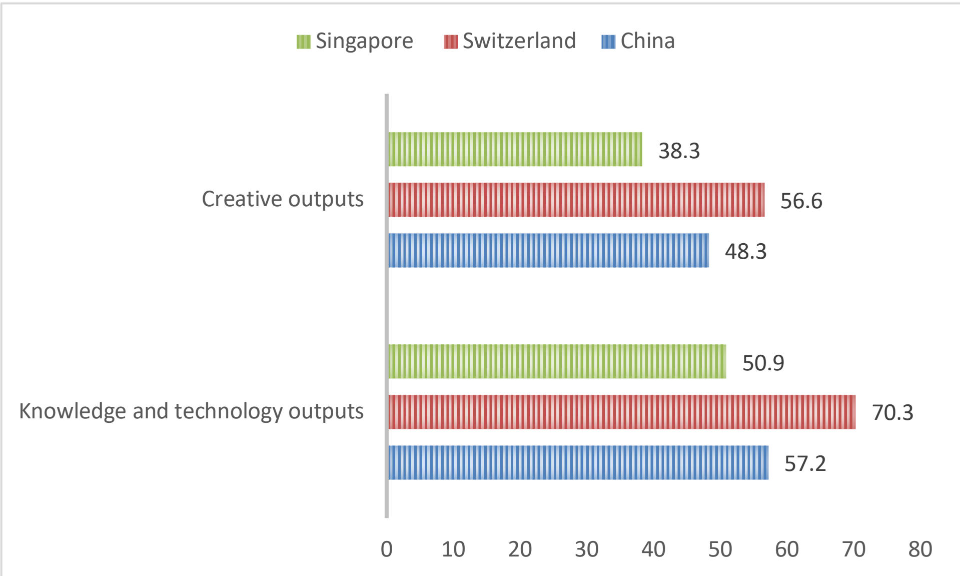



**Figure 4.2 Innovation output sub-indices. Source: Adapted from the 2019 GII report.**

The competition to achieve innovation quality is fierce and not limited to high-income economies. The GII 2019 report measures innovation quality as the aggregated scores of the following proxy indicators:

- the quality of local universities (QS university ranking)
- the internationalization of patented inventions (Patent families)
- the quality of scientific publications (Citable documents H-index).

Among the high-income economies, the US ranks first in innovation quality, followed by Germany, Japan, and Switzerland. Table 4.3 indicates that Singapore is ranked behind China in innovation quality. This mediocre performance in innovation quality provides a piece of striking evidence that a less wealthy economy, such as China, can nevertheless achieve more significant innovation quality. Singapore must narrow this quality gap by either improving the university ranking or the scientific publications. While Singapore is keen to remain competitive by investing in the innovation input, it has become imperative to determine how the high financial input into innovation can be translated to recognised outputs.

**Table 4.3 Innovation quality of the US, Switzerland, China and Singapore. Source: Adapted from the 2019 GII report.**

| | University | | Patent | | Publications | | Innovation quality |
|---|---|---|---|---|---|---|---|
| | Score | Rank | Score | Rank | Score | Score | Sum of the Score |
| USA | 99 | 1 | 3.3 | 15 | 100 | 1 | 202.3 |
| Swizerland | 81.6 | 4 | 9.6 | 4 | 66.6 | 9 | 157.8 |
| China | 82.5 | 3 | 1 | 27 | 54.2 | 13 | 137.7 |
| Singapore | 68.9 | 12 | 2.2 | 18 | 36.5 | 23 | 107.6 |

One way to increase innovation outputs would be for Singapore to become a design and commercialisation hub in Asia. The vision involves making Singapore the preferred location for companies, local or foreign, wishing for access to ideas not necessarily initiated in Singapore, but co-designed there, and able to be commercialised using Singapore's supporting resources (Economic Strategies Committee 2010):

> *We should also leverage on design to come up with new products, services and business models. We can establish Singapore as Asia's Innovation Capital – a hub for innovation and enterprise, and a location of choice for commercialisation, even for ideas not invented here…Provide ease of access to a range of ideas and IP from both public and private sectors. This should also include knowledge capital from abroad as part of the strategy of 'not invented here but commercialised here'. One way to do this is to attract fully-managed*

> *premier service incubators to bring about a step change in how we incubate start-ups. (Economic Strategies Committee 2010, p. 24)*

To achieve that goal, the ESC recommended a two-pronged approach:

- Firstly, Singapore would become a global R&D hub.
- Secondly, Singapore would become the leading innovation hub or capital in Asia.

The ESC identified the *ability to translate ideas to the marketplace* as '*innovation capital'* (Economic Strategies Committee 2010, p. 56).

Despite already investing heavily in ways to stimulate innovation, Singapore increased R&D investment in public technology knowledge creation. One of the ESC's challenges was how to foster public-private sector IPTC to increase innovation output. *Innovation capital* was enhanced through the establishment of different innovation platforms for public technology producers (universities, RIs, polytechnics) and private companies (MNCs and SMEs) to translate R&D ideas into the marketplace. Although most platforms were established for MNCs and universities, the Centre of Innovations, COIs at polytechnics was one of the co-innovation platforms targeted for local SMEs.

Another interesting platform concept, a use-driven platform, was recommended to connect practitioners (clinicians) and high-technology start-up companies to translate proven R&D outcomes into breakthrough solutions.

This user-driven platform can be replicated in a polytechnic-SME IPTC model where practitioners, in this case retail managers who have knowledge about problems faced by end-users, collaborate with polytechnic engineers to develop IP for commercialisation

According to Verganti (2009), conventional product innovators provide new products with better:

- technical functionalities
- features, or
- aesthetic.

Although such incremental innovation approach works, a *design-driven innovation* approach can change the competition radically(Verganti 2009). Based on Verganti's design-driven innovation approach, designers innovate collaboratively through a community of like-minded people, including designers, scientists, critics, and executives, to position product that creates a different meaning or purpose for the end-users. An example highlighted in Verganti's article includes a cone-shaped kettle (model 9093) designed to provide the end-users with a unique breakfast experience, not for boiling water.

### 4.1.1 Agency innovation characteristics

Generally, Singaporean agencies embrace evolutionary innovations. Under the National Research Foundation (NRF), the Singapore government began implementing long-term R&D strategies in 1991. Ten years later, a five-year strategy – known as RIE2015 – evolved to focus on industry R&D, aimed at new product and service commercialisation in the biomedical sciences, environment and water industries (Liu 2015).

Just like private companies, officials from government agencies travel globally to study best practice and adapt this for local adoption. At the 45th St Gallen Symposium, Stephen John Sackur, an English journalist, emphasised that Singapore had economically transformed itself from a developing city-state into a developed power – an economic miracle (St Gallen Symposium 2015). In the same symposium, the Deputy Prime Minister of Singapore, Tharman Shanmugaratnam, explained that the government had been successful in researching and experimenting with different nation-building policies adopted from developed countries and adapting them to benefit the nation. This dynamic approach to policy setting was evidenced in Tharman's response to the question of how Singaporeans can be more creative:

> *There are two parts to the question … it is true that developing Singapore into a more innovative society, which is what its future has to be, this requires a certain amount of free play of ideas, at the level of individuals, or group of individuals, and we have to allow for that, and I don't think allowing for that means that we just mimic the Bay Area in the United States. We are of a different society, we got to evolve, we got to give more free play to individuals, to individual choices, they may be right or wrong choices, but people will learn with time. (St Gallen Symposium 2015)*

The need for more time to adapt and localise the Bay Area concept is a clear articulation of how a small and poorly resourced nation that has little to offer except a hardworking, multicultural workforce is shaping public innovation policies. Such pragmatic thinking embraced by a top government official will influence the ways in which agencies frame the national innovation policies in IP commercialisation.

The economic success of a city can be attributed to its ability to put technology, talent, and tolerance – known as the 3Ts of economic development – together (Florida 2003). According to the article:

> *Talents are attracted to San Francisco Bay Area, Boston, Washington, DC, Austin, and Seattle because of their tolerance, work and social environment that is open, inclusive, and diversity. (Florida 2003)*

Failing to embrace the tolerance element (one of the 3Ts) in their economic development had set regions like Baltimore, St Louis, and Pittsburgh behind the Bay Area despite their abundant technology pool, and world-class universities as technology producers. In the long term, the Singapore government hopes to transform its current work and social environment to a more tolerant one, as implied by Tharman's interview at 2015 St Gallen Symposium.

**Housing.** Two concrete examples of evolutionary public innovation policies were discussed and highlighted during the St Gallen Symposium: (i) public housing policy and (ii) public education policy (St Gallen Symposium 2015). During a study of public housing policy, Yuen (2007) observed that 85% of Singapore's population lives in public housing that has evolved to ensure that people from a variety of ethnic backgrounds are co-located. Racial or ethnic integration is enforced by law in public accommodation for reasons explained by Tharman in a public forum:

> *Every single precinct has a rule on ethnic balance which means that they are on the same floor taking the lift up-and-down every day. You have certain interaction that is quiet and unstated and normal. But it also means critically that the kids go to kindergartens and primary schools that are integrated because kids tend to go to schools that are quite close to where they live … but getting some sports and dance together you just become more comfortable with each other, so being willing to have some intrusive rules in the interest of cohesion in the interest of preserving common space is I think critical. We did it in our own way given on circumstances and there are different ways in other societies but they can never think that the natural workings*

*of society would somehow produce cohesion usually the opposite happens. (Singapore Forum 2015)*

Tharman's point on the need for an ethnic balance rule has translated the seemingly ordinary public housing policy into one that has practical effects and is exemplary of an evolutionary and innovative approach. However, such a forced ethnic integration rule incorporated in the public accommodation policy could be viewed and criticised by many as authoritarian. Nonetheless, the truth is that it has produced the desired ethnic diversity with significant benefits, both social and economic, for Singapore.

**Public education.** Singapore inherited public education policies from Britain and adapted them locally to ensure global competitiveness. Yiannouka (2015), the Chief Executive Officer of the World Innovation Summit for Education, attributed the success of Singapore's education systems to the wisdom of its leaders in adapting the British education system, by building on the established framework that was provided under colonial rule and expanding the tertiary sector beyond the country's first university, the National University of Singapore (founded in 1905), and the first polytechnic, Singapore Polytechnic (founded in 1954). Singaporean universities have gone on and achieved global recognition for their educational standards. The National University of Singapore and Nanyang Technological University were among the highest-ranked in the most recent Times Higher Education World University Rankings, at 25 and 61 out of some 400 universities (THE 2015).

Similarly, Singaporean secondary students still take the Singapore-Cambridge General Certificate of Education Ordinary Level 'O' and 'A' examinations, which have evolved since colonial times, confirming the nation's evolutionary thinking. According to Yiannouka (2015), there has been a shift from focusing on science, technology, engineering, and mathematics to humanities, arts, and sport, which provides further evidence of cultural evolution in Singapore. The evolutionary changes that Singapore has undergone have resulted in the public education system producing students and institutions that are consistently competitive (OECD 2010). For example, Singapore’s students perform well in the Organization for Economic Co-operation and Development’s (OECD) Program for International Student Assessment.

However, being internationally competitive is not the only policy goal. The challenge for MOE is to ensure that public education is accessible to all who aspire to acquire skills and advance through life. According to Yiannouka (2015), Singapore has been successful in providing hundreds of local schools, institutes for technical education, and polytechnics that offer high-quality education for all. Similar to the Institute of Technical Education, a polytechnic education system that was also inherited from Britain is sustained in Singapore to enable secondary school graduates to develop practical career skills. In contrast, school graduates who aspire to pursue more academic or professional qualifications can proceed to university.

**Public agencies’ roles in IP creation and deployment.** Agencies in Singapore are proactive in providing the resources required to transition Singapore to a knowledge economy. The triple helix innovation model (Etzkowitz 2003) assumes that innovation occurs at the intersection of university-industry-government (U-I-G). Such U-I-G interactions can lead to knowledge of discovery or creation. Figure 4.3 illustrates the possible intermediation of the players or actors in a triple helix innovation. The figure has been conceptualised from an understanding of the relevant concepts as outlined by Leydesdorff and Etzkowitz (1996), OECD/ERIA (2018) and Wang (2018) and discussed in subsequent paragraphs.

Although the roles assumed of public agencies are critical in the dynamic relationship of industry and academia, the roles assumed by civil society and internationalisation cannot be neglected, as explained by *Quadruple Helix* innovation model (Leydesdorff 2012). While the involvement of civil society will lead to inclusive public policymaking, the internationalisation aspect will facilitate Singapore's vision of becoming the commercialisation hub in Asia (Economic Strategies Committee 2010).

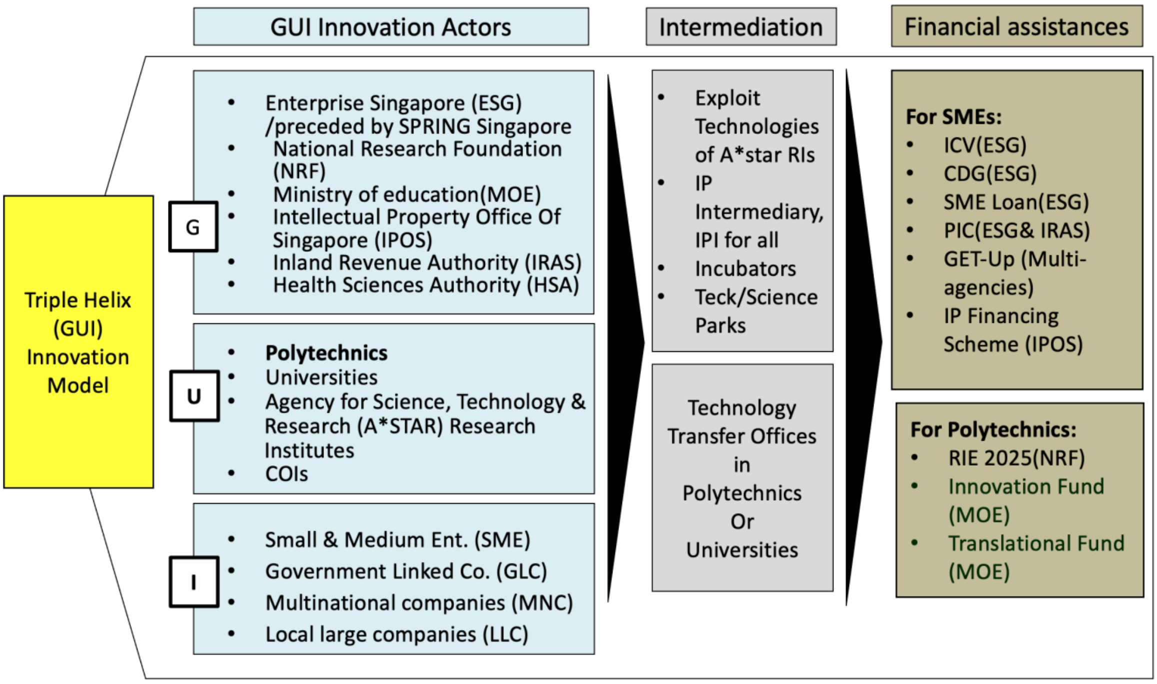



**Figure 4.3 Intermediation of the contextualised triple helix innovation model.**
**Source: Adapted from Sim & O'Connor 2014, p. 1072.**

**Financial assistance.** In 2018, the *Standards, Productivity, Innovation and Growth (SPRING)* and *International Enterprise of Singapore* were merged as *Enterprise Singapore (ESG)* to implement policies designed to help Singapore-based enterprises (both micro-SMEs and large enterprises) to innovate, grow and expand overseas (OECD/ERIA 2018). As the first-stop government agency; Enterprise Singapore (ESG) has supported the (OECD/ERIA 2018):

- Push for more public-private IP transfer and development through the Innovation and Capability Voucher (ICV).
- Capabilities and productivity enhancement through the Capability Development Grant (CDG).
- Approval for the government-backed SME loans (Wang 2018).

In addition, qualified firms can claim tax incentives for investments in innovation and productivity improvement under the Productivity and Innovation Credit (PIC) scheme, administrated by the tax department (Inland Revenue Authority of Singapore 2007; Wang 2018). Among other activities, the Productivity and Innovation Credit (PIC) supports the costs of the IP in-licensing activities that SMEs are seeking in most innovative product or service developments. SMEs could use an IP asset as collateral to secure a financial loan under the IP Financial Scheme administered by IPOS (Wang 2018).

In technology innovation space, listed below are more recent innovation programs offered by A*STAR. The first two were offered in collaboration with other funding agencies (OECD/ERIA 2018):

- *Growing Enterprises through Technology Upgrade (GET-Up) program*.
  This multi-agency program, jointly initiated by A*STAR, Enterprise Singapore (ESG), EDB and MOE, provides help for SMEs to improve absorptive capacity through schemes such as R&D workforce secondment, technology road mapping and technical consultancy.
- *Tech Depot Hub*.
  This online platform is another multi-agency initiative. It connects SMEs to pre-approved technology solutions to improve their productivity, and was developed by A*STAR, Infocomm Media Development Authority (IMDA) and Enterprise Singapore (ESG).
- *Tech Access program*.
  SMEs can access advanced manufacturing equipment, facilities and expertise while experimenting with their innovative ideas.
- *Head-start Program.* SMEs can use IPs developed collaboratively with A*STAR IP for up to three years without royalty payment.

While Singapore may have been considered slow in taking up technology transfer and R&D initially, the country has taken marked steps to address the situation by introducing a series of five-year R&D plans, some 30 years ago, beginning in 1991 (Government of Singapore 2020; Mok 2015). The national R&D plans are developed and coordinated by the NRF under the Prime Minister’s direct chairmanship (Mok 2015). Over time, titles used to identify such plans have included the National Science and Technology Innovation Plans, and the Research, Innovation and Enterprise (RIE) Plans. NRF is providing polytechnics with innovation and translational R&D funding via MOE, ringfenced for the polytechnic sector only.

Under these plans, public R&D funding grew by 650% over the 15 years from 1991 to 2006, when funding grew from an initial S$2bn, tripling in 2000 to S$6bn and doubling again by 2006 to S$13.55bn (Lim, M 2009). Recently, the government approved a S$25bn RIE2025 Plan, for 2021 to 2025 to invest in (Government of Singapore 2020):

- basic research for scientific capabilities and IP creation
- scope expansion of existing RIE domains into Human Health and Potential, Urban Solutions and Sustainability, Manufacturing, Trade and Connectivity, and Smart Nation and Digital Economy
- strengthening technology translation and SMEs' innovation capabilities.

Approximately 15 years ago, under the fourth National Science and Technology Innovation 2010 Plan, the Singapore government initiated the promotion of technology transfer and IP management for SMEs, and the facilitation of better coordination between the public and private sectors (Mok 2015). Today, under the RIE2025 plan, relevant IPTC capabilities and knowledge relevant to technology-industry fit have been recognised as a common challenge in product innovation. Consequently, new HC development initiatives for SMEs, such as the Innovation Advisors for new products introduction and the Innovation and Enterprise Fellowship programs for skills development in IP commercialisation (Government of Singapore 2020), have been implemented. Why the focus on SME innovation skill development now? Singaporean SMEs need more time to learn how to commercialise IPs, they were dependent on foreign MNCs to provide relevant high technology (De Wet, Gideon 1999), and most of them have been content to support MNCs downstream activities (Chua 2002) - neglecting the upstream innovation activities. In summary, the Singapore government is still active and agile and is able to pivot its national innovation plans in response to prevailing economic phases. Although both industry and public technology producers are resourced to promote indigenous innovation capabilities, producing a more SME-reliant innovation approach.

**Intermediation**. SMEs in Singapore are provided access to a variety of IPTC infrastructure and innovation platforms, including the COIs, incubators, technology and science parks, and technology-transfer offices (OECD/ERIA 2018).

Most COIs are set up in partnerships with polytechnics as one-stop centres where SMEs can develop their innovation projects through the provision of prototyping facilities, consultancy, and training in targeted industries, including electronics, supply-chain management, environment and water, food, and offshore engineering. There is a plan to expand COI in polytechnics to new areas, such as medical technology and clean energy (Economic Strategies Committee 2010). Continuous investment in the COIs in polytechnics confirms the public confidence in polytechnics' competencies in innovation prototyping.

Institute specific TTOs have been established as the commercial arms of various institutes to interface with industry. A more neutral TTO, known as IP Intermediary Ltd, has also been established to connect registered IPs and seekers to co-create their respective innovations at a global level (IPI-Singapore 2018), extending the reach of IPTC opportunities beyond Singapore.

Access to professional services within the intermediation infrastructure matters. In the 1990s, with the $1 billion Technopreneurship Innovation Fund (TIF), the government co-invested with venture capitalists in technology start-ups in the life-science and information and communication technology spheres. According to Liu (2015), many engineers responded to the call and started dotcoms in the late 90s. However, critics were not optimistic that such funding would achieve much (Arnold 1999) based on the mediocre performance of another program, the Technology Incubator Program (TIP), in which only four out of 149 enquiries had been approved.

According to Arnold (1999), critics have argued that top-down funding policies are contrived, and that relevant knowledge among the members of the assessing panel has been somewhat limited. Arnold's report also noted that public agencies had engaged savvy venture capitalists to co-assess and co-invest in high-tech start-ups, after acknowledging the agencies' underlying knowledge gap. Responding to Arnold's article, Mahbubani (1999) defended Singapore, stating that the region simply needed more time to learn from others. Mahbubani, a professor in the Practice of Public Policy and Dean of the Lee Kuan Yew School of Public Policy at the National University of Singapore, was confident that Singapore had a fighting chance of providing an environment conducive for technopreneurs, based on its past economic performances.

In attempting to address the knowledge gap, the ESC recommended that the competency of IPTC professionals, patent agents, or mentors be elevated (Economic Strategies Committee 2010). After several years, Singapore launched its first national-level skills development framework to further develop IPTC talents for the IP sector in 2019 (Mathews, M 2018). Such moves validated the needs for more local IPTC talents.

In a recent study, Wang (2018) found that the city-state government is perceived as highly involved in the upgrading of both public (IHLs) and private (SMEs) research and innovation capabilities with a variety of funding schemes and national plans. However, the number of local innovation players within the narrow innovation focus in Singapore is noticeably limited. The researcher agrees with Wang (2018) suggestion that Singapore should shift its research and innovation policy attention to benefit more local SMEs, not just benefiting the limited 'star' companies, the government-linked companies (GLCs). Such a policy attention shift may eventually help Singapore to improve its innovation quality performance as reported in the 2019 GII (Cornell University, INSEAD & WIPO 2019). With more inclusive policy attention and a relook at the grant administration gaps as highlighted by Arnold (1999), hopefully Singapore will be able to sustain and grow its indigenous innovation players (IHLs or SMEs).

**Patents as a competition tool.** Big firms, not IHLs, seek international patents as a competitive strategy. Only 14% of Singaporean patent applicants to the United States Patent and Trademark Office were from universities and research institutes, whereas the top patent applicants were from large MNCs and GLCs in the semiconductor and electronics industry (Wang 2018). Despite the cautious IP strategy adopted by IHLs, data from the 2014 CPI makes it clear that through its TTO, Singapore is positioned as one of the highest-rated Asian countries for IP protection and U-I collaboration. However, polytechnics are mainly excluded from considerations about IPTC processes, raising questions about the legitimacy and potential of polytechnic IPTC processes. According to the 2014 CPI report, as a nation Singapore is still ranked behind Japan, Taiwan, and the Republic of Korea in the performance of IP protection in terms of the number of patents filed per capita.

What to patent is a complicated business decision. Polytechnics, being industry-focused, are expected to build strong industry linkages to establish capability development projects, industry-orientated training programs and facilities. Through reinforcing polytechnic-industry networking, more industry applicable patents could be co-created or exchanged.

Another patent-related indicator, the Science-Link indicator, is used to gauge a company's ability to close the gap between patents and basic R&D (Deng, Lev & Narin 1999; The Economist Intelligence Unit Ltd & Asian Development Bank 2014). Deng, Lev and Narin (1999) claim that a product is well-grounded in science if it features a high patent Science-Link value, which is sought after in the biotechnology industry. However, they also demonstrated that the Science-Link value does not affect innovations that aggregate mature or established patented technologies. Based on this observation, polytechnics seeking patent protection on their applied R&D outcomes may have to look beyond the non-biotechnology industry for potential IP commercialisation partners.

**IPTC through an IC perspective.** The potential outcomes arising from IPTC depend on the investment in intangible resources, that is, the intellectual capital (IC) assets of each stakeholder. Rapid deployment of accessible IC assets into values, either internally (closed-innovation view) or externally (open-innovation view) fosters innovation. According to Lev (2000):

> *Innovations are created primarily by investment in intangibles. When such investments are commercially successful and are protected by patents or first-mover*

*advantages, they are transformed into tangible assets creating corporate value and growth. (pp. 16)*

### 4.1.2 Polytechnic innovation characteristics

Polytechnics are commonly regarded as the IP translators in Singapore's RIE landscape. Today, the polytechnic sector consists of five publicly funded institutions:

- Singapore Polytechnic
- Ngee Ann Polytechnic
- Temasek Polytechnic
- Nanyang Polytechnic
- Republic Polytechnic.

As stated in a book chapter co-authored by the ex-principal of Nanyang Polytechnic, Chan Lee Mun, the polytechnic education system is characterised by its distinctive industry-oriented education (Birger, Lee & Goh 2008, p. 135); moreover, the polytechnic sector collectively provided more than 140 practice-oriented diploma programs to more than 60,000 students in 2006. Most polytechnic graduates join the workforce directly after completing their study, while some pursue university programs after a few years of work experience.

Each polytechnic is resourced in accordance with its enrolment numbers. A typical polytechnic with 1,200 to 1,400 staff could receive an annual budget of 180 million Singapore dollars, as well as a development budget for buildings and infrastructure (Birger, Lee & Goh 2008, p. 137). In addition to teaching and learning, secondary sources show that the polytechnic sector has helped industry to develop utility-oriented product ideas.

The presence of applied RIE resources and capabilities in the polytechnic sector, such as the COIs, and various technology centres, provides an avenue for SMEs to translate their product ideas into the marketplace, as well as the research universities to translate basic research into commercially applicable products, processes or applications, thereby linking utility-driven innovation patents to basic science. These arrangements reinforce polytechnics' position as IP translators for SMEs to develop their business ideas into innovative solutions and subsequently improve Singapore's overall position in innovation productivity.

**Polytechnics versus universities.** Compared with universities, polytechnics are not expected to deliver upstream research publications or breakthrough scientific discoveries. However, there is an increased expectation for the polytechnic sector to provide more commercially applicable IP to SMEs who are lacking in product innovation. This emerging phenomenon could alter the existing RIE landscape to be a more inclusive one that is not restricted to scientific knowledge production.

Public knowledge of polytechnics' roles as IP translators is limited. Previous literature discusses the roles played by local universities (Wong, Ho & Singh 2007), research centres (Lee, J & Win 2004) and the government (Yong & Keng 1992). At the regional level, Wong (1999) expressed concern about the limited literature discussing university-industry technological collaborations in newly industrialised economies, such as Singapore. The study used Singapore as the research context, and triangulated secondary data from different public sources, including the annual national R&D survey, to inform the university-industry collaboration landscape.

In addition, Wong (1999) points out that the inconsistent use of tertiary institutions as a collective entity to represent universities, RIs and polytechnics in large-scale surveys could lead to data resolution issues if sector-based data (such as in the polytechnic sector) is needed. In a joint publication, Wong, Ho and Singh (2007) present data on the IPTC activities of a leading university – the National University of Singapore, not on polytechnics. The current study aims to explore new knowledge in the IP commercialisation space between polytechnics and SMEs, hence filling the knowledge gap in polytechnic–industry technological collaboration.

As alternative public IP translators, almost all polytechnics undertake applied R&D and experimental research projects with varying levels of intensity. Etzkowitz (1998) found that entrepreneurial universities are expected to perform successfully in all three functions of teaching, research, and economic development. Economic developments are third-stream activities that are undertaken outside regular teaching and research activities (Lockett, Wright

& Wild 2013). Over the years, the polytechnic sector has collectively invested 35 million Singapore dollars in R&D to deliver close to 200 patent applications, and 34 commercialised products or services (Chew, C 2009).

Secondary sources of data show that polytechnics are continuously seeking opportunities to co-innovate with local industry through TTOs or technology centres (Nanyang Polytechnic 2011; Ngee Ann Polytechnic 2010; Republic Polytechnic 2013; Singapore Polytechnic 2013c; Temasek Polytechnic 2012). Polytechnic-industry third-stream missions are achievable through mechanisms, such as industry commissioned projects, secondment of polytechnic R&D staff to industry, and IPTC to industry. Through real-life industry projects, polytechnics can sustain and renew their human, structural and relational capital. According to Chen, Zhu and Xie (2004), the IC of an organisation is supported fundamentally by its human capital, which grows alongside three other elements: structural capital, innovation capital, and customer capital.

Supported by experience working in one of the polytechnics, the researcher observed that, through various polytechnic-industry collaboration projects, the polytechnic sector is developing its IC assets to fulfil all three organisational missions of teaching, research and commercialisation. Figure 4.4 presents an overall IC framework that could be used as a reference framework for in-depth investigation of the polytechnic–SME relationship.

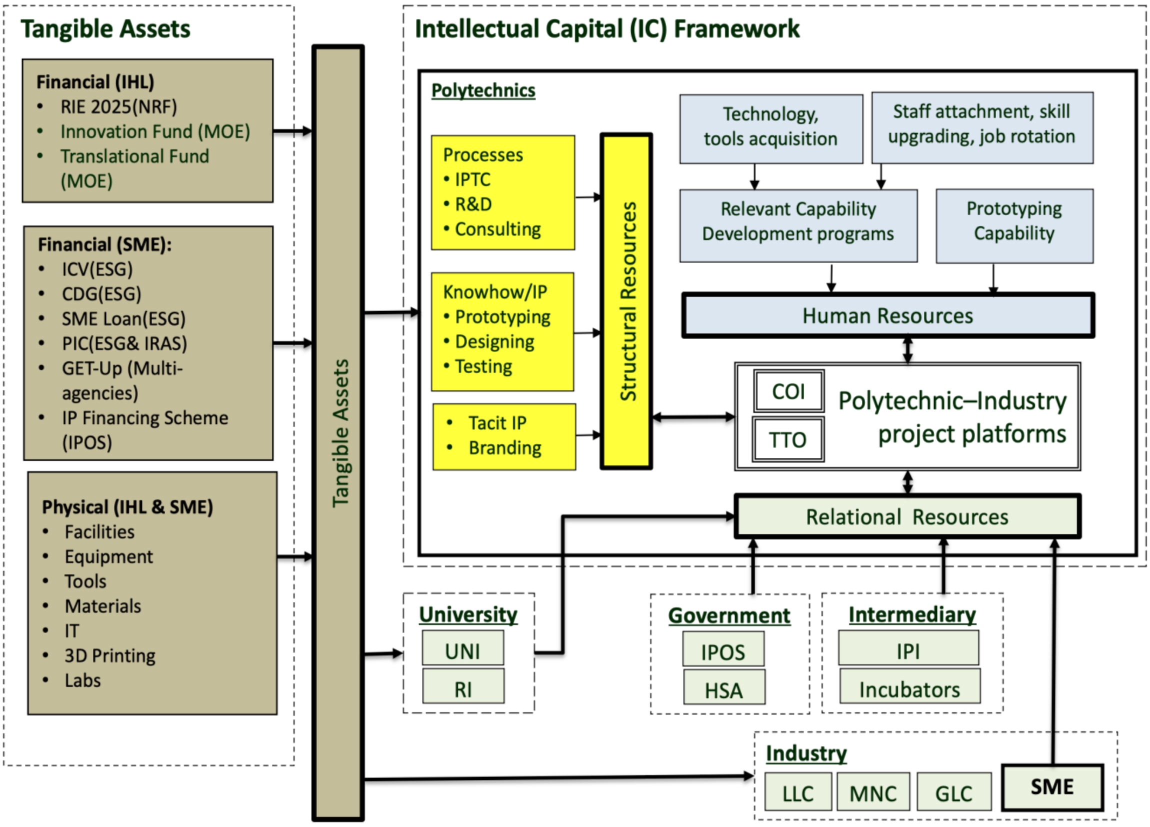



**Figure 4.4 Overall IC framework of the polytechnic–SME relationship derived from researcher assessment. Source: Adapted from Sim & O'Connor 2014, p. 1066.**

A compelling question is how this IC framework would influence value co-creation. A validated IC framework would ensure that polytechnics have a common understanding of accessible IC assets. Effective management of these IC assets would differentiate them in their ability to produce useful IP for the industry. Typically, polytechnics are capable of producing IC assets in subject matter, including technological knowledge, project management expertise, hands-on training expertise, prototype development knowledge, patents, copyrighted materials, registered designs and trade secrets. While some of these IC assets can be transferred readily to SMEs, many need further development. The following subsections contextually review the polytechnic–SME IPTC environment by examining secondary data of agency reports, news articles and web sources.

**Knowledge transfer and generation.** A polytechnic's primary mission is to provide work-ready education (Chan 2008; Lin, CT 2002; Varaprasad 2016); whereas, most universities are founded to conduct teaching (first mission activity) and research (second mission activity). Gulbrandsen and Slipersaeter (2007) discuss third-mission activities, in which entrepreneurial universities provide knowledge contribution to society and the economy, either directly or indirectly, by engaging in IP translation or deployment activities.

**Through practice-based graduates.** In Singapore, the polytechnic sector is the largest public IHL preparing a practice-based workforce for the industry. Table 4.4 presents various IHL missions extracted from their respective corporate websites. Examining the polytechnics' statements confirms that they are primarily established to provide knowledge transfer through:

- pre-employment education (in Table 4.4, words related to this are **in bold**), and
- education for continuous skill upgrading (in Table 4.4, words related to this are underlined).

In Table 4.4, the *italicised* words related to research and knowledge creation and advancement are being incorporated with the mission statements of major public universities to reflect their commitment to their secondary mission. The absence of such words from the polytechnics' mission statements could mean that polytechnics are not expected to create new knowledge through research. Most polytechnics' mission statements are either silent or unclear in stating their third academic mission as a public technology producer – except for Nanyang Polytechnic (see Table 4.4 below: 'We will harness our resources, expertise, creativity and innovation to support the development of business and industry and to complement Singapore's globalisation effort').

**Table 4.4 Mission statements of public IHLs in Singapore**

| Polytechnics' Mission Statements | Universities' Mission Statements |
|---|---|
| 'To nurture lifelong learners who are imbued with 21st-century competencies and valued at the **workplace and by society'**. (Ngee Ann Polytechnic 2015) | 'A great global university founded on *science and technology*, **nurturing leaders** through *research* and broad education in diverse disciplines'. (NTU 2012) |
| 'We nurture individuals to prepare them for **a dynamic world** in partnership with stakeholders, leveraging problem-based learning'. (Republic Polytechnic 2015) | 'To develop individuals who build on their interests and talents *to impact society* by providing a nurturing environment that is uniquely enriched by world-class partners'. (SIT 2013) |
| '**Life Ready.** To fill the knowledge gap in polytechnic–industry technological collaboration, World Ready … A future-ready institution that prepares our learners to be life ready, **work ready and world ready'**. (Singapore Polytechnic 2014) | 'Foster closer international partnerships for *transformative* global engagement'. (NUS 2015) |
| 'We provide quality education and training to prepare students and adult learners for **work** and life, equipping them to be life-long learners and to contribute to the technological, economic and social development of Singapore … We will harness our resources, expertise, creativity and innovation to support the development of business and industry and to complement Singapore's globalisation efforts'. (Nanyang Polytechnic 2013) | 'To create and disseminate knowledge. SMU [Singapore Management University] aspires to generate *leading-edge research* with global impact as well as to produce broad-based, creative and entrepreneurial leaders for the *knowledge-based economy*. SMU is committed to an interactive, participative and technologically enabled **learning experience.** Towards this end, it will provide a rewarding and challenging environment for faculty, staff and students to kindle and sustain a passion for excellence'. (SMU 2015) |
| 'To prepare school-leavers and **working adults** for a future of dynamic change, with relevant knowledge, life-long skills, character, and a thirst for continuous improvements'. (Temasek Polytechnic 2014) | 'The Singapore University of Technology and Design is established in collaboration with MIT to *advance knowledge* and nurture technically **grounded leaders** and *innovators to serve societal needs*. This will be accomplished, with a focus on design, through an integrated multi-disciplinary curriculum and *multi-disciplinary research*'. (SUTD 2015) |

According to Chen, Zhu and Xie (2004), individuals' competencies increase with the transfer of theoretical knowledge through formal education, and transfer of practical skills through routine practice. Coupled with the desired attitude (which is difficult to measure), a highly competent individual can deliver the needed human capital to their industry. In terms of numbers, the Department of Statistics (2013) reported that the polytechnic sector had been producing more than 60% of public IHLs' annual graduates during the previous five years. For example, in 2012, 25,063 diploma graduates completed polytechnic courses in a wide range of practice-based knowledge and skills, including engineering, information technology, sciences, design, business management, media and communication.

Based on the Science and Technology Plan 2010, the polytechnic sector is expected to supply industry with quality graduates. If a sizeable number of these polytechnic graduates (equipped with an appropriate attitude) decide to join their particular industry after completing their courses, the resultant flow of their acquired knowledge and skills will be beneficial to that industry.

**Through practice-based academic staff.** The academic and technology professionals in polytechnics are typically pragmatic and capable of developing close-to-market prototypes. Being pragmatic, they have a utilitarian mindset in translating intellectual assets into reliable and cost-effective inventions or solutions. Such IP development works are usually meticulously executed sequentially under the supervision of a team leader. In contrast, the university sector generally lacks the human resources or capabilities required to develop IP into commercially viable products (Lipinski, Minutolo & Crothers 2008). Polytechnics' academic staff members are more practice-oriented than are their university counterparts.

The Department of Statistics (2013) reported that the polytechnic sector is resourced with 4,945 academic staff. Almost all of these are university graduates with prior industry work experience. Some of these academic members are involved with polytechnic-industry collaboration projects through technology centres or TTOs. In addition, they engage with industry through national initiatives, such as the COIs and Growing Enterprises with Technology Upgrade (GET-Up) program, under the purview of A*STAR (A*STAR 2015; Menkhoff & Wah 2008).

A COI is a one-stop resource centre for product or service development, where local SMEs and the COIs co-innovate, co-funded by SPRING (Menkhoff & Wah 2008; SPRING Singapore

2012b). Today, six COIs are co-funded by SPRING. Their respective hosting technology translators are as follows:

- Food Innovation Resource Centre (at Singapore Polytechnic)
- Centre of Innovation for Electronics (at Nanyang Polytechnic)
- Marine and Offshore Technology Centre of Excellence and the Environment and Water Technology Centre (both at Ngee Ann Polytechnic)
- Centre of Innovation for Supply Chain Management (at Republic Polytechnic)
- Precision Engineering Centre of Innovation (at SIMTech, an A*STAR Research Institution).

Of that list, only the Precision Engineering Centre of Innovation was established outside the polytechnic sector, at SIMTech (A*STAR Research Institution). The increasing number of polytechnics engaging with SMEs in downstream co-innovation activities has robustly validated the polytechnic sector's role as a key technology or IP translator. Such an IP translator role, focusing more on applied research and in-vivo prototyping, could be incorporated in Rombach and Achatz's IPTC model (Rombach & Achatz 2007).

Another national initiative that endorses polytechnics' R&D competency is the Growing Enterprises with Technology Upgrade (GET-Up) program, which encourages polytechnics to provide short-term R&D workforce and acquisition of technologies to help local SMEs transition to more R&D-intensive activities (Menkhoff & Wah 2008; SPRING Singapore 2012a). However, all national initiatives will fail to deliver the desired outcomes if a necessary proportion of human capital stock is absent from the polytechnic system – a strategic resource that is more valuable than financial capital (Bjerke 1998).

**Through utility-oriented product IP.** Polytechnics excel in applied research and experimental studies that lead to commercially applicable IP. Lipinski, Minutolo and Crothers (2008) estimate that only around 3% of universities' technology in the US is deemed suitable for start-up companies. They also state that most large companies prefer to license well codified and protected technologies as incremental improvements to their established products (Lipinski, Minutolo & Crothers 2008).

Such inclination could be interpreted as indicating that continuous improvements or incremental IP are preferred to radical change. On the other end of the entity type spectrum, micro-sized enterprises generally favour incremental innovations, driven by the founder who is also the innovator (Jones et al. 2014). Slightly better resourced and informed about market potential, SMEs also value incremental innovation of existing products (Collier, Gray & Ahn 2011). This is evidenced by secondary sources of data obtained from the individual polytechnic's annual reports published between 2011 to 2013, where a number of polytechnics' incremental IP has been embodied in commercial products or services. Some of this commercially deployed IP is grouped and listed in the following categories:

<u>Examples of existing product extension</u>

- a quick alert system that prevents unwanted falls of bed-confined patients, which was commercialised through Plenitum Cares (S) Pte Ltd (Ngee Ann Polytechnic 2011)
- an elderly-friendly walking aid (rollator) that allows the user to be seated quickly without having to turn around, thereby eliminating risky guesswork as the user can see the seat before seating, which was licensed to Greenstyle Pte Ltd – a subsidiary of Rehab Mart Homecare (Nanyang Polytechnic 2012)
- a thin plastic film that converts smartphones or tablets into 3-D graphic devices, which was commercialised through Nanoveu Pte Ltd (Temasek Polytechnic 2013)
- an ergonomic backpack designed for primary school students to shift the load centre nearer to the user's centre of gravity, commercialised through Nexwav International (Republic Polytechnic 2012).

<u>Examples of process IP</u>

- unique herbal drink brewing methods (for teas made with Rose-Roselle, Plum-Hawthorn and Luo Han Guo-Dates flavours) for the health benefits, which were commercialised through Eu Yan Sang (Republic Polytechnic 2011)
- an innovative method of producing the world's first 19-karat solid purple gold to replace gold as an the alternative costume jewellery, which was patented and licensed to Aspial (Singapore Polytechnic 2013b).

Examples of software IP:

- an algorithm that augments virtual reality to enhance the classroom learning experience, which was licensed to an international publishing company (Republic Polytechnic 2013)
- a customised machine control software for washing and rinsing life science products, which was licensed to a company that produces DropArray plates (Nanyang Polytechnic 2011).

Examples of recipe IP:

- healthier gourmet sausages, which were commercialised by Wang Foong Foodstuffs Suppliers(Singapore Polytechnic 2012)
- a new beverage commercially known as 'Lemonsi Delight', produced using local fruits (lemon and calamansi), which was licensed to Pokka Corporation (Singapore Polytechnic 2013a)
- several secret recipes for ice-creams and healthy beverages, which were introduced to the marketplace through local companies (Nanyang Polytechnic 2011).

There is currently no clarity on the performance of the above commercially deployed IP; however, their existence suggests that polytechnics' IP are commercially applicable. Based on the public information of the listed examples, a good mix of firms has collaborated with the polytechnic sector. These firms range from established ones, such as Eu Yan Sang, Aspial and Pokka Corporation, to start-ups, such as Nanoveu Pte Ltd and Plenitum Cares Pte Ltd. It is also interesting to note that established consumer retailers, such as Greenstyle Pte Ltd, which does not possess any R&D resources, have started to employ the polytechnic sector for complementary co-innovation resources to stay ahead of the competition. Besides local demand, a more relatively recent newspaper article reported that a bundle of Temasek Polytechnic's IP relating to a compact and light-weight fuel cell applicable to cars, drones and scooters, was commercialised through Jiangsu Ice-city Hydrogen Energy Technology in China (Tan, C 2018). This seems to suggest that a polytechnic's IP can have a value outside of Singapore.

This group of SMEs – established consumer retailers, compared with young start-ups – are financially stronger and endowed with richer market knowledge. Depending on the firm's absorptive capability (Cohen & Levinthal 1990) and deployable resources, an established consumer retailer could rapidly introduce new products or services without investing in R&D, via functional collaboration with a matching technology producer. Regardless of the types of IP, there is a general perception that the polytechnic sector tends to produce more market-ready IP than the university sector does.

**Knowledge generation through publication.** New knowledge and technology costs money and time to develop. In terms of new knowledge creation through article publication, Thomson Reuters (2014) reported that in 2014, Singapore produced 17 highly cited researchers, while Australia produced 80. The 2015 RIE report (Ministry of Trade & Industry 2013) states that Singapore invests at least 1% of the national GDP in this area (In billion Singapore dollars) each year. This indicates that there is a need for heavy investment in RIE to produce quality knowledge and knowledge producers.

This study used The University of Adelaide's library resources (The University of Adelaide 2013) via the *Primo Library* discovery tool (hosted by exlibrisgroup.com) to examine the number of articles published by the university and polytechnic sectors. In obtaining this data, the specific names of the public IHLs (four universities and five polytechnics) were used in the search field, and the search boundary was defined by the following filters: 'articles', 'with my exact phrase' and 'anywhere in the record'. The cumulative count of peer-reviewed journals by sectors confirmed that the polytechnic sector produces less publishable foundational knowledge than the university sector. Figure 4.5 indicates that the university sector produces 97% of peer-reviewed journal articles, well ahead of the polytechnic sector. This finding supports the claim that the polytechnic sector is not expected to produce publishable outcomes from upstream or basic research, that is, foundational research knowledge.

**Knowledge generation through patents.** In addition to publishable articles, this study conducted a comparative review of the number of patents filed in Singapore by accessing a public resource or database hosted by the IPOS (Intellectual Property Office of Singapore 2013), along with other analyses.

*Intellectual Property Office of Singapore.* The search of the IPOS database was undertaken with the specific names of each institution (four universities and five polytechnics) entered in the search field allocated for the names of applicants, proprietors and inventors.

Figure 4.5 indicates that the two IHL sectors have collectively filed 1,274 patents in Singapore since 1991. The polytechnic sector contributed 295 (23%) to this total – a better than expected performance in relation to the stocktake of publishable materials. Teng (2016) conducted a study on IPTC activities in the polytechnic sector from 2001 until 2016, and reported that a total of 281 patents was filed by four polytechnics (NP's number was not available). The polytechnic sector was quick to lodge its first patent, just four years after the university sector filed its first. Most patent offices would determine the patentability of an invention by its novelty, non-obviousness and usefulness (von Wartburg, Teichert & Rost 2005). Thus, this analyse affirms that the polytechnic sector has generated a respectable number of patents that are novel, innovative, and industry applicable.

However, the values of patented technologies to a SME should be validated through primary research.

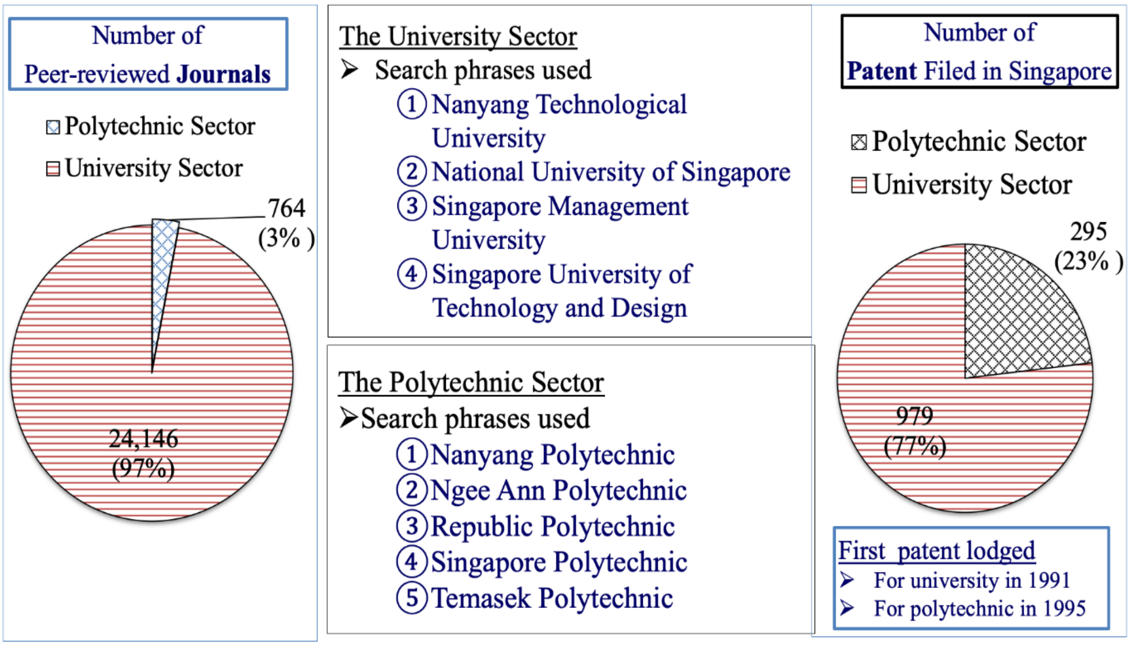



**Figure 4.5 Patenting and publication activities of the polytechnic and university sectors. Source: Sim & O'Connor 2014, p. 1070.**

*Innography*. In an attempt to establish the value of polytechnic patents to the industry, another comparative study between the IHL sectors was undertaken using *Innography* – a subscription-based online patent resource system (Innography Inc 2016).

A patent quality search was initiated by first entering the specific names of each institution as a 'connected string' (four universities and five polytechnics) into the patent search field. This action returned relevant information about all patents and their families (different patents filed in other countries for the same invention) filed worldwide by the specified institution.

An optional patent strength analysis was then activated through the unique *PatentStrength* feature. Patent strength is computed based on a proprietary algorithm with input parameters, such as the age of the patent, number of references, number of citations, number of claims and jurisdiction (Innography Inc 2014). Table 4.5 shows the worldwide patent strengths of the two IHL sectors listed in ascending order, with a strength of 100 being the highest score.

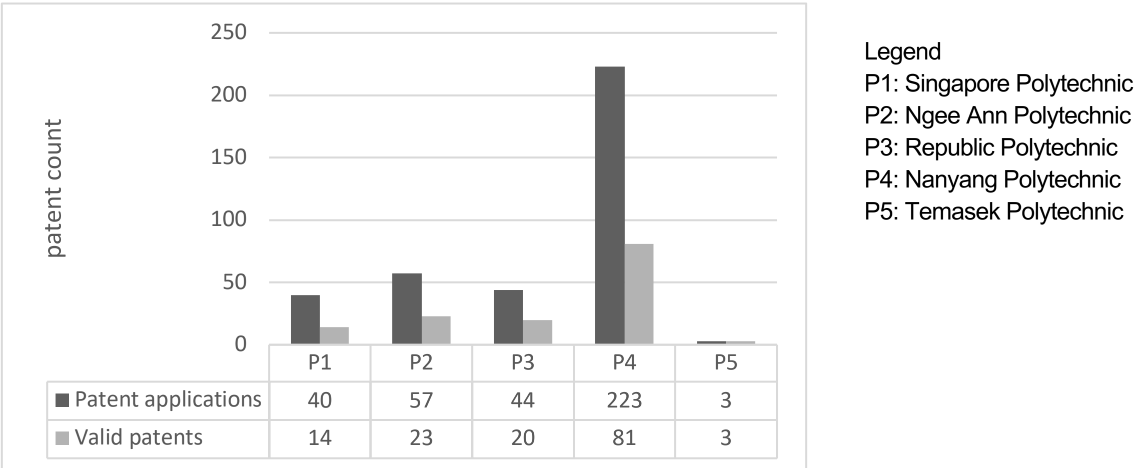
**Table 4.5 Quality of worldwide patent portfolio.**
**Source: Created with Innography online patent resource, accessed 12 May 2016.**

| Innography's patent strength | Number of worldwide patents filed | | | |
|---|---|---|---|---|
| | University sector | | Polytechnic sector | |
| 0–10 | 1,622 | | 266 | |
| 10–20 | 1,182 | | 153 | |
| 20–30 | 1,019 | | 104 | |
| 30–40 | 619 | | 70 | |
| 40–50 | 470 | | 36 | |
| 50–60 | 398 | | 32 | |
| 60–70 | 463 | | 20 | |
| 70–80 | 371 | 15% strong patents | 10 | 3% strong patents |
| 80–90 | 233 | | 6 | |
| 90–100 | 414 | | 6 | |
| | 6,791 | | 703 | |

Comparing the number of patents filed that scored a strength of 70 or better indicates that the polytechnic sector – with only 3% strong patents (22 of the 703 patents filed) – may wish to reconsider its patenting strategy to strengthen its patents for the industry. Regardless of its strength, a strong or a weak patent document will be publicly published for all interested parties, licensee or non-licensee included. In this respect, a non-licensed patent will remain as a common resource for all in terms of knowledge transfer.

*Reuters News ranking.* Patents are cited by university and industry publications as an indicator of knowledge transfer. Reuters News conducted an objective ranking of global universities in their innovativeness by measuring impact of patents using the Derwent World Patents Index and the Derwent Innovations Index on scholarly journals using the Clarivate Web of Science Core Collection database for the period between 2010 to 2015 (Evans & Johnson 2013). The study shows that National University of Singapore is ranked 70 out of the top 100 global universities, and one of the top 20 in Asia. However, if the criteria for looking at innovative global IHLs is based on published articles and patents and their interrelationship, polytechnics in Singapore will not be qualified in this ranking as polytechnics sector is not expected to perform fundamental research and produce peer-reviewed journal articles, as discussed in subsection 4.1.2 under *Knowledge transfer through publication*.

*Polytechnics adopt a quick patenting strategy.* Another investigation using the IPOS public patent resource found that the polytechnic sector adopts the quick patenting strategy. Figure 4.6 records the number of patent applications and active patents of all five polytechnics. By taking a simple average, 38% (141 of 367) of patents filed in the polytechnic sector were still found to be valid or active; the majority (62%) had been abandoned. As a non-product producer, the polytechnic sector and is cautious and quick to decide when to abandon commercially non-applicable patents in order to avoid the escalating costs of patent renewal as the patent ages.




| | P1 | P2 | P3 | P4 | P5 |
|---|---|---|---|---|---|
| Patent applications | 40 | 57 | 44 | 223 | 3 |
| Valid patents | 14 | 23 | 20 | 81 | 3 |

**Figure 4.6 Polytechnic patenting activities.**
**Source: IPOS online patent resource, retrieved 27 June 2016.**

### 4.1.3 SME innovation characteristics

SMEs are viewed as a driving force for innovation and entrepreneurship in Singapore, and are strategically important to economic development (Lee, NH 2002). Singapore has 154,000 SMEs that make up 99% of total enterprises, employing 70% of the workers, and contributing 60% of total value-add generated by all enterprises (Lee, YS & Png 2011). An SME in Singapore is defined as having at least 30% local ownership, with either annual sales revenue of no more than S$100 million, or a workforce of less than 200 workers (SPRING Singapore

2015). Wong (2001) categorises Singaporean firms broadly into the following based on their IP generation capability:

- *technically advanced SMEs*
  Technically advanced SMEs tend to undertake process improvement R&D activities to satisfy their multinational corporation (MNC) customers' needs, with many venturing into new product development.
- *government-linked companies (GLCs)*
  Government-linked companies (GLCs) are well-resourced firms that invest proactively in innovation activities.
- *high technology start-ups*
  High technology start-ups are those founded by entrepreneurs who had accumulated sufficient prior work experience (including Creative Technology, Eutech Cybernatics, CSA and Genelab), a few of which were acquired by larger firms. More recent high technology starts-ups involve founders from public technology producers.

While Wong acknowledges that GLCs are well resourced for independent R&D, he does not discuss the need for GLCs to collaborate more with SMEs to co-innovate in order to protect the domestic economy from being dominated by MNCs (Chew, R 2010). Wong's view that technically advanced SMEs are more inclined to practise process innovations may be due to the higher costs involved in new product innovation, and lower entry barriers related to incremental innovation.

**A lack of made-in-Singapore innovations.** To date, Singapore can pride itself on two outstanding local product producers – namely, Creative Technology, which manufactures personal entertainment devices, and TREK 2000 International, which invented the thumb-drive for portable media storage (Liu 2015, p. 205). Incidentally, the founder of Creative Technology, Sim Wong Hoo, graduated from the polytechnic system (Wee 2016), and is a classic example of a polytechnic education outcome in technology commercialisation

However, only a small number of Singaporean firms are internationally renowned for their new products. Examples of Singaporean-owned, world-class companies include Singapore Airlines, Keppel Corporation, Creative Technology and Hyflux Ltd. Hyflux is an exemplary innovative firm that originated as a small trading company before establishing itself as a regional water specialist that provides advanced water treatment technology, and has been named by Forbes as one of the 'best 200 small companies in the world' (Menkhoff & Wah 2008). Aside from Creative Technology, which produces MP3s, most of these global companies are simply efficient technology users that innovate beyond technology and inventions. Other successful publicly listed companies that focus on service innovations or customised engineering solutions include Univac Precision Engineering Pte Ltd and Uraco, both founded by polytechnic graduates (Lin, CT 2002).

The lack of made-in-Singapore innovations has been explained in the Science and Technology Plan 2010, which points out that the majority of SMEs in Singapore are either technology followers or technology indifferent (Ministry of Trade & Industry 2006, p. 44). In addition, Lee Kuan Yew, the father of modern Singapore, himself commented that Singapore should be realistic about its market size and resource limitations, and be adaptive in adopting innovation strategies:

> *I am not depressed by this, I am realistic. I say these are our capabilities, this is the competition that we face and given what we have, we can still make a good living provided we are realistic.(Han et al. 2011, p. 139)*

Lee further asserted that Singapore could better innovate by ensuring a multinational company (MNC)-friendly environment (Han et al. 2011). Financial, legal, logistics and telecommunications factors are examples of environmental factors that attract top MNCs. In the interview, Lee justified his strong endorsement for an MNC-reliant innovation strategy by citing case examples when discussing the challenges faced by SMEs (Han et al. 2011, pp. 146-160):

- **Lack of local R&D talents**. Top-tier talents did not join SMEs, but opted for more rewarding jobs in the public, medicine, law, and finance sectors. Creative Technology was cited as a case example, in which the company had to recruit foreign talent from Silicon Valley to develop the Sound Blaster card. In addition, Lee was concerned about the potential of Philip Yeo's life science initiative because Singapore did not have the R&D brainpower offered by China, India, and Vietnam.

- **Promising SMEs were either acquired or merged**. Tee Yih Jia was cited as an example of a successful food and beverage company that was acquired by an MNC (PepsiCo). In another publication, Liu (2015, p. 205) provides similar examples, whereby JIT Manufacturing was acquired by Flextronics, and Natsteel Electronics was acquired by Solectron.
- **Innovative ideas have been stolen and replicated by developing countries**. For example, the chrysanthemum tea formulated by Yeo Hiap Seng (another food and beverage company) was copied and adapted by a Chinese company. This is generally true for businesses with low entry barriers, in which ideas can be replicated easily and cheaply.
- Given such an unfavourable environment to innovate, it is unsurprising that many SMEs choose to simply buy and sell or provide engineering services to larger MNCs.

In Singapore, larger local enterprises are recognised with the Enterprise-50 award for their success in collaborating with foreign MNCs to generate greater export sales than traditional SMEs, which are inwardly focused on domestic markets (Lee, NH 2002). In addition, the Economic Strategies Committee has recommended programs to encourage more SMEs and large local enterprises (LLEs), as well as Singapore companies and foreign MNCs, to co-innovate for international markets (Economic Strategies Committee 2010).

MNCs come and go, and the negative effect arising from MNCs leaving Singapore cannot be underestimated. Singapore was once the global hard disk capital; however, thousands of jobs were lost when the three major hard disk companies – Seagate, Western Digital and Toshiba – either ceased or scaled down their operations in Singapore (Liu 2015, p. 139). Similarly, Singapore suffered economically when most computer manufacturers left in the late 2000s (Liu 2015, p. 148). Thus, it is timely to recalibrate the effectiveness of the MNC-reliance strategy, and refocus Singapore's energy on grooming SMEs.

**Increasing the level of digital technology used by SMEs.** Most recently, the GLC SingTel (Singapore Telecommunications) announced a partnership with two of the polytechnics, Ngee Ann Polytechnic and Temasek Polytechnic, to support heritage SMEs in improving their digital technology (Choudhury 2017). These SMEs include traditionally focused, family orientated enterprises that have been passed down from one generation to another. The importance of these partnerships is that they will enable family-oriented SMEs to establish e-commerce capabilities, thereby increasing their customer base (Choudhury 2017).

The partnership of SingTel and the two polytechnics is part of a program launched in 2015 that targets SMEs in order to align them with partners who can further the business by linking innovation and digital technology, which is viewed as a challenge by over two-thirds (64%) of SMEs interviewed (Choudhury 2017). Solving productivity problems using 'ready-made' e-commerce solutions has already allowed Singapore's SMEs to tap into the $150 million SPRING's Technology Innovation Programme to focus on exploiting IT as part of a knowledge driven economy (Lim, H 2008; Menkhoff & Wah 2008).

Public reports on Singaporean firms' performance in IP creation and exploitation are rare. Wong, Ho and Singh (2006) conducted a significant survey on Singaporean firms' innovation, IP creation and deployment. Of 2,500 firms surveyed, only 188 firms responded – 94 each from the manufacturing and service sectors. More than 80% of the survey respondents were SME type entities, and about three-quarters were innovating firms that had introduced new products or processes to the marketplace during the previous three years. Listed below is a summary of the key findings:

- Most SMEs were cautious and invested less in innovation inputs. The survey showed that SMEs spend less than 2% of sales in either R&D or innovation activities, compared to larger firms who doubled SMEs' investment for similar activities. Cautious investing indicates that the SMEs were generally risk averse
- SMEs were also slow in securing government grants to boost their innovation inputs. Only 10.9% of firms used the Local Enterprise Technical Assistance Scheme; while another 10.9% used the Technology for Enterprise Capability Upgrading; 3.1% used the Patent Application Fund; and 1.6% used the Growing Enterprises through Technology Upgrade schemes. These percentages indicate that greater outreach efforts are required by relevant agencies to engage with and enable more local SMEs to innovate with government support.
- Firms in Singapore are inward-looking and prefer to collaborate more with IHLs and RIs in the innovation process. More than three-quarters (76%) of the product

and process innovators surveyed preferred to develop their innovations in-house, while only 18.8% opted to co-create with other firms or institutions.

- In the context of this research, it was of interest to note that more than half of these partnerships occurred between firms and IHLs (52.5%) or public RIs (50.8%). The polytechnics' performance in relation to partnerships was not explicitly discussed, but the polys were embedded in the IHL sector.
- The next most highly preferred collaboration partners were suppliers of equipment, materials, components or software (32.2%) and clients or customers (27.1%). The survey showed that innovating firms tended to shun collaborating with competitors; only 6.8% of innovating firms collaborated with competitors and other firms from the same industry.
- This inward-looking behaviour was confirmed by the finding that only 17.7% and 15.6% of the survey participants licensed a third-party patent or non-patent IP, respectively, as their innovation strategy.
- Most firms were cautious and adopted a quick patenting strategy to protect their innovation output. The survey showed that over one-third (37.6%) of all firms surveyed applied for patents, with the biomedical and electronics sectors the top patent applicants. Depending on its commercial value, once granted, a patent application can either be renewed to ensure its validity or abandoned as publicly accessible knowledge. Figure 4.7 presents the patent filing and maintenance data of four selected industries (biomedical, electronics, R&D, and finance and business services). It demonstrates that the service firms (R&D and finance and business services) abandoned half of their filed patents that offered little or no strategic importance.

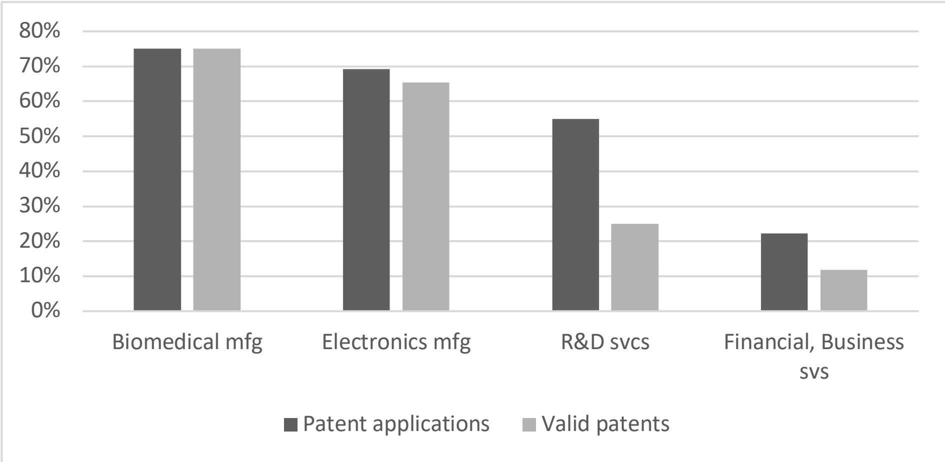



**Figure 4.7 Patents filed and maintained by firms.**
**Source: Adapted from (Wong, Ho & Singh 2006, p. 63).**

- The IPTC from universities and RIs requires further strengthening. The survey findings indicated that a minority of firms (17.7%) depended on externally licensed-in patents to innovate. Figure 4.8 recreates a graph on the use of externally licensed-in IP in four selected industries (biomedical, electronics, R&D and finance and business services). This figure demonstrates that the electronics manufacturing (38.5%) and R&D services (30%) industries were ahead of others in the use of externally licensed-in patents, while non-patent IP was more common in the financial and business services (22%). In terms of the preferred licensors, universities and RIs ranked sixth of the eight types of licensors, following foreign-based firms, external buyers and parent firms.

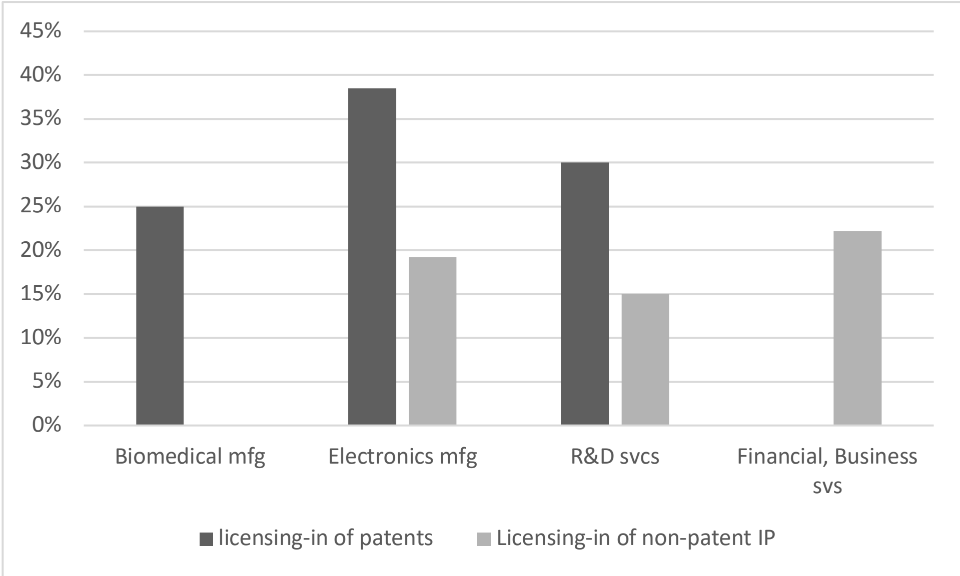



**Figure 4.8 Firms' licensing-in activities.**
**Source: Adapted from (Wong, Ho & Singh 2006, pp. 64-65).**

- The contribution of licensing incomes is mediocre. Firms that depend on externally licensed-in IP to innovate reported that 0.5% of their turnover can be attributed to the licensed-in patents, compared to 0.2% of non-patent IP. For the reverse flow, in which IP is licensed-out, non-patent IP outperformed patents. Only 7.9% of firms with licensed-out patents had positive earnings, compared to one-quarter of their non-patent counterparts.

- Nonetheless, the survey respondents still regarded patents the most strategic IP for commercial exploitation. This finding was especially true for patented products with overseas market potential. The survey stated that Singapore firms are in the early stage of designing their IP strategies. Patent protection and exploitation is perceived to be less effective than other non-patent IP, including knowhow and branding. Thus, it is logical for firms to consider protecting both patent and non-patent IP before their exploitation.

## 4.2 Technology transfer in Singapore

According to the Agency for Science and Technology Research (A*STAR), Singapore is still in the early stages of IP commercialisation (A*STAR 2015). Hence, talent development in IP creation and commercialisation is a key IPTC agenda. As a national IP agency, IPOS installed the 10-year IP Hub Master Plan to improve IPTC outcomes. This master plan was eventually supplemented with a comprehensive national IP Competency Framework, defining various IP professional roles and their corresponding competencies for the IP industry (Intellectual Property Office of Singapore 2019). Such awareness helps both IHL and industry to identify IP competency gaps when developing their own IP talent pool.

According to Wong and Singh (2008), Singapore's success in strengthening future IP creation capabilities will depend on its ability to:

- develop greater training opportunities for local research and development talent while being receptive to foreign talent
- escalate efforts to encourage local technology entrepreneurship
  Local talent requires a shift in the cultural norm that views working for established MNCs, and public service as safe options. The conventional Singaporean prefers professional careers in medicine, law or accountancy to starting their own businesses (Lee, YS & Png 2011).
- encourage entrepreneurs in the small domestic market to think globally
- identify successful role models who can inspire and mentor budding technology entrepreneurs.

To boost the number of individual IP creators, in 2001 the government initiated an attractive National Science Scholarship program to sponsor 1000 talented young Singaporeans to be educated as researchers in biomedical, physical and engineering sciences by 2020 (Yeo 2011). This two-decade capability development initiative was supported by the leadership of several hand-picked world-class figures, including Professor Sir David Lane, Dr Judith Swain and Professor Edward Holme (Yeo 2011). The father of modern Singapore, Lee Kuan Yew, however, was critical of Philip Yeo's plan, saying:

> *I met the chief of (pharmaceutical company) Norvatis, who is Swiss and has great confidence in Singapore. So I said, 'we are trying to go into R&D.' He said 'very difficult, you need a big talent pool. From Switzerland, we have to put R&D in*

*Boston. There are seven or eight universities there we collaborate with at any one time.' The talent pool is not just in Norvatis, but in the community around Boston where all the bright minds are teaching and researching.*

*So I had my serious doubts when they put up this proposal to go into the life sciences. It was Phillip Yeo's plan. I said, 'Look, where is the brain power? Whatever we do, the Chinese and Indians will do, the Vietnamese will do. How can we compete?' (Han et al. 2011, p. 158)*

Singapore can outperform China, India and Vietnam in attracting top talents by ensuring stability, security, connectivity, along with good healthcare and education systems (Han et al. 2011).

Technology transfer offices (TTOs) were established and resourced with required IPTC experts to facilitate IPTC process flow. In three short decades, TTOs were established as commercial arms of most public technology producers (universities, A*STAR RIs, polytechnics) to facilitate technology transfer (WIPO n.d.). In 1992, NUS founded the Industry and Technology Relations Office, and this TTO managed a portfolio of more than 700 patents with 84 licensed IPs within its first 15 years (WIPO 2007). Some eight years later, Nanyang Technological University (NTU) joined in the technology transfer business by establishing the Innovation and Technology Transfer Office in 2000 (WIPO n.d.). In a more recent study, Lim, P (2017) reported that Exploit Technologies Pte Ltd was set up as the TTO of the A*STAR research institutions to manage approximately 3,400 patents and 800 licensing deals.

Like the universities and RIs, polytechnics were quick to set up their respective TTOs. In fact, the first TTO in the polytechnic sector was founded in 1990 by Singapore Polytechnic, two years ahead of the university sector (WIPO n.d.). This pioneering TTO has served as a bridge to industry since its inception. One of its most successful case studies is about a patented formulation licensed to a local jeweller, Aspial, for making and selling purple gold in a global market (WIPO n.d.). In 2008, the Centre for Technology Innovation and Commercialisation, a TTO, was established by NYP to manage a portfolio of 188 patents and 33 licensing deals (Jewell 2012).

Understanding the mutual benefits of IPTC is crucial for both universities and industry if they are to achieve a competitive advantage in either sector (Lee, J & Win 2004). Universities must ensure that their professors enjoy the freedom to transfer knowledge through publication and teaching, unrestricted by industry partners (Powers 2003). For Lee, J and Win (2004), the three A*STAR RIs they studied derived cost savings through joint projects with industry by sharing R&D costs and resources, while the ownership of their IPs was protected through patents acquired prior to public disclosure. A*STAR RIs facilitated IPTC through standardised and simplified license agreements, and provided SMEs co-IP developer royalty-free licensing deals for an initial 36 months (OECD/ERIA 2018)

Articulating the benefits of IP ownership, Michael Lim, M (2009) asserts that A*STAR transfers technologies for public benefit while safeguarding A*STAR freedom-to-operate. In addition to technology transfer, A*STAR transfers knowledge and knowhow to industry through technology road-mapping, secondments of research engineers and technical advising (Lim, M 2009).

Part of the Singapore governmental policy of fostering a knowledge based competitive economy is the continued support of education hubs through purposeful partnership with world-class universities from China, the US, Australia, France, India, Germany, and the Netherlands to offer both training and research programs in Singapore (Knight 2011; Lai & Maclean 2011). Nonetheless, Singapore's education hub concept needs further investigation of its desired outcomes arising from the withdrawal of two foreign institutions that had been invited to set up branch campuses. The failure of this relationship demonstrates a gap between expectations and realities (Knight 2011).

On the whole, however, the polytechnics are seen by foreign investors as providing Singapore with a competitive advantage in the manufacturing industry (Lee, SK et al. 2008; Varaprasad 2016). The importance of Singapore's knowledge based competitive economy is directly associated to the innovation and new knowledge created by such institutions as polytechnics in the education hub (Lai & Maclean 2011), one of a nexus of players that personify a collective strategy directed towards innovation and knowledge production (Knight 2011).

In summary, Singapore SMEs play an integral role in forging a more balanced knowledge based economy by reducing dependence on FDI and MNCs. The SMEs, both those domestically focused and those with a more international market focus, can provide a way to embrace technological developments while generating revenues. Over the years, SMEs licensed and commercialised IPs taken from polytechnics. From the case examples shared in this chapter, listed below are exemplary products that are still marketed today:

- purple gold from Aspial
- elderly-friendly walking aid (rollator) from Rehab Mart Homecare
- Luo Han Guo-date drink from Eu Yan Sang
- "Limonsi Delight" drink from Pokka corporation

Singapore is not only leveraging the education hub as a development platform, but also as a mechanism to increase the country's competitive advantage through application of knowledge at the local level, and thereby increase its global competitiveness.

## 4.3 Summary

This chapter provided an overview of literature and documentation focused on the characteristics of resource providers (agencies), technology translators (polytechnics), product producers (SMEs) in Singapore. This contextual evidence justified the study of polytechnic as an alternative applied technology producer by drawing on secondary data sources: survey reports, paid or public databases, news articles, and corporate web sources. The next chapter will provide an analysis of the case interviews using the coding technique.

Chapter 5

# Embedded case study subunit 2: Case interview analysis

This chapter presents the analyses of the 13 interviews with SME managers. This research aimed to identify the key resources – tangible and intangible – in the IPTC process and extract valuable insights. Data sought for this study included:

- the profile of the SME managers
- their perspectives on
  - IPTC marketing
  - IPTC licensing negotiation
  - IPTC licensing deal finalising experiences.

The consolidated account of the participants' responses provides an informative summation of the SME managers' responses to events during their IPTC process. Wherever appropriate, the voices of the SME managers are heard through direct short quotations. However, a judicious combination of relevant quotations and the researcher's interpretation ensures a balance in revealing and interpreting the participants' voices. A pilot study of five SME managers was conducted and the preliminary findings were discussed in a conference (Sim & O'Connor 2014).

Chapter 6 combines empirical evidence gained from this case study with the theoretical insights to broaden our understanding of IPTC.

## 5.1 Profile of SME executives/managers

The term *manager* has been used as a generic term to represent the range of job titles of the 13 SME executives interviewed. Based on the business cards received from the participants, there were a range of job titles, including chief executive officer, managing director, general manager, and manager. Regardless of their job titles, all participants were at a managerial level in their organisations, and involved in negotiating an IP licensing deal with a polytechnic.

Table 5.1 summarises participant profiles based on data obtained from the *LinkedIn* social networking platform or the interview data.

**Table 5.1 Participants' profiles.**
**Source: Extracted from interview transcripts, and *Linkedin,* viewed October 31 2019.**

| Pax number | Cat. @ | Business Nature @ | Position # | *Age Category* | Company Founder? | Number of IHL Partners | Nature of Entry tertiary Qualification | Further Qualification* |
|---|---|---|---|---|---|---|---|---|
| Pax 1 | EC | Software | GM | 40+ | Yes | 2 | Business | Nil |
| Pax 2 | ER | Healthcare | M | 30+ | Yes | 1 | Business | Nil |
| Pax 3 | ER | Healthcare | MD | 40+ | Yes | 1 | Non-biz | M(Business) |
| Pax 4 | EC | Electronic | MD | 40+ | Yes | 1 | Non-biz | PhD (Non-biz) |
| Pax 5 | ER | Healthcare | MD | 40+ | Yes | 2 | Business | Nil |
| Pax 6 | EC | Software | MD | 40+ | Yes | 3 | Non-biz | Nil |
| Pax 7 | ISU | Chemical | MD | 40+ | Yes | 3 | Non-biz | M(Biz) |
| Pax 8 | ISU | Electronic | GM | 30+ | Yes | 1 | Non-biz | Nil |
| Pax 9 | ISU | Chemical | CEO | 40+ | Yes | 3 | Non-biz | PhD (Non-biz) |
| Pax 10 | ISU | Healthcare | MD | 30+ | Yes | 1 | Non-biz | Nil |
| Pax 11 | EC | Healthcare | M | 40+ | No | 2 | Business | Nil |
| Pax 12 | ISU | Medical | CEO | 40+ | Yes | 2 | Non-biz | B(Business) |
| Pax 13 | ISU | Healthcare | MD | 30+ | Yes | 2 | Non-biz | B(Business) |
| @ | Company category<br>▪ EC: Established company, ER: Established retailer, ISU: Innovative Start-up<br>▪ Source: SME category and nature of their businesses are extracted from Table 3.1 | | | | | | | |
| # | Interviewee's positions<br>▪ M: Manager, MD: Managing Director; GM: General Manager; CEO: Chief Executive Officer<br>▪ Source: Interviewee's position of the participants was obtained from their business name cards | | | | | | | |
| * | Interviewee's formal qualifications<br>▪ B: Bachelor's degree; M: Masters; PhD: Doctorate<br>▪ Non-biz: Non-business<br>▪ Source: Information on *qualifications* were sourced mainly from the *LinkedIn* social website | | | | | | | |
| The following information was sourced from the interview data:<br>▪ Interviewee's *age category (Age = 20 + age year of case interview – age year of the first job)*<br>▪ Company founder member?<br>▪ Number of IHL partners | | | | | | | | |

Notably, more than 80% of the SME managers made a mid-career switch to start new businesses before embarking on their IPTC journeys. All managers interviewed, with one exception, were either company founders or co-founders. For profiling purposes, the managers were grouped into two age bands: either 30+ (for participants aged between 30 to 40) or 40+ (for participants aged beyond 40). The two broad age groups were selected to avoid an undesired breach of a participant's identity. The actual ages of the participants ranged from the early 30s to mid-60s when the interviews were conducted.

Asking a person's age is not an Asian norm, so for those participants who did not reveal their age information during the interview, their age was estimated mathematically using information accessible in *LinkedIn*. *LinkedIn* allows a registered user to share their education and career advancement information.

Typically, a Singaporean young adult will be in his or her early twenties before entering the job market. In this research involving participants who didn't provide their ages, age was estimated by adding 20 years to the elapsed years between the case interview year and the first job commencement year. When the year of commencing their first job could not be established, the first tertiary qualification award year was used as the reference instead. Based on the age estimation, none of the SME managers was in their entry-level career stage; almost 70% were 40+ (mid-career stage). During one of the interviews, one of the experienced retail managers, recounted:

> *I'm the founder of this company …We import professionals to run it and myself has been in this sector for the last 40 years. And to date we have about maybe 11, 10 outlets throughout Singapore and Malaysia, running on our staff, managing our shops, our logistics. (Pax 5)*

Echoing a similar view, another veteran retail manager attributed to a rich sales and marketing experience the motivation to start a business:

> *I'm an XYZ by training, graduated in 19XX. I worked in an MNC for about 20 odd years in Sales and Marketing positions. So in 19XX, I decided I'll be my own boss. (Pax 3)*

Unlike many high-tech start-up founders who are usually in their entry-level career stages, these mid-career company founders were better informed on market intelligence because of their constant interaction with end-users or customers. Their experience, maturity and market intelligence contributed to their increased interest in IP commercialisation from public technology producers; more than 60% of the interviewed managers had at least two different IPTC experiences with different IHLs or RIs.

Most SME managers grounded their pre-employment education with non-business qualifications (tertiary in either science or technology domains). Two-thirds of the participants entered their careers with non-business qualifications, and many had progressed their careers into the marketing of domain-specific products and services. About half went on to complete a further degree (Bachelor or Masters) in a business-related field. This development pathway suggests that a business qualification was considered as a means to enhance their experiences in starting up their companies.

Among the participants, only two attained domain-specific PhD qualifications. These two participants were expert in their respective domains; they published articles and produced patents; hence they were well informed about the ways that polytechnics could be of value in their unique IPTC journeys. One EC manager related his past experiences:

> *What we do is we are a technology solutions provider. Our category of SME is slightly different probably from some of whom you have interviewed or will be interviewing in the sense that they rely on perhaps a third party to provide a fair bit of their technology. We do our innovations. So far, we have about six or seven patents filed in terms of our designs and the way we do things. So also we are quite innovative in that sense. We have collaborated with a few of the Polytechnics in Singapore. (Pax 11)*

All SME managers were able to articulate their views, feedback, and arguments relating to the IPTC process passionately. It was noteworthy that most of the managers were clear about what types of IP would be of value to them. For instance, managers mentioned that their firms looked for research findings, idea prototypes, and integrated technology solutions:

> *Like this, we study certain things are good, we take the components and add our own creation...I think for SME to survive we don't have the deep pockets to do the institutional research. That's not what we do well. We should not be doing that. (Pax 11)*

> *Most of the times actually what we wanted the school to involve in our major development project on the preliminary studies. Sometimes, we called it the proof-of-concept (prototype). (Pax 8)*

> *Once this kind of core area (technology) becomes slightly established, meaning some level of maturity. I mean the technology starts to stabilize… integrating the various core components (technologies) to form a system. This kind of integration has actually created value. (Pax 4)*

Concerns on how to sustain the company's innovative approach to achieve a competitive edge often surfaced in the interviews. All except one of the SME managers, who was running the social enterprise, were pragmatic innovators who strove to keep the company operating successfully and profitably while innovating. For this reason, most of the interviewees were seeking incremental IPs from the polytechnics to extend their existing products to offer better efficiency, productivity and a competitive edge. Although accessing breakthrough technologies was recognised as necessary, most managers regarded breakthrough technologies to be of secondary importance. Such a pragmatic approach could be influenced by wishing to avoid the higher risks associated with the development of a breakthrough technology, which is not common in a polytechnic setting anyway.

> *Well, we are looking for incremental technology because if our cash cow for this particular technology brings us the cash cow we want to have that continuously generating income. So, we need to improve the incremental technology. But at the same time, we are looking for breakthrough technology. (Pax 6)*

> *I supposed if it is a breakthrough technology, of course the chances of making a higher profit will be much higher. Here again, even if it's something incremental and if the incremental value is significant, I think that is equally good. (Pax 3).*

The case selected for this research encompassed the roles and relationships between SMEs (the product firms) and polytechnics (the IP producers). The following subsections present the case interview analyses within the demarcated study areas – IPTC marketing, IPTC licensing negotiation and deal finalising. While reviewing interview data within these study areas, interesting data relevant to the resources and the capabilities required to support IP deployment post-IPTC were also identified and added.

Based on the reflexive TA advocated by Braun and Clarke (2019), the researcher adopted a bottom-up approach where interesting data segments relevant to the research question were coded and organised into similar or conflicting clusters through the researcher's interpretative frameworks and research notes using *Atlas-ti*.

Code clusters, not the code frequency count, were further analysed to identify the underlying concepts or themes. Initial codes were iteratively recoded or even dropped, resulting in a more refined interpretation of patterns across the data. Code clusters on how to influence SME IPTC performance can be understood through the lens of the dynamic interaction of intangible resources (human, relational, organisational/structural) and tangible resources (Pike, Roos & Marr 2005).

## 5.2 Analysing the interview data

In using the thematic analysis method, relevant interview data were identified and coded with the help of *Atlas.ti.* This coding process was repeated throughout each data item and the entire data set. As the coding progressed, initial code labels were revisited and updated to better represent the voice of the participants. The coding process ended when the entire data set was fully coded, and the data relevant to each code had been collated. Related codes were combined to form clusters and themes that meaningfully captured the entire data set or a certain aspect of it. Figure 5.1 provides examples of six value-adding codes (orange) and two barrier codes (red) generated from the review of the entire 13 interview data sets. In this example, a total of 38 data extracts or segments was collated.

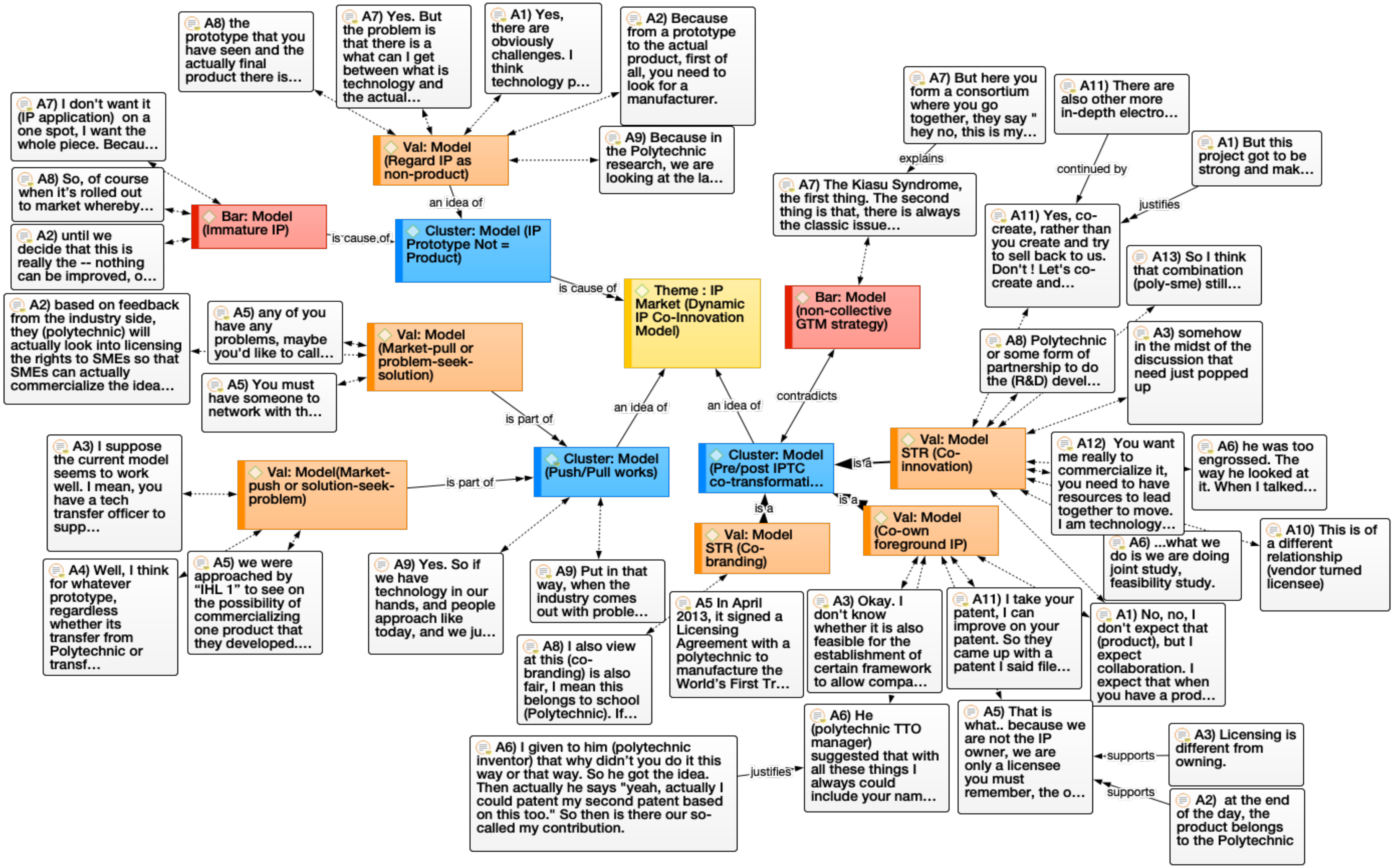



**Figure 5.1 Six codes with illustrative data segments extracted from interview data**

This iterative thematic analysis ended with six identified themes reported in three demarcated research areas:

1 IPTC marketing

2 IPTC negotiation combined with deal finalising

3 post-IPTC support

Table 5.2 outlines the 41 generated codes, 12 code clusters for the six identified themes. A total of 197 relevant quotations were collated. Typically, two to six themes were reported for a 10,000-word in-depth analysis that is able to convey richness and complexity of the data (Braun & Clarke 2012). Relevant TA maps on the six identified themes are attached in Appendices 2,3,4,5,6, and 7.

Each identified theme was unique and had a clear purpose and scope; identified themes were unrelated but were connected sequentially as a typical IPTC process flow – starting with pre-IPTC (IP marketing, IP negotiation and finalising), and completed with the post-IPTC support. Such flow provides a coherent story about what data says about available resources and capability. Following Table 5.2, Table 5.3 provides an overview of resources and capabilities that either value-add or impede the polytechnic-SME IPTC processes – the question asked in this research.

**Table 5.2** **Relationship of generated codes, code clusters and themes**

| Theme | Code Cluster | Value-adding codes | Barrier codes |
| --- | --- | --- | --- |
| Theme: IP Market (Pragmatic IPTC Marketing resources) | Cluster: COMM (Timely & complete disclosure) | | Bar: COMM STR (Inaccessible Data) |
| | | | Bar: COMM STR (Incomplete Data) |
| | Cluster: COMM (No to open innovation) | | Bar: COMM REL (Arm's length) |
| | Cluster: COMM (2-tiered info exchange) | | Bar: COMM REL (NDA) |
| | Cluster: COMM (Proactive sharing non confi) | Val: COMM HC (Diverse talents) | |
| | | Val: COMM PHY (Diverse equipment/labs) | |
| | | Val: COMM REL (Prior experience) | |
| | | Val: COMM STR (Funding) | |
| | | Val: COMM STR (Policy consistency) | |
| Theme: IP Market (Dynamic IP Co-Innovation Model) | Cluster: Model (IP Prototype Not = Product) | Val: Model (Regard IP as non-product) | Bar: Model (Immature IP) |
| | Cluster: Model (Push/Pull works) | Val: Model (Market-pull or problem-seek-solution) | Bar: Model (non-collective GTM strategy) |
| | | Val: Model (Market-push or solution-seek-problem) | |
| | Cluster: Model (Pre/post IPTC co-transformation) | Val: Model STR (Co-innovation) | |
| | | Val: Model (Co-own foreground IP) | |
| | | Val: Model STR (Co-branding) | |
| Theme: IP Nego (Appropriability regime) | Cluster: IP Nego (Strategic intangible asset) | Val: IP Nego (Purposive IP in-licensing) | Bar: IP Nego (Due D on indemnification) |
| | | Val: IP Nego (Purposive IP protection) | Bar: IP Nego (Variability in IP knowledge) |
| | | Val: IP Nego (Non-Patent IP equally important) | |
| | Cluster: IP Nego (Patents as strategic reputation assets) | Val: IP Nego (IP up investor confi) | |
| | | Val: IP Nego (IP up consumer confidence) | |
| | | Val: IP Nego (IP up public perception) | |
| Theme: IP Nego (Inability to reach a valuation agreement) | Cluster: IP Nego (Embracing IP and barriers) | | Bar: IP Nego (KPI patents has no value) |
| | | | Bar: IP Nego (Prohibitive IP costs for SMEs) |
| | | | Bar: IP Nego (Unfriendly valuation methods) |
| | Cluster: IP Nego (Financial goal incompatibility) | Val: IP Nego (Equity taking, bursary, risk sharing) | Bar: IP Nego (Immediate IP cost recovery via licensing fees) |
| | Cluster: IP Nego (Unrealistic IP valuation) | | Bar: IP Nego (Lacks business Sense -HC) |

| Theme | Code Cluster | Value-adding codes | Barrier codes |
|---|---|---|---|
| | | | Bar: IP Nego (IP valuation is an art) |
| Theme: Post-IPTC (Scaling up Challenges) | | | Bar: Post-IPTC (Poly IP needs further works) |
| | | | Bar: Post-IPTC(inability to meet MoQ) |
| | | | Bar: Post-IPTC (High Manufacturing Cost) |
| Theme: Post-IPTC (Co-innovation of Transformational Services) | | Val: Post-IPTC (Applied IP, but needs further work) | Bar: Post-IPTC (Lack follow-through supports) |
| | | Val: Post-IPTC (Product exhibition) | |
| | | Val: Post-IPTC (Prototype testing) | |
| | | Val: Post-IPTC (User-centric validation) | |
| | | Val: Post-IPTC (long-term commitment) | |
| **List of abbreviation used in the above coding labels** | | | |
| Intellectual capital (IC) | HC | Human capital | Resources that are intrinsic to human include individual education level, cognitive abilities, experience, or behavioural norms |
| | STR | Structural or Structural capital | Resources that people develop for the company include IP, brand image, knowhow, culture, process, workflow, and system |
| | REL | Relational capital | Resources that people develop within the company with external suppliers, customers, regulators and partners |
| Tangible capital | PHY | Physical capital | Tangible resources; include infrastructure, land, IT, equipment, materials, prototypes and products. |
| Others | COMM | Communication | |
| | GTM | Go-to-market | |
| | Bar | Barrier | |
| | Val | Value | |
| | Nego | Negotiation | |
| | MoQ | Minimum Order Quantity | |
| | Confi | Confidence | |

**Table 5.3 Overview of the value of available resources and capabilities.**
**These either value-add or impede the polytechnic-SME IPTC process – the question asked in this research.**

| Category | Main Theme | Perceived barriers | Valued resources |
|---|---|---|---|
| Marketing | Pragmatic IPTC marketing resources | ▪ Inaccessibility of timely and full enabling IP disclosure<br>▪ Online collaboration platform that discloses SME market intelligence | ▪ 2-tiered information exchange<br>▪ Online information portal for essential resources provided by polytechnics |
| | Dynamic IP co-innovation model | Lack of polytechnic-SME collective efforts | ▪ Either market-pull or -push innovation model works<br>▪ Pre- and post- IPTC co-innovation and co-branding is the way forward.<br>▪ IP co-ownership motivates co-innovation |
| Negotiation and deal finalising | Appropriability regime | ▪ Lack of understanding of IP due diligence<br>▪ Large variability in the IP awareness | ▪ Purposive IP in-licensing and protection build strategic IP assets<br>▪ Non-patent IPs are equally important<br>▪ Patents as a strategic reputation asset |
| | Inability to reach a valuation agreement | ▪ High IP costs<br>▪ Business-unfriendly valuation methods<br>▪ Quality issues of IP filed to meet KPI<br>▪ Business IP creators lack business sense<br>▪ Unrealistic IP valuation<br>▪ Financial goal incompatibility obstruct IP valuation agreement | ▪ Deferred royalty payment<br>▪ Zero upfront payment<br>▪ Royalty calculated based on a profit made, not on sales revenue<br>▪ Bursary provision instead of upfront or running royalties<br>▪ Co-investment by direct or conversion of royalty incomes |
| Post-IPTC support | Scaling up challenges against post IPTC success | ▪ High local manufacturing costs<br>▪ Inability to fulfil MOQ | Manufacturing readiness of an IP |
| | Co-innovation of transformational services | ▪ Polytechnic IP is closer to market, but needs further work<br>▪ Dynamic user's requirements | ▪ Co-development in prototyping and testing, user-centric validation, networking.<br>▪ Dynamic co-innovation capability |

## 5.3 IPTC marketing

The following subsections describe polytechnic IP marketing resources from the perspective of the SME managers. The analysis looks for interesting data features (recurring, surprising, important, supported by literature) that revealed some of the ways in which the participants explored, recognised, and seized opportunities when interacting with polytechnics.

### 5.3.1 Pragmatic IP marketing resources

The analysis of the data indicated that the participating managers were seeking *effective* poly-SME communication. In the area of IPTC marketing, SME managers and polytechnic TTO managers would interact to exchange information that is intrinsic to human or the human capital resource. Information in this context consists of knowledge, insights, experiences, knowhow, skills, capabilities and relationships created by people.

Reflective analysis of the managers' responses identified sub-themes related to areas of concern for the business people, such as a:

- 2-tiered information exchange
- timely and complete information disclosure
- a distaste for online collaboration platforms
- proactive communication.

**A 2-tiered (informal first; formal later) information exchange was preferred**. SME managers preferred to start exploring an IPTC opportunity with an informal chat related to the problem with which they were concerned. Only after a formal non-disclosure agreement (NDA) is reached are strategic information and knowledge exchanged, one of the managers explained:

> *I would say that that's supposed to be a standard practice. When you work with external company of any other places, the first thing I have to sign the Non-Disclosure Agreement and then I then I don't look at it as an issue. It has basic necessity as to getting it done. (Pax 4)*

Generally, a NDA is a legally binding contract that allows contracting parties to share confidential information (knowledge, insights, knowhow, experiences, skill and relationship) without fear of unauthorised disclosure to competitors. In a demand-pull innovation model, the SMEs guarded their unique knowledge on commercial market needs or stakeholder feedback, as it was considered a key human capital that was a result of constant interaction with their end-users or customers over time. The respondents felt that a NDA would prevent an undesired leak of confidential information to their competitors.

**Complete and timely information disclosure was expected.** Although challenging for the polytechnics, SME managers expected a complete and timely disclosure of information when polytechnic managers marketed their IPs to the SMEs. Managers who experienced delays, poor explanations of what was required of them or a poor result were discontented and disillusioned with the Polytechnic-SME relationship, as shown by comments in Table 5.4.

SMEs valued candid information sharing in the initial stage of the marketing phase. Any intentional or unintentional delay of information would jeopardise commercialisation owing to an underestimation of the project scope.

**SME managers shunned automated collaboration platforms**. In Singapore, IPI Singapore offers an online collaboration platform where problem solvers (polytechnics) are connected to solution seekers (SMEs) at arms-length. SME managers shunned online collaborative platforms to avoid telling the public, especially their competitors, what they knew about a specific product, the associated insights on product utility and user experiences. Although intermediary services were present, mainly in cyberspace, SMEs may require a life-changing experience like the COVID 19 pandemic to engage in more activity online. With or without third-party involvement, both the pre- and post-IPTC processes remain unchanged.

**Table 5.4 Comments from unsatisfied SME managers**

| Quotation segments | Elaboration |
|---|---|
| *I wouldn't call it a bad experience … we are as a SME, we are an outsider, so we do not really know what the full functional of capabilities does the Polytechnic have. (Pax 2)* | As an external partner, the SME expected a complete knowledge of polytechnic resources and capabilities that were made available and accessible for IPTC purposes. |
| *And then after that, we started to realise that during the discussions of this initial project, we were not actually being told that we actually need to get live data, all right, of the tidal information of that particular region, and actually in a particular place. (Pax 1)* | In this example, the manager was informed with incomplete data for a software IP licensed from a polytechnic. This incomplete information led to a misjudgement of difficulty of implementing the application globally. |
| *Even the code that given to us, …the algorithm was really embedded. We couldn't do any study. We cannot really pull it out and do it. (Pax 1).* | In this similar case, the SME was supplied with an algorithm delivered as a programming interface without the native source codes. Such application programming interface protects the polytechnic interest, but limits SME's freedom to advance the software solution. |

An interesting result revealed by the data analysis was the fact that not all SME managers were accessing online IP collaboration portals to seek polytechnic IPs:

> *Nobody looks at the portal. I mean it's just like you are talking about trillions and trillions of website pages. How many do you look at? It's just a page. As far as I'm concerned, it's just page. You still need the human touch. Human interaction is very important. (Pax 7)*

The SME managers who agreed with Pax 7 clearly preferred face-to-face human interaction in IP marketing. The sharing of information online or through collaboration portals induced stress in the online viewers and could cause a feeling of information overload.

Not only was real-time face-to-face sharing appreciated, but the dissatisfied respondents also expressed fear of disclosing their knowledge on market trends, competitors, and user experiences (e.g. pain points, feedbacks or suggestions) required by some online collaboration platforms or communities:

> *Because by posting their problem (in a portal), they're actually… revealing a potential good invention. (Pax 5)*

Given this mindset, it will take time before local SMEs are willing to use or adjust to similar online collaboration portals, such as Nine-sigma and InnoCentive, as a first stop to collaborate with solution providers.

**Essential public information should be shared proactively.** The SMEs felt that non-confidential information on the availability of resources should be shared proactively to improve communication. The respondents reported that the lack of consistent information frustrated them.

For example, proactive sharing of information about available structural resources (IP, culture, processes, strategy, structure, policy, and brand) which a polytechnic offers to support IPTC was regarded as important. IPTC related policies, approval workflows, and information on available resources were identified as inconsistent across the polytechnic sector:

> *So, even the policies among the polytechnics are so different. Do you get me? The policy coming from IHL 1 and IHL 2 is not the same. (Pax 7)*

> *Every polytechnic has a different approach, different policies, different way of calculating license fee, different way of calculating royalties. (Pax 5)*

> *We are not aware. I mean you can just tell us -- just briefly tell us what services part we might not know in-depth. (Pax 2)*

> *Now my understanding when I started a process, it is a bit tedious, because there are so many approvals that have to go through a lot of their revisions. (Pax 6)*

Relevant IPTC information should be shared publicly with SMEs proactively. Information on accessibility to IPTC human capital (staff or student capabilities) was considered by SME managers as valuable, too:

> *They (students) go around with the gadget as well as the questionnaire. Actually, they mobilized almost 30 students, they divided it into three teams. (Pax 6)*

> *T-up (staff attachment) is a good program but of course if you have that one stop service where you can still have SMEs to come in and speak to the relevant people that can help also. (Pax 13)*

> *Actually, in the market we always have some opportunities but of course various companies or SME they don't know actually who is the best in the local can offer such solutions. (Pax 8)*

> *HR also has lot of things (restrictions). So, this cannot do, that cannot do that, a lot of things cannot do. (Pax 9)*

These examples from the data affirm that polytechnic students were capable of conducting IP validation studies, while staff with specialised knowledge could be attached to SMEs for an IPTC deployment.

Sharing of prior knowledge on relational capital (funding agencies, regulators, other IPTC partners, and community) established externally would help SMEs to learn from good and bad IPTC experiences:

> *They (grant agencies) have scholars all over the countries. And their main job is to help Singaporean companies. To me is that it's only right we ask IE (Grant agency) to help us. But how can we get help, I really don't know. (Pax 7)*

> *Because the technology and the manufacturing were done by us, it was done by me, so I know what is what. (Pax 10)*

Despite the managers of the SMEs' awareness of accessible public IPTC funding, some perceived public funding as complicated, time-consuming and KPI laden. During the interviews, it was noted that SMEs were reluctant to use them because the funding schemes were viewed as *too complex* (Pax 12); and the application process was time-consuming, as Pax 11 noted, saying, *so many paper works to complete to get your $5000* . As a result, SMEs would rather *forget (the public funding), don't waste time* (Pax P13). This frustration was also echoed by Pax 5:

> *They (SMEs) will be spending more time writing reports than doing business. The KPI every three months, we need to put up a report.* (Pax 5)

These negative perceptions on public funding can be correlated to the survey results of Wong, Ho and Singh (2006) that SMEs were slow in securing various government grants to boost their innovation inputs. Those SMEs who applied, but failed, to secure public funding raised questions on the quality of the assessment process:

> *They (public funding for startup) are supposed to actually help us but they are restricting in everything and especially, I am really pissed off with the 'ABC startup funding' panel. It's too much. Yeah. It's wrong.* (Pax 10)

All these findings indicate that government agencies need to simplify the funding policies and raise the assessment team's quality.

The research also indicated that certain SMEs leveraged public funding to increase their company's profile in RIE capabilities.

During the marketing phase, SME managers would like to be informed of accessible physical resources (infrastructure, facilities, equipment, products, materials), for example, a 3D printing facility to test and verify a new product concept:

> *I could not afford a very expensive metal printing 3D for example. You guys have it. So, if we work together in a way then my final prototyping product rapid could be a titanium based. It's raises the level to this much. (PAX 12)*

Besides physical resources, proactive sharing of accessible monetary resources, such as public funding for IPTC purposes, was cited as useful information that helps SMEs to defray the IPTC costs:

> *Even for the licensing fee, maybe the Polytechnic can be more proactive in a way that maybe they can suggest other avenues of funding. (Pax 2)*
>
> *Actually, most of our grants are all backed by higher learning institutes. (Pax 13)*

Overall, most SME managers felt that a unified baseline IPTC policy for the polytechnic sector would deliver a consistent marketing message to the public. They felt that polytechnics should adopt a proactive approach to communicate complete and timely information on accessible resources, both tangibles and intangibles.

Of all the insights to come out of the data, the fact that SME managers disliked internet collaboration platforms as a marketing tool was the most unanticipated, although their reasons seemed valid – to avoid divulging market intelligence to the public, especially to competitors.

### 5.3.2 Dynamic IP co-creation marketing model

Literature shows that in a market-push innovation model, research universities will market their scientific discoveries to the industry without a clear understanding of market demand. On the contrary, product-making SMEs are looking for IPs after gaining an understanding of the commercial market's demands or stakeholder insights – hence the market-pull innovation model.

**IP is not a finished product.** The SME managers expressed desire for a polytechnic to deliver mature IPs during the marketing phase. This was evidenced in the language used by the interviewees:

> *When it's rolled out to the market, whereby there are not many technical issues…(Pax 8)*
>
> *Until we decide that this is really there is nothing can be improved, optimized. (Pax2)*
>
> *I don't want it (licensed IP) on one spot, I want the whole piece… (Pax 7)*

Although this expectation was prominent in the evidence, SME managers in the interviews were clearly able to differentiate IP from an actual finished product. IP was understood to be something such as: a *prototype* (Pax 2), *laboratory technology* (Pax 9) or *not a complete product* (Pax 1). They understood that further product development would come through the application of the SME's internal capabilities, polytechnic-SME collaboration or third-party contracting, all of which are needed for an IP licensed from a polytechnic.

**Either market-pull or -push innovation model works well.** Regardless of the chosen product development pathway, some of the managers had approached polytechnics fully equipped with knowledge of market demands and stakeholder insight:

> *So, when we give you that problem, it becomes a challenge for the polytechnic to take it on as a project. (Pax 5)*

This situation is considered the *market-pull* innovation model. The SME identifies a problem and goes to a polytechnic looking for a solution.

It was noted that the market-push innovation approach works, too:

> *We started from maybe five years ago when we were approached by 'polytechnic ABC' to see on the possibility of commercialising one product that they developed. (Pax 5)*

For a SME, both market-pull and -push innovation models work well. However, pushing a ready solution or IP to a willing SME licensee requires no further development efforts, while being pulled into solving a problem based on stakeholders' insights can be challenged by accessible capabilities and resources.

> *So, if we have technology in our hands, and people approach like today, and we just directly tell them 'this is my technology, if you are interested then we'll license it out.' But if the people give us current problems, yeah, sometimes we need to further develop because we may not have ready solutions today. But either way will work. (Pax 9)*

The founder of an electronics firm with its own R&D capability had added a new dimension to the IPTC model – the internal IPTC – to further develop IP sourced from the polytechnic internally:

> *Well, I think for whatever prototype, regardless whether its transfer from polytechnic or transfer from elsewhere or even internally, we have transferred ourselves in the company or transfer the product from the R&D side to the production. You also need the production engineering to improve it. So, these are necessary process. (Pax 4)*

Only well-resourced SMEs would have the management capability to ensure the cohesiveness of their internal IPTC processes, such as Pax 4 described. Other participant managers either outsourced the product development to a third-party directly after taking a naked IP from the polytechnic, or continued to co-develop the licensed IP with the polytechnic before the production phase.

**A lack of collective effort can impede the innovation process.** One SME manager attributed the failure of Singapore SMEs to transform into global innovation players to the lack of collective effort, and inherent *kiasu* (a local dialect that means 'selfish attitude') syndrome.

> *The kiasu (selfish attitude) syndrome, the first thing. The second thing is that, there is always the classic issues. You look at a company, let's say in Taiwan. When they want to do a certain global project, they find that okay the industry players all comes together, works together, to develop. (Pax 7)*

In this manager's opinion, to succeed in innovation, a SME must engage and leverage the collective strength of all industry players, polytechnics included.

**Co-innovation is the way forward.** It emerged from the data that the participants shared an interest in the idea of co-innovation with the polytechnic, and a collaborative approach was advocated when the licensed IP needed further development. They spoke of co-research, co-design, co-creation and co-development during both the pre- and IP post-licensing phases, saying:

> *No, no, I don't expect that (poly to develop the product), but I expect collaboration. (Pax 1)*
>
> *What we do is we are doing joint study, feasibility study. (Pax 6)*
>
> *I think somehow, in the midst of the discussion, that need just popped up and I can't really exactly remember whose idea it was. (Pax 3)*
>
> *Yes, co-create, rather than you (polytechnic) create and try to sell back to us. Don't! Let's co-create and co-join this. And it is a win-win really. It is a win-win. (Pax 11)*
>
> *Polytechnic or some form of partnership to do the development, be it in Taiwan even or in Malaysia. (Pax 8)*

According to managers from more established SMEs, overzealous polytechnic inventors are sometimes a barrier to innovation, although the inventors would ultimately open themselves to the SME's ideas through a co-designing process. The change in the attitude of the poly inventor could be transformative, changing narrow-minded perspectives.

> *I saw that, and eventually he (polytechnic inventor) was stuck on a certain way of doing things, he was too engrossed. The way he looked at it. When I talked to him,*

> *and I've suggested different way of doing things and then suddenly he realizes that I managed to solve his problem. (Pax 6)*

**IP co-ownership motivates co-creation**. Most of the managers were able to differentiate IP ownership from IP licensing, and valued either form of IP strategy. One participant aptly stated that *licensing is different from owning* (Pax 3). Most appreciated this difference, and were knowledgeable of the pros and cons of either strategy.

Under a typical non-exclusive IP licensing deal, a polytechnic, the legal owner of the licensed IP, will lease out the right to use the licensed IP for a specific period in exchange for royalty payments. However, for an IP derived from a co-creation activity, one manager commented that his firm *also want[ed] to be part of the IP* (Pax 1) and wanted to have the joint IP recognised and protected:

> *After they filed the first patent. You see, that's why I say I qualify that the difference between us and the rest of SMEs is that we don't just take it. I take your (polytechnic's) patent, I can improve on your patent. So, they came up with a patent I said filed A and B. We took the device we created C and B. (Pax 11)*

In this case example, the SME licensee was able to add new patentable features C and D to the licensed patent (original features A and B) from the polytechnic. The new patent (features C and D) created by the SME licensee is commonly known as a foreground patent, while the licensed patent (features A and B) is regarded as the background patent. Protecting the product with a background patent for IP created by the polytechnic and a foreground patent for IP created by either the SME alone or through a polytechnic-SME joint effort would improve the commercial value of the new product. If the foreground IP is a joint effort, the patent will be co-owned by both parties. Those SMEs aspiring to own their IP may consider patent co-ownership an incentive to enhance and commercialise a product.

**Co-branding, a viable go-to-market strategy.** The idea of co-creation was extended to co-branding for marketing purposes. One SME manager was excited with the idea of leveraging on a polytechnic's reputation as one of the viable go-to-market strategies; the manager said that *co-branding* helps (Pax 8). After one of the interviews with another SME manager, the manager proudly shared the company's website that says:

> *ABC company signed a licensing agreement with XYZ polytechnic to manufacture. (Pax 5)*

The use of the XYZ polytechnic name in the marketing material speaks volumes about the high trust that a SME has in a polytechnic's reputation. From the structural resource perspective, IPs taken from the polytechnics, although applied in terms of the technology, still need considerable adaptation to meet scaling up requirements. SMEs that lack R&D and production capabilities would understandably like to co-innovate with a polytechnic beyond the licensing phase – a uncommon post-licensing co-innovation IPTC model. Most higher education technology producers tend to end the IPTC relationship after an IP licensing deal is completed, on the other hand.

## 5.4 IPTC negotiation and deal finalising

The following subsections describe polytechnic negotiation and deal finalising resources from the perspective of the SME managers. The analysis looked for interesting data features (recurring, surprising, important, supported by literature) that revealed some the ways in which the participants explored, recognised, and seized opportunities when interacting with polytechnics.

### 5.4.1 Appropriability regime

Teece (1986) uses the term *appropriability regime* to describe how the ease of imitation varies with knowledge types (tacit or codified) and the strength of the IP rights (patents and non-patent IP). Appropriability regimes of a company will be strong if knowledge replication is deterred by sticky knowledge (dynamic capability and knowhow) and supported by multiple IP rights (patents and non-patent IP).

**The strategic asset of protected IP.** Most SME managers considered IPRs strengthened the appropriability regime of their critical technologies and assets. There was a shared agreement that patent, either building from scratch or licensed-in, could be recognised as a strategic asset to prevent unauthorised imitations by competitors. In Singapore, a patent confers on the owner the right to exclude others from using the IP without his/her consent for 20 years from the patent application date. Just like any valuable property, a patent can be sold for a large sum of money, be licensed for a running royalty income, or be used for fundraising from investors.

**Purposive IP in-licensing, a SME strategy to build strategic intangible assets to overcome limited R&D capability.** When asked about the rationale of taking a patent license, the following established healthcare retailer MDs replied:

> *I would say the patent is important; it's very important because when you have a new product on the market, of course, it might not be successful immediately. But when it is successful, there might be situations where other companies try to copy the product. So, you have a patent in the first place. You prevent your product, protect this product from being copied. (Pax 2)*

> *I'm happy to know; actually we've patented the function, not the design. I'm very happy to hear that. (The) function is very important, not design. (Pax 5)*

Being connected with end-users and related influencers, the established retailers would have the necessary market insight to commit to an IP licensing deal. The participation of established retailers in IPTC suggests that some retailers have higher risk appetites after accumulating market intelligence.

One of the retailers was planning to market a mobility product infused with licensed IP from a polytechnic into the US market, for example. In such circumstances, it makes business sense to license a technology with legal rights conferred by the US government for that market. However, during post-interview interactions, I noted that SME managers in retailing businesses paid little attention to the technical details of the licensed IP or the scope of rights afforded by the patents (i.e., narrow or wide). They appeared to be simply overwhelmed by the underlying business opportunities, and relied on whatever legal rights were afforded to the only licensed

IP to repel any unauthorised infringers, ignoring the importance of a proper IP due-diligence conducted by qualified IP or patent agent.

**Purposive IP protection, a SME strategy to build strategic intangible assets for technology-intensive SMEs.** The manager of an established electronic company that had internal R&D capability explained that:

> *We think it's (patenting is) an essential part of protecting your innovations. That's the reason why we filed six to seven patents ourselves. (Pax 11)*

In this light, one medical technology start-up founder who had acquired extensive prior R&D experiences replied:

> *We have eight patents pending on our own. But, eight patents pending on our own and we still keep on filing. (Pax 12)*

Seeking patent ownership is complicated and costly, and not for every SME. Only technology-intensive SMEs tend to build their internal IP, while sourcing for key complementary IP assets from their environment (polytechnic included) to strengthen their appropriability regime. As one of the SME managers eloquently put it, *patenting is just a game (Pax 12)*, and not all SME managers adopt a patenting strategy.

**Non-patent IPs are equally important.** SME managers who were more IP savvy sought different legal mechanisms, patents or non-patent IP (copyright, registered design, and trade secret), to strengthen their companies' technology assets and appropriability regime. The chance of winning an infringement case is higher if a product is protected with different IP types. In explaining the rationale for why a new chemical formulation should not be patented, one ISU founder remarked:

> *It depends on the what is the product or what is the technology that you are dealing with. I mean if you are dealing with something that is mechanical that you know your design will produce a certain kind of effect, then you get it patented. But if it is a chemical kind of situation or formula then I would say don't get it patented. Keep it as a secret. Because very simply said, 18 months' time your patent is open. People can read the process. You just put A+B+C, then the next person will put A+B+C+D, you cannot sue the guy. It's simple as that. (Pax 7)*

A chemical formulation patent can be designed around easily with a variation to the formula, and patenting will require full disclosure of the enabling information, which can be accessed by the public. Hence, disclosure when applying for a patent may encourage the design-around of non-infringing products. On the other hand, keeping a chemical formulation as a trade secret is a challenge. Trade secrets require strict confidentiality control measures implemented to guard against undesired disclosures.

Different legal mechanisms can be used to strengthen the appropriability regime of the company according to the type of technology and its use. One of the software managers pointed out that extra care was required when assessing the need for software patenting because the software technology could end up being deployed in countries that are inexperienced in dealing with IP protection and enforcement.

SMEs that focused on simple mechanical technologies might opt for quick market access, leveraging on the registered designs instead of patents:

> *I will look for the design, the marketability of the idea. (Pax 3)*

> *When you roll out your product it is essential that a certain part of the design still allows us to claim back some royalty. And, this is also important in the way that one can have a long run business. (Pax 8)*

Overall, a range of SMEs (covering retailer-innovators to med-tech innovators) valued both self-generated or licensed-in patents as a means by which they could develop their pool of unique and difficult-to-imitate IP assets. In fact, 11 of the 13 interviewees were involved with at least one patent licensed from a polytechnic.

A start-up company founder suggested the interesting idea that small design contract companies could partner with polytechnics to collectively pool relevant IP assets (both foreground and background IPs) into a compelling technology offer to a matching product company:

> *Today's world is changing especially getting more IP's. And it's always good for the SME that they have their patents or trusted partners (polytechnics included) whereby you can protect your certain IP. (Pax 8)*

**Patents as strategic reputation assets.** The data analysis indicated that patents were perceived as a strategic asset to boost the reputation of the business and investors' confidence. The founder of a medical technology start-up company that had filed eight patents discovered that business investors also value patent, commenting that:

> *We do patents more for the sake of defending ourselves, more for the sake of keeping our value relevant to the financial world or to the people that want to invest in us. (Pax 12)*

Investors in medical technologies, on the whole, look for a strong and defendable patent portfolio before making an investment decision. It is not uncommon to see that medical technology ventures will secure several future rounds of investment before the product has finally cleared all required regulatory testing due to their patent strategy. Investors can only measure the strength of differentiated patents when attempting to predict the future of their investment. This IP-centric fund-raising strategy affirms public confidence in IP that is legally protected, especially from financial entities, such as banks or venture funders.

The MD healthcare retailer recognised the role of patents in ensuring high consumer confidence in the quality of the innovation, saying:

> *Absolutely it is important! otherwise, if there isn't IP protection, there's no guarantee that consumers will buy a product instead of a look-a-like. (Pax 3)*

Public perceptions of the value of patent on product quality, a firm's technological strength, and its market position will continue to influence SMEs to seek patented technology from polytechnics as a competitive technology asset.

**Variable understanding of IP due diligence and its importance.** Most of the managers understood the competitive advantages of building a product or solution with in-house developed IP or through licensing-in IP from external sources. While most managers who take an IP license from an external source may gain financially compared to those building IP from scratch, the data indicated that many of the managers in the case study failed to appreciate the importance of engaging a qualified IP professional to assess their IP infringement risks when they were using an out-sourced product.

A SME who invented an incremental innovation with additional patented features is obligated by law to ensure all relevant background IPs were licensed-in before they added patented features in order to avoid future litigations for IP infringements. One of the deep tech SME managers explained:

> *One type of a patent cannot do a bigger system. We are looking at the system level. We are not looking at one item at the system level. And then if this is put together, somebody wants to sue you on this (Pax 12)*

A company that commercialises a product that is enabled with several background IPs is required by law to get permission from the existing IP owners to avoid potential infringement litigation. Concerned that IP licensed from polytechnics might infringe on existing IP, most polytechnics would only sign an IP contract with some sort of provision of indemnification by licensees. SME licensees who will develop a new product incorporating multiple licensed IPs from different sources are expected to defend, indemnify and hold harmless their licensors.

It appeared that polytechnics felt no obligation to take any responsibility for any infringement cases if they were not involved in the final product development. However, according to a veteran retail manager, the value of the IP is in the enforcement of its uniqueness, and if the IP is not protected by the licensor (the poly), it has no value:

> *I don't value them (IPs), because I know at the end of the day, there's no value. Unless you (polytechnics) go all out to protect the licensee. (Pax 5)*

On the other hand, SMEs that were less risk-averse agreed that it should be the SME licensee that bears the risks, at least limited to the claims made in the patent specifications:

> *I mean it's fair (indemnity), because at the end of the day we are the one that manufacturing everything. (Pax 10)*
>
> *Yes, I am okay with that (indemnification clauses)… the legal things nobody looking when the product is successful. (Pax 7)*
>
> *You only protect (indemnify) me that I use this claim that I don't get sued. That's alright. (Pax 12)*

From a cost perspective, it is expensive to engage an IP professional to ensure all relevant background IPs are licensed-in before the new product or solution is commercialised. - Checking for possible patent infringements is an aspect of the fulfilment of the IP rights assessment, sometimes known as 'freedom to operate' (FTO) requirements. When asked about their understanding on FTO, one ISU manager admitted that:

> *No (SME don't understand FTO)...we do not, I mean at least for our company I don't have an (IP) advisor around this. (Pax 13)*

Pax 13 claimed that start-up companies were mostly overwhelmed by a need to bring in sales revenue to maintain financial stability:

> *We just focus on okay, where to sell, right? How much to sell, who to sell and how fast we can push up this whole thing, right? That's what we are thinking of. So, we are not even think of trying to collateralize the other aspects of the patent in a sense. (Pax13)*

When SME managers involve professionals to assist with acquiring IP, they tend to hire ordinary business solicitors to prepare the licensing contract, which could be detrimental to the firm in the long run. Unlike an IP professional (a patent agent, or a certified IP technology consultant), a business lawyer without an IP background is not able to evaluate the scope of the patent protection accorded by a patent, which often requires interpretation through a technological lens. Only an accurate and reliable assessment of the IP rights by experienced IP professionals will help a company to shape strong IP protections and improve the company's appropriability regime.

However, SME managers with different levels of IP knowledge come to the polytechnics to seek IPTC opportunities. An established SME manager commented:

> *Well, I think for various reasons people go to the polytechnic. Ranging from people who don't know anything about patent, about technology. They go there (polytechnics) and seek anything. (Pax 4)*

For example, the retailing participants were under a false impression that new products or solutions embedded with just one licensed IP could be commercialised without any legal implications, unaware of the rights afforded by different IP rights mechanisms (patents, copyrights, design, trademarks). These less savvy SMEs were the ones who often engaged a business solicitor to review and advise on matters related to IP licensing contracts. On the other hand, technology-intensive SMEs were more informed about the complexity and subjectivity of IP protection and enforceability.

During one of the casual discussions after a formal interview, one retail manager shared a painful lesson learned when he had to pay a US inventor additional in-licensing fees to legitimise the sales of a product incorporating IP licensed from one of the polytechnics.

Such a painful experience could be avoided if SMEs allocated more efforts and resources to considering the enforceability of the legal rights afforded to all relevant IP assets linked to a new product. While it is clear that SMEs were aware of the importance of leveraging IP assets to strengthen the company's appropriability regime, it is equally essential for SME managers to reinforce their IP protection and deployment knowledge and skills to compete in larger and sophisticated markets.

### 5.4.2 Inability to reach a valuation agreement

Embracing an IP as a go-to-market strategy is an expensive venture. Pax 5, an established healthcare retailer recounted: *We lost almost half a million on the first (IPTC) venture.*

> *At the end of the day, the cost of the patent is very high. So sometimes the small SME, we may not be able to pay for a patent. (Pax 1)*

Business is about the capability to attain financial stability with positive cash flow. Investing over S$10,000 to seek patent protection for the Singapore market makes little business sense for a SME. This is especially true when the SME is marketing the patent-infused product in the global market, where separate patent protection in those target markets is required. Owning a patent as a competition tool will burden the SME with compulsory patent maintenance fees and contingency patent enforcement costs. One established retailer put it bluntly: *It (enforcement) would cost me tons of money ... we will report to you (polytechnic) if there's a copy (Pax 5).* Pax 5 was expecting a polytechnic licensor who is the IP owner to enforce the IP rights, not the IP licensee who was merely renting the IP.

Instead of owning a patent, a mutually agreed IP license will offer a cheaper alternative for SME licensees to strengthen their technology appropriability regime. Avoiding high patent protection costs, inadequately resourced SMEs sought externally developed technologies through IP licensing contracts. Either party would ultimately reach an agreement on the royalty fee structure and license terms after iteratively reviewing the valuation criteria. General speaking, an IP licensing contract should allow sufficient time (e.g. more than one year) for the licensee to productise the licensed IP. During this pre-revenue period, a licensee is expected to commit substantial financial resources to convert the licensed IP into a product.

**Business-unfriendly valuation methods.** Polytechnics, as public IPs, are expected to negotiate differently from other private technology producers. The SME managers raised issues based on how some license fees (e.g. upfront, milestones, and/or running royalties) are structured. One standard IP valuation method is about cost recovery over the licensing period. Another method commonly used is based on industry benchmarking. A representative comment from one of SME managers was:

> *You (polytechnics) are not a profit centre. You cannot be more expensive than I have money and do it (by myself). Then why should I work with you. (Pax 12)*

One healthcare product retailer was upset by the eagerness of polytechnics to transfer the IP development and protection costs to the licensee:

> *I'm telling you, it's a big hurdle to a SME to leverage a polytechnic like that because they (polytechnics) do have some costs to recover ...the payment of license fees and royalties, actually it's quite a big hurdle to SMEs. (Pax 5)*

From the above comments, the SME seemed to dismiss or fail to understand the standard valuation methods (cost recovery and benchmarking) practised by most public technology producers.

**Not all IP offers were of good quality.** Critical SME managers felt that some polytechnics lacked stringent due diligence in seeking IP protection. They explained their annoyance as follows:

> *When I negotiated the 'Poly ABC', they talked so much about IP and they have filed this and filed that (Pax 5)*

> *There are tons of IP patents, but many patents have flaws… do it (patenting) just for the sake because there is a KPI. So, a lot of these patents are useless patents, a waste*

*of money. So, there must be within the institution a panel to more or less assess the value. (Pax4)*

*Out of 100 projects maybe one project will see the light. The other 99 projects put inside the bank vault and nobody knows what's going on inside it. (Pax 7)*

SME managers criticised the lack of polytechnic quality control in seeking patent protection to fulfil polytechnics' key performance indicators (KPIs) is a waste of financial resources. KPI driven outcomes alter the IPTC behaviour too. An established healthcare product manager echoed a similar sentiment with additional concern over lack of long-term commitment:

*But I always tell them you know yeah you may have KPI, the first year only right, what about the continuation? So (to) them, it is like whatever happens none-of-my-business. (Pax 11)*

Since the performance of polytechnics' TTO is commonly measured by KPIs, such as the number of patents filed or commercialised, it is not entirely unfair for some SME managers to blame polytechnics for having a myopic view of their goals and their role in the polytechnic-SME relationship, and of demonstrating an unwillingness to support post-IPTC activities.

Clearly, SME managers felt that the polytechnics ought to review their IP protection strategies, and only seek IP protection for IPs that the poly had themselves validated with proper due diligence. In addition, polytechnics also need to incentivise more staff inventors to commit efforts and resources to follow through end-to-end any IP license deal.

**Polytechnic IP creators lack business sense.** On individual IP creator, competency, the comments of the SME managers on polytechnic human capital can be characterised as follows:

- Polytechnic staff excel in IP development.

  *In the technical side they are quite okay. (Pax 6)*

  *We (a spin-off founder from ABC polytechnic) are all academia or researchers. (Pax 9)*

- Polytechnic staff lacks in a business sense.

  *A lot of lecturers, actually they don't have entrepreneur spirit… they are not going to involve too much in entrepreneurship. (Pax 1)*

  *Unfortunately, that business side they (IHL's inventor) are not that good yet. (Pax 6)*

  *Polytechnic might not know of the reality -- of the real situation. (Pax 2)*

  *We (a spin-off founder from ABC polytechnic) don't know how to deal with NGO and VC. We don't know how to give a presentation and write a business plan. (Pax 9)*

Consistently, polytechnic IP creators were recognised by SMEs as competent in IP research and development. However, SME managers were frustrated by the lack of understanding of business reality by polytechnic staff. On the other hand, SMEs were unfamiliar with the culture and priorities of academic institutions. The different knowledge offered by both parties in IPTC negotiation can be complementary, as well as a potential source of tension, providing challenging circumstances in which to reach a realistic valuation agreement. Pax 5 commented that *institutions put a lot of value in IP, but I (SME) do not.*

**An objective and reliable IP valuation is an art**. IP valuation subjectivity and complexity increases when a licensed patent was bundled with other relevant transfer objects, including trade secrets, copyrighted materials and knowhow. The reality is that the valuation of *knowhow is complicated and is not so easily valued in a way (Pax 12).*

IP valuation is indeed a subjective and complicated task, as claimed by Pax 12. Another SME manager, an electronic domain expert, observed that IP valuation conducted by internal experts was more reliable than valuations performed by external consultants, but that the internal consultants had to be highly capable:

> *They (certain SMEs) have internal R&D, like us perhaps. And then you'll be able to assess them (IP value) accurately. But if you want to buy some core IP, then your internal technology directors or expertise must be of a very high calibre in order to assess accurately. (Pax 4)*

Pax 4, a sceptic of consultants' capabilities, argued that not all consultants were capable of producing a fair IP valuation:

> *So many times, they (consultant) are flawed, their consultant, they can say whatever their expertise. But their true capability and competency are serious doubts. (Pax 4)*

SMEs that lack internal IP valuation expertise, but have sufficient financial resources, can themselves engage suitable consultants to conduct an IP valuation as part of the pre-licensing due diligence. This poses a dilemma, however. Either they can risk valuable resources on a comprehensive technology assessment with no guarantee of its accuracy or they can trust their own business judgement, also with no guarantee on the valuation reliability.

Secondary analyses suggest that IP offers from the polytechnic sector are less foundational or core; therefore, IP valuation using business acumen instead of scientific literature or patent review may suffice. This makes IPTC with a polytechnic a much simpler operation.

**Financial goal incompatibility obstructs IP valuation agreement.** From a cost-recovery perspective, polytechnics tend to impose an upfront and running royalty immediately after a licensing deal is signed. A running royalty is commonly linked to either milestone or gross sales revenue performances, not on the profit made. Most interviewees expressed their unease about paying upfront and running royalties during the production phase, when there was no profit to be made:

> *I agree because the upfront fees actually is not so high, but zero is better. (Pax 9)*
>
> *Even before I make money, you say take something from me...SMEs don't have a big pool of money that they can draw upon. So, which means to say, that the starting point is wrong already. (Pax 11)*
>
> *I mean if there is no profit, then how to share. You cannot share. (Pax 7)*

It was clear from the data that SMEs and polytechnics have incompatible financial goals during an IP negotiation process. To maintain financial stability, most SMEs would prefer to abolish upfront fees and defer royalty payments until such time a profit is made. However, as a non-profit making entity, a polytechnic usually wishes to recover the associated IP costs within the shortest possible time frame.

Such different financial perspectives cannot disappear immediately, given the circumstances of the negotiating parties, one of which is private and profit-making, while the other is public and non-profit. This fundamental difference in the nature of the businesses explains why polytechnics failed to empathise with the SMEs. One of the managers estimated that: for *the first two years you (SME) cannot make it (Pax 7*), and, therefore, royalties should be deferred during the startup years. Once a profit is being made, the payment of royalties could be initiated.

One manager argued that paying a royalty calculated on the gross sales revenue during a loss-making time was untenable:

> *I mean we are running a conservative P&L (profit and loss) company. So, losses and you still pay a percentage of sales. Double whammy, you know? (Pax 7)*

Therefore, although the polytechnics' fees were relatively more affordable than the those of the universities, many of the participants would have preferred profit-based royalty fees, as evidenced in the language used by Pax 5 and Pax 7:

> *If you can remove that barrier (upfront royalty payments)...I'm happy to pay you (Pax 5); and I'm happy to share profit later. (Pax 7)*

The deferred and profit-based royalty payments deviate from the current practice where various royalty payments are collected immediately by the polytechnics to recover the IP protection costs – disregarding the time and financial investments needed by SMEs to attain the break-even point when the IPTC venture witnesses a profit. Granting a SME a deferred and profit-based royalty payment is business-friendly, but its adoption would require a polytechnic licensor to embrace a high risk-sharing position to walk the entrepreneurial journey with a SME licensee. Altering the customary payment arrangements for IP would be a challenge due to the incompatibilities inherent in a relationship between businesses and higher education.

The SME managers interviewed were keen to explore other means of recognising the agreed royalty payment, including bursaries and equity sharing. The Table 5.5 shows the two alternatives – bursary provision and equity sharing.

Replacing licensing fees with appropriate bursaries, although unconventional, is compatible to the polytechnic mission. The bursary recipients will gain an unforgettable learning experience in a polytechnic that helps SMEs to be more innovative. In addition, the adoption of bursary as one of the IPTC outcomes will create a positive public image for a polytechnic that aspires to be an entrepreneurial institute of higher learning.

**Table 5.5 Alternative means to recognise royalty proposed by SME managers**

| Quotation segments | Elaboration |
|---|---|
| *I am happy to share profit later…We will donate anytime… It's just when I was talking to the SPEC president can you donate for this bursary. I said no issues, no problem (Pax 7)* | Interesting to note that one of managers was thinking of compensating IP licensed with a bursary to help needy students.<br><br>This alternative is compatible with polytechnic primary mission – education. |
| *I mean if that's truly the intention then I think this venture term would come in properly where you have a skin of the game. And skin of the game obviously is just not taking royalty collecting consulting fees but looking into having another subsidiary which is not conflicting the mission of the school (Pax 13)*<br><br>*School (Polytechnics) have school fund (venture fund) and invest. That's a different story…Because you see with direct injection of cash it also means credibility for a young guy if an institution (polytechnic) want to invest, put money into the smaller companies then you are endorsed. You are doing good. (Pax 12)*<br><br>*If the Polytechnic can come out with co-op, co-op funding, that will be great (Pax 7)* | Innovative startup SMEs were more open to capital dilution welcomed the idea of letting polytechnics to co-invest and 'have a skin of the game'. In addition, as a co-investor, polytechnics are expected to co-own the problems faced in the entire IPTC journey.<br><br>Co-investments may take the forms of a direct cash injection, conversion of relevant fees to equity and co-op funding.<br><br>This alternative is incompatible with a polytechnic's primary and secondary missions. But, somewhat aligned with the third mission – IP commercialisation. |

As public-funded training providers, polytechnics are not required to raise funds by investing in private businesses. Nevertheless, a private venture arm had been set up within each polytechnic to translate home-grown early-stage IPs via spin-off companies to an acceptable level for IPTC.

Data from the case interviews indicated that half of the innovative startup SMEs were behaving like spin-off companies, expecting polytechnics to inject cash or in-kind investment into their IPTC ventures. The in-kind investment amount could be derived from the total royalty income receivable from a pre-agreed licensing agreement.

In a joint venture arrangement, not only would the polytechnic hold company equity, but would also be held jointly accountable in any commercial failure. Since the cost of commercial failure can be many times more than licensing fees, it is understandable that most public technology producers would be very wary of an IPTC partnership as an alternative relationship to the traditional royalty and fee arrangements. Furthermore, the participants from established SMEs interviewed for the study indicated that they prefer autonomy to practice IPTC by delinking their post-licensing activities from polytechnics.

Overall, SMEs believed in leveraging external IP in-licensing to strengthen their appropriability regime with combined internal and external IP assets. In negotiating for licensing deals, they encountered the following barriers:

- variability in IP protection and enforceability knowledge
- prohibitive IP protection costs
- unfriendly IP valuation methods
- unrealistic IP valuation
- financial goal incompatibility.

When prompted with questions on how to overcome barriers, the following themes were surfaced regularly:

- deferred and profit-based royalty payment (use-first-pay-later royalty scheme)
- skin-of-game' (co-investment by direct cash or conversion of royalty incomes).

## 5.5 Post-IPTC support

The following subsections describe post-IPTC resources required to support the IP deployment from the perspective of the SME managers. The analysis looks for interesting data features (recurring, surprising, important, supported by literature) that revealed some the ways in which the participants explored, recognised, and seized opportunities when interacting with polytechnics.

Most SME managers were attracted to the applied nature of IPs offered by polytechnics. However, there were the following shortcomings mentioned:

> *The standard of it (java content) is not really high. (Pax 1)*
>
> *Okay, how can we further develop it (healthcare product)? (Pax 11)*

These sorts of comments seem to suggest that polytechnic IPs were not ready for an immediate scale-up large scale production. Development works that stretch beyond the licensing contract were, therefore, a necessity. Polytechnic commitment to support the SME licensee on post-licensing development is valued and urged.

### 5.5.1 Scaling up challenges against post-IPTC success

SMEs that offer a new product that can only be produced in mass production facilities are commonly confronted with two main issues: high production cost and minimum order quantity (MOQ).

**High manufacturing cost for a local scaling up.** SMEs that require large scale production facilities expressed their frustrations over the prohibitive manufacturing costs for manufacturing done either internally or externally:

> *A lot of frustration, and we were looking into full-time production here (Singapore), but again, the cost involved is too high. (Pax 5)*
>
> *Definitely not (to manufacture) in Singapore. (Pax 13)*
>
> *We have finalized an agreement with China manufacturer. (Pax 3)*

The comments recognise the fact that Singapore is unsuitable for manufacturing due to high cost. Out of 13 cases, only one chemical startup proudly claimed that *we are manufacturing it ourselves* (Pax 9). Listed below are a few costs contributors recognised by SMEs:

- upfront costs of *tooling* (Pax 8) or *mould* (Pax 2) for metal stamping or plastic injection processes
- high human resource cost in production due to *manufacturing here (Singapore) is very difficult to get workers* (Pax 9)
- optimum cost-recovery production quantity, *because if you don't produce enough, then you don't have an optimum costing* (Pax 13).

**Inability of SME to fulfil the minimum order quantity (MOQ).** Another concern expressed by the participants in the interviews was that scaling up a new product that required mass manufacturing facilities was the minimum order quantity (MOQ).

Pax 3 complained that the quantity (MOQ) is by the thousands, if not, tens of thousands, and such a vast inventory would take years to be sold, and that he could only sell maybe a few hundred in a month, at least one or two years of stock. Similar high MOQs were reported as frustrating by Pax 5, Pax 9 and Pax 13. Over time, the inventory costs would have a negative impact on an SME's financial stability.

MOQ was also applicable to chemical manufacturing. Pax 7 explained that his company outsourced its chemical production because it had no choice, saying *that we worked with a paint manufacturer… there is a minimum order quantity, definitely, definitely….*

High production costs and MOQ issues are challenging to resolve. Accompanied by an established SME, the researcher had the rare opportunity to discuss scaling up related matters with an original equipment manufacturer (OEM) in China. In that interaction, the researcher observed that the trust built between the established SME and the OEM over 20 years helped to relax the MOQ requirements.

On the contrary, young startup SMEs may not have 20 years to develop trusting relations and will have to seek other avenues to lower their production costs. One of the possible avenues discussed during the case interviews was to co-innovate product ideas with the continual support of polytechnic resources and capability.

### 5.5.2 Co-innovation of transformational services

Throughout the interviews, it was noted that IP outcomes created by polytechnics were *more application ready* (Pax 7), and *very close to the market* (Pax 9). However, there were still a *bit of development* (Pax 11) required to bring the IP nearer to the scaling up phase. Certain SMEs were expecting polytechnics to contribute more than required in the IPTC contract by providing the following post-IPTC contract transformational services:

- **Prototyping and testing,** in which prototypes were subjected to iterative revisions *from maybe type 1 to type 2 to type 3* (Pax 2). Biomedical or chemical prototypes were extensively tested by different stakeholders, including the use of *clinical trials* (Pax 10).

  > *Tests done in the polytechnic, may not be enough or sufficient because they (manufacturers) also want to test the product… this product was actually validated by a French MNC, already in the market actually. (Pax 9)*

- **User-centric validation,** where new product concepts were validated with end-users directly. *We even bring the product to different medical institutions to get their feedback* (Pax 2). Direct inputs from end-users helped SMEs to understand their different needs, *because the clients' needs are very different* (Pax 11). For example, by asking elderly *what type of application the elderly want to have in a certain gadget* (Pax 6) helped the product development team to determine what font sizes and colours would provide the desired user experience.
- **Networking and outreach support via product exhibitions,** where new product ideas were further validated before scaling up. The presence of a polytechnic *as an inventor, as an institution* (Pax 5) was appreciated as the endorsement of a public-private collaboration. Such endorsements help to convince the public on the quality of a new product. In the event an inventor could be present in the trade exhibition, *just putting our product or maybe a banner* (Pax 10) will help to spread the message.

The above requests recognised the polytechnics' capability to provide post-IPTC product testing, user validation, and networking supports. These long-term supports where both parties are expected to *follow through for the next 2-3 years to get the whole project to be successful* (Pax 7) or *at least 6 months to one year* (Pax 9) for an idea validation were regarded as crucial to elevate SMEs' dynamic capability to pivot in order to respond to feedback received from market validation or from customer discovery, hence, readying the product ideas for large scale production.

Polytechnics that are able and willing to provide these post-IPTC supports will be heartened to hear remarks like *without that (post-IPTC support), I don't think we can succeed* (Pax 5).

On the other hand, SMEs that failed to secure post-IPTC support candidly urged polytechnics to *follow the industry player and help throughout until it becomes a success* (Pax 7); and *even after the product is out, continue to engage your partners and ask what are the things that you can do to help* (Pax 11). The comments suggest that certain SME managers were desirous of post-IPTC support. The reason for such a need was suitably explained by Pax 11, an established SME manager:

> *If you work with us (SMEs), it is not that we are challenging, clients are challenging, client's requirements are challenging. So alright you could get the requirements, but one or two weeks time, they may come and say I need to add more things because competition requires me to be such. So, we will need to re-adjust again. But, lecturers may not have this mindset to say your requirement is a requirement, that you give me, that one thing not going to add two more things. (Pax 11)*

Pax 11 illustrates the fact that a dynamic SME in a competitive market faces evolving demands to which it must respond with new design specifications that the SME would like approved or augmented by the polytechnic inventors. With such evolving design requirements, SMEs want polytechnic inventors to embrace a mindset shift to user-centric designing.

This case interview analysis points to the reality that IPTC is not a simple buy-and-sell or trade transactional process. A typical IP contract is a naked one that excludes any follow-through post-IPTC support. Willingness to support SMEs beyond the licensing contract would require polytechnic staff to adopt a new mindset and develop an incentivising IPTC policy. Secondary analyses indicate that the polytechnic sector is suitably resourced with the requisite human capital stock to translate IPs relatively closer to the marketplace.

## 5.6 Summary

This chapter provided an in-depth analysis of the 13 case interviews using reflexive thematic analysis focused on gaining insight into why and how to commercialise an IP taken from a polytechnic based on the experience and perceptions of SME managers.

The analysis of relevant quotations extracted from the interview data identified the SME managers as pragmatic IPTC negotiators who were able to leverage on their mid-career industry knowledge and experiences.

The reflexive thematic analysis of the interview data identified six main themes related to resources and capability, and noted features of both that either value-add or impede the polytechnic-SME IPTC processes – IPTC marketing, IPTC negotiation, combined with deal finalising and post-IPTC support.

The next chapter will provide a discussion on the main findings on the practical, policy, strategic and theory-development implications.

Chapter 6

# Discussion and conclusion

Generally, an IPTC process involves movement of ideas and IP among intra- and inter-organisational partners (IP creators and IP recipients), using different IPTC mechanisms (publications, training, contract research, IP licensing and start-up) to strengthen at least one partner's knowledge, expertise and competitive advantage. The interaction and the outcomes may vary due to historical, cultural and environmental contexts, rendering IPTC research a contextualised field.

## 6.1 Objective of the research

This chapter extends the discourse of scholars and practitioners to enhance our understanding of the overall experience of polytechnic intellectual-property transfer to SMEs and commercialisation (IPTC) outcomes. Using Singapore as a single case, this case study research integrates an investigation of public-private IPTC stakeholders' characteristics, with an evaluation of how the exchange of resources, the roles of the participants and their inter-relationships strengthens a SME's competitive advantage when they take and IP license from a polytechnic. Although there are other IPTC mechanisms through which a polytechnic can contribute to the society or industry, IP licensing was chosen for this research because it is the sharpest edge in an IPTC mechanism; a relationship in which a SME licensee is expected to commit a substantial financial investment to convert the licensed IP into an innovation available in the market.

In Singapore, the polytechnic education sector, consisting of five different, has operated for six decades, providing a practice-based workforce and collaborating with industry in various innovative activities of varying intensities. In addition to the conventional role of transforming thousands of post-secondary learners' lives by providing technical knowledge transfer, this research demonstrated that polytechnics in Singapore complemented SMEs, providing a resource other than universities for a range of IP, patent and non-patent products and services. However, the IP take-up rate by SMEs depended on a mutual commitment to co-innovate, which was shaped by the perceptions of the value of inter-organisational resources, roles and relationships.

The inter-organisational aspects relating to SMEs taking IP from polytechnics in order to commercialise it is an under-researched problem in the Singapore RIE context. Over the years, IPTC scholars and practitioners have paid significant attention to university IPTC knowledge generation, but little is known about the polytechnic IPTC process. In the absence of direct literature on the polytechnic IPTC space, three key literature streams on university IPTC processes, the university IPTC ecosystem, and competitive strategies regarding IPTC were consulted to inform the development of the general research questions for the present research. To reiterate, the RQ was: *How do human and structural resources contribute to or impede the IPTC process in the Singapore polytechnic context?*

## 6.2 Research method

The researcher applied an embedded single-case design to analyse relevant data drawn from:

- *Documentary research*, described in case study subunit 1 (Chapter 4) to identify environmental characteristics that influence IPTC or the innovation capability of polytechnics and SMEs in Singapore.

  The characteristics of IPTC stakeholders (government agencies, polytechnics, universities or SMEs) were identified and analysed. Innovation capability was investigated because the word 'innovation' is widely understood to overlap the phrase 'technology transfer' (Dubickis & Gaile-Sarkane 2015).

- *Thematic analysis* of the 13 case interviews, discussed in case study subunit 2 (Chapter 5).

  Themes related to polytechnics-SMEs' IPTC resources, roles and relationship exchanges, to explain how polytechnics IPTC resources and capabilities are structured, the adopted licensing strategies, and their link to decision making.

Both Chapters 4 and 5 summarised and discussed the two case study subunits' results straightforwardly, integrated with the literature. However, this chapter will describe the major findings (information) overall, explain those findings (insights) and discuss the implications (interpretations) by exploring relevant linkages to more conceptual and theoretical issues.

## 6.3 Major findings

The findings of this research are two-fold. Firstly, the research demonstrated that at the environmental level, public agencies and public IP producers' unique characteristics are leading SMEs to consider IP licensing as a feasible IP commercialisation strategy. Secondly, it was established that at the inter-organisational level, there were practical, policy, and theoretical implications arising from this research.

From the resource perspective, IPTC partners were looking for meaningful collaboration between partners who possessed value-adding knowledge and knowhow in design, technology, business and customers. The choice of IPTC partnership, autonomous or interdependent, would be influenced by the stock of knowledge and knowhow that the IPTC partners possessed.

### 6.3.1 Influence of IPTC environmental factors

Overall analyses of the influence of the IPTC environmental factors indicated that:

- *IPTC success is challenging to attain.*
  At the macro level, IPTC problems can be attributed to the characteristics of the following roles and their relationship:
  - agencies (NRF)
  - public IP producers (polytechnics)
  - private IP recipients (SMEs).

  There were missing elements for each of these sources that ought to be addressed to improve SMEs' ability to translate licensed IP from polytechnics into the marketplace.
- *The missing elements were identified as:*
  - Agencies were agile and pragmatic, but must stretch the RIE policy's goals beyond basic R&D, leaning more towards IP translation.
  - While universities were pursuing their goals of being world-class research institutions with scientific publications, polytechnics could fill the missing role

as the public IP translators in a typical RIE ecosystem, presenting SMEs with options for a direct IPTC partnership in an open innovation environment.

– SMEs that were cautious or inadequately resourced were unable to fully understand and translate the licensed IP independently without a polytechnic's continued involvement.

### 6.3.2 The response of public agencies

*The public agencies are agile and pragmatic, but somewhat challenged in fostering IP commercialisation beyond basic R&D.*

This finding emerged from the documentary research into the government's efforts at innovation facilitation. Over the years, public innovation funding policies have shifted from a MNC-reliant strategy to one more SME-friendly, pursuing the nation's aspiration to become regional Asia's innovation hub with greater emphasis on design, and commercialisation of R&D outputs.

The enlarged, combined goals of design and commercialisation of ideas were clearly articulated as part of the nation's desire for more products that were 'not invented here but commercialised here' (Economic Strategies Committee 2010, p. 24). Even though this is a pragmatic approach to foster R&D outcomes, universities in Singapore will have to look beyond basic R&D for ways to foster the design and commercialisation of ideas and IP.

Each year, the government agency (NRF) invests billions of Singapore dollars in supporting innovation inputs through five-year innovation plans (e.g., RIE2020), hoping to encourage innovation outputs. Such a substantial investment has consistently placed Singapore at the top of international innovation surveys (GII and CPI). Nevertheless, the same surveys found that Singapore lacked in innovation output. *This finding suggests that investing heavily in innovation inputs does not necessarily create or improve innovation capacity.*

Singapore is in the early stages of developing its IPTC capacity, and the Economic Strategies Committee (ESC) cited a need for more competent IPTC professionals, patent agents, and business mentors in their 2010 report. Public IP producers' innovation capacity requires creativity, but also competent IPTC professionals with cross-disciplinary (technology and business) knowledge who can effectively connect IP producers to IP recipients; qualified IP agents assist IP producers and IP recipients to conduct IP-related due diligence; and experienced business mentors provide business development advice to high-technology startups.

In the discipline-specific human capital of the innovation ecosystem, Singapore invested 1000 scholarships in 2001 to expand the pool of R&D talent by creating new IPs in the biomedical, physical and engineering sciences. *As a small nation with no natural resources, talent development is always the key consideration.*

### 6.3.3 Expectations of polytechnics

*Unlike universities, in the area of IP producers, polytechnics are expected to value add in the RIE ecosystem as IP translators.*

Since the 1980s, IPTC scholars have attempted to understand the complexity of successful technology transfer between public IP producers to private IP recipients. One of the traditional views was that IPTC involved a linear process, starting from universities' early-stage science discoveries, followed by RI's role in creating inventions from those discoveries, which could ultimately be transferred to the marketplace as innovations via high-tech spin-offs or start-ups. Although this linear IPTC model is ideal and heavily supported by high-tech start-up entrepreneurs, it is not suited for SMEs that lack the absorptive capacity for sophisticated technologies.

Like many other research universities, the research data shows that NUS was pursuing curiosity-driven and grand challenge R&D pathways to bring nontrivial ideas and IP into the marketplace to benefit a mass market. The industry-driven applied R&D pathway was only one of the NUS's three R&D pathways that aimed to produce utility-oriented ideas and IP. This observation aligns with the finding of Cripps et al. (1999) that university researchers lack interest in performing applied R&D, which is usually time-consuming and contains little activity or content suitable for academic publication.

Since universities' reward systems are heavily biased toward high impact publication and successful research grant applications and performance at a highly theoretical level, applied R&D is not popular as a means by which to advance a researcher's career. This implies that a change in university KPIs and reward systems is needed if university researchers are to be expected to perform applied R&D in conjunction with basic R&D, or if institutions want them to spin out more high technology start-ups as per the linear IPTC model.

In a less linear model, IPTC stakeholders (IP producers, IP recipients, IP intermediaries, product producers and end-users) are open for direct engagements. SMEs would engage directly with a polytechnic rather than a university, to bring a utility-oriented product to the marketplace. As discussed in Chapters 4 and 5, the research indicated that SMEs do engage with polytechnics to translate utility-oriented product ideas and IP requiring mainly contemporary technologies. Polytechnics improved the capabilities of SMEs to access new knowledge through the provision of IP that was optimally modelled and tested. In this way, SMEs could increase their learning through functional or design prototypes without the need to grapple with the natural gaps in basic university research. In this way, they can access functional or design prototypes, bypassing basic university research.

Interview data supported the finding that a good prototype can remove the ambiguity associated with commercial applicability (through iterative prototyping and user testing), and the strength of the resulting IP (patents, copyrighted materials, registered designs and trade secrets) will facilitate the smooth closure of an IP licensing deal, improving the polytechnic's position as a value-adding IP translator.

### 6.3.4 Polytechnics, the IP translators

*This research suggests that a polytechnic should occupy an IP translator position between applied research and real-environment prototyping.*

This position requires polytechnics to translate early-stage SME product ideas or university discoveries through iterative prototype design and development into functional prototypes using mainly contemporary technology. Despite a few negative comments on polytechnics' IP readiness for scaling-up, the general comments affirmed that prototyping capability fits the polytechnic profile as an educational provider that transfers contemporary knowledge engineering skills, design, IT, and healthcare within real-world teaching systems. Figure 6.1 shows graphically the position of a polytechnic based on the researcher's understanding of various innovation processes in relation to parameters, such as innovation players and outcomes, arranged in one single relationship diagram.

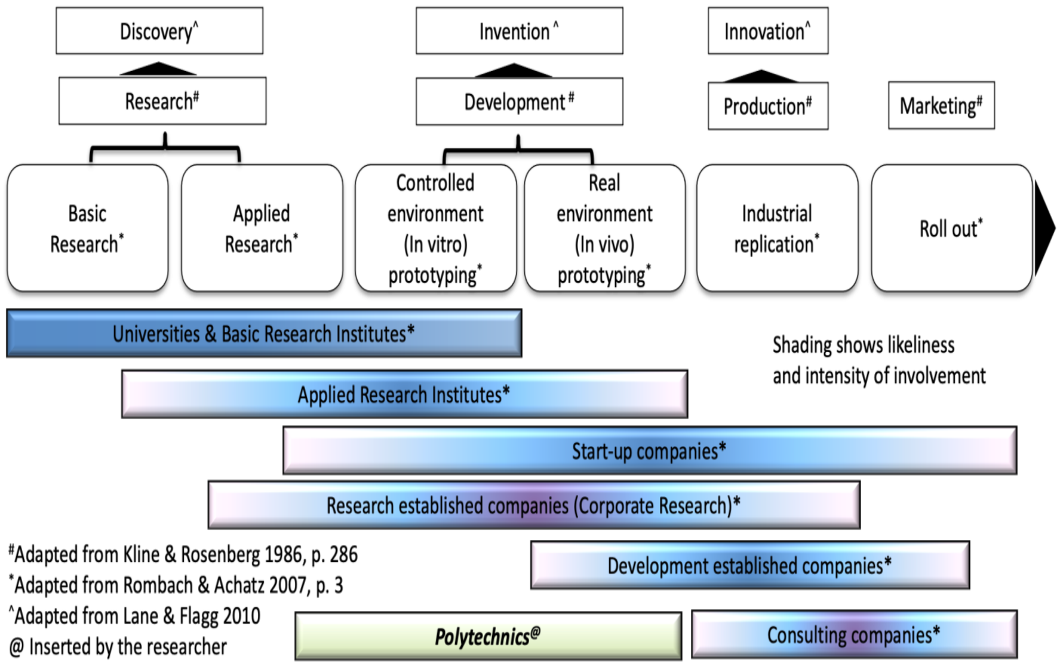



**Figure 6.1 Various aspects of innovation and their parameters. Source: Adapted from Kline & Rosenberg 1986, p. 286; Rombach & Achatz 2007, p. 3; and Lane & Flagg 2010.**

The idea that polytechnics are better equipped with IP translational capability was discussed by SME managers in the interviews, connected to terms such as 'idea prototype', 'integrated technology solution' and 'incremental IP'. Polytechnics' innovation outcomes were evidenced by documentary research results of 91 IPTC deals made by four polytechnics (2003-2016), 300 patents filed (1991-2013), five out of six Centre of Innovations or COIs established. The presence of a range of COIs in the polytechnic sector further confirmed the public confidence in the sector's competencies in IP translation through idea prototyping.

Examples of incremental IP that have been embodied into commercial products or services cited in this thesis include several product extensions, food and beverage recipes, and process control algorithms. These were products or solutions that solved industry or society's problems and brought immediate financial gains for the product producers, not the longer-term public good (Cripps et al. 1999; Geiger 2006). This combined evidence justifies locating polytechnics as IP translators, a role situated between universities (fundamental IP producers) and established product development companies (industrial replication). This finding implies that polytechnics are capable of becoming SMEs' IPTC partners for translating utility-oriented IP.

The overarching research problem is how to encourage more SMEs who are sophisticated technology seekers to look beyond the traditional IP producers (universities or research institutes) and explore with polytechnics the transfer and commercialisation of a wide range of IP, including incremental utility-oriented IP.

### 6.3.5 Greater knowledge and appetite for risk

*As IP recipients, SMEs need to increase their IPTC knowledge and appetite for risk to innovate.*

In this research, a SME was the target IP recipient. IPTC started in early 1980s in the US following the approval of the famous *Bayh–Dole Act*. SMEs in Singapore started their IPTC journey in the late 1990s – 20 years later. Since SMEs are essentially in the early-stages of IPTC development in Singapore, it was not surprising that most SMEs were perceived by the research participants as risk-averse in making IPTC related decisions. This argument can be supported by the risk-averse characteristics established by a relevant IPTC survey conducted by Wong, Ho and Singh (2006). The survey confirmed that out of 150 SME respondents, SMEs were cautious in R&D or innovation investment (only 2% of the sales) and inward looking. They preferred internal innovation, but did not shun collaborating with non-competitors. universities were ranked sixth out of eight of the most preferred licensors.

### 6.3.6 Choice of IPTC mechanisms

*The IPTC process needs to be made easier in order to achieve a win-win IPTC partnership between SMEs and universities and between SMEs and polytechnics.*

The literature review indicated that most research universities adopt an 'out-the-door' IPTC approach, allowing IPTC partners the freedom to develop products from the licensed codified IP (e.g., patent specifications) straightforwardly without involving the transfer of tacit knowledge – akin to the 'naked' IP licensing approach shared by Davis and Harrison (2002).

However, this research indicated that while SMEs with internal technological R&D capabilities might prefer the 'naked' IPTC approach where freedom to develop the IP was a priority, SMEs without internal technological R&D capabilities (e.g., retailers) were more likely to transfer IP via a ‘dressed’ IPTC approach, engaging in co-innovation activities (e.g., prototyping and testing) during pre- and post-IPTC stages.

Typically, where the literature focussed on the merits of the ‘naked’ IPTC mechanism over the ‘dressed’ one, it was primarily concerned with the detrimental effect on the research culture of universities of shifting from a focus on publication to a focus on IPTC. The literature also noted that IPTC is mostly the third mission in most research universities, and that the co-innovation model of an end-to-end IPTC process preferred by some SMEs is a relatively new idea for public research universities.

In summary, although Singapore public agencies have played a pivotal role within the triple-helix innovation model to transform Singapore into a knowledge-based economy by investing heavily to foster innovation capabilities, the roles, resources and relationships require management to ease the IPTC process to achieve a win-win IPTC partnership between SMEs and universities and between SMEs and polytechnics.

### 6.3.7 The influence of the research, innovation, and enterprise (RIE) goals

*SMEs seeking a polytechnic IPTC partnerships are pragmatic in terms of RIE, looking for innovation capability and resources to take their businesses forward.*

Overall analyses of the influence of RIE capabilities (e.g., applied R&D, prototyping, user testings, resource management) and resources (e.g., human or structural) in relation to polytechnic-SME IPTC indicated that IPTC success can be attributed to how RIE resources were managed to address IPTC problems at the inter-organisational level and cross-disciplinary in nature. There were two categories of resources that SMEs spoke of seeking during the interviews: structural and human.

Examples of structural resources discussed were IP, infrastructure, processes, strategies, knowhow, and image – developed by SMEs or polytechnics. On the other hand, human resources include individual creativity, knowledge, experiences, capabilities, and attitudes that are intrinsic to people.

IPTC processes involve the dynamic capability to manage and exchange resources in the least problematic way. This research demonstrated that most SMEs were aware of the different RIE capabilities and resources offered by polytechnics and universities in Singapore. This awareness implies that SMEs seeking a polytechnic IPTC partnership will not be looking for scientific discoveries, but downstream innovation capability and resources.

#### 6.3.8 The potential effect of low technology readiness level (TRL) IP

*Low TRL IP, a structural resource gap, can potentially cause IPTC failure.*

While it is a common dream for both IP producers and recipients to produce radical block-buster products based on nontrivial discoveries, technologies and IP, such dreams are difficult to realise. One of the causes for IPTC failure identified in the literature is low levels of technology readiness in the IP. Low TRLs mean that the IP is far from mature, with considerable development still required. Technologies with higher TRLs and IP means greater certainty of successful implementation and better control over the IP, but acquiring mature technology and IP is costly. Therefore, it is not surprising that SME licensees eagerly sought high TRL, utility-oriented technologies and IP, such as that produced by polytechnics, as a cost-effective means for IPTC.

This preference for utility-oriented ideas and IP to extend their established products' values is consistent with the literature and polytechnics' annual reports reviewed in Chapter 4. However, not all SME managers were content with the TRL of the licensed IP. Many expected continued technical support from the polytechnic in order to increase the TRL.

The implication of this finding is that co-innovation during and after licensing will increase the TRL of the ideas, technologies and IP, ameliorating the risk of IPTC failures.

### 6.3.9 Poor communication

*Incomplete communication process, another structural resource gap, can potentially cause an IPTC failure.*

For ease of transfer, companies – small or large – prefer to license well codified and protected IP. Although codified ideas and IP facilitate IPTC information flow, the transfer of tacit knowhow and incomplete information was found to be problematic for IPTC, a concern regularly raised in the interviews. The continued involvement of the polytechnics' IP creators during and after the licensing would ensure tacit knowledge is not lost in the process of transfer.

### 6.3.10 Understanding the legal concept of intellectual property

*The understanding of the concept and legal status of IP varied among SMEs, a human resource knowledge gap that could lead to the over simplification of the complex IPTC process.*

During the interviews, some SME managers expressed a very simplistic view of the adoption and use of IP. They were prepared to have IP licensing contracts scrutinised only by a business contract manager, without an IP agent's involvement. Overwhelmed with the market potential, some SME managers took the high risk decision (informed or uninformed) to bring a new product to market, even though it was embedded with existing instances of protected IP.

By ignoring the need to secure permissions from the existing IP owners, careless SMEs were inviting undesirable infringement litigation. Although the threat of likely infringement litigation was real, it was a risk worth taking if every stakeholder in the target market were equally ignorant about the technicalities of IP and the enforcement of IP protection. SMEs in those markets experimented with various IP monetisation strategies while still in their IP knowledge acquisition phase.

Such experimentation might eventually result in an IP lawsuit that would strain the existing rapport between polytechnics and SMEs, particularly when SME licensees were expected to defend, indemnify and hold guiltless their polytechnic licensors. The fact that the government installed the 10-year IP Hub Master Plan in 2013 and supplemented the plan with a comprehensive IP Competency Framework in 2019 indicated the agency's acknowledgement of the highly variable awareness of the legal status of IP that exists among both the IP producers and IP recipients.

## 6.4 Practical implications

This section analyses the practical implications of the findings from the study, and recommends what actions should follow and who should take them. No single solution will ease the IPTC process and foster greater uptake from the polytechnics by the SMEs. Although not all the recommendations are new to IPTC scholars or practitioners, they were consistent discussion points that surfaced in the interviews, hence necessitate a revisit. Table 6.1 (see Summary section 6.4.6) lists the findings' practical implications and the corresponding recommendations made for either the polytechnic's or SME's consideration.

### 6.4.1 Communication

*A candid communication approach facilitates the IPTC process.*

A clear understanding of resource limitations helps IPTC partners decide how to approach IPTC using either a 'naked' or a 'dressed' mechanism. One of the implications of adopting the 'dressed' mechanism is that both IPTC partners must commit the resources required to co-innovate for the long-term, beyond the IP licensing stage.

At the outset, before the IP negotiation process, some SMEs without their own technological resources eagerly sought co-innovation opportunities to eliminate the insecurity related to resource limitations. For example, SME managers expected to share with the polytechnic relevant, but non-confidential, technical and management information throughout the IPTC process, before an IP license was actually finalised. However, confidential enabling information shared openly in an online platform or personally without a NDA was shunned by SMEs. Although it is commonly argued that online open-innovation platforms encourage unrestricted information flow and exchanges between IP producers and IP recipients, the data from this study indicated that SMEs preferred to share enabling information in an offline setting.

This unexpected finding suggests that SMEs tend to guard their IP (market and relational intelligence), or were unfamiliar with and didn't understand or trust online sharing tools and techniques. In the absence of market intelligence from the SMEs, the public IP producers could only make guesses about the market or conduct secondary research on what the market needed.

*A compromise method for handling sensitive communications would render the IPTC experience less problematic.*

### 6.4.2 Cross-disciplinary problem solving

*Technological-business cross-disciplinary problem solving necessitates co-innovation.*

SMEs and polytechnics must collaborate intimately to successfully conduct IPTC, because neither party has the requisite cross-disciplinary knowledge to ensure a smooth transfer from a technical domain into the business domain. SMEs contribute market knowledge, while the polytechnics provide technical knowhow and expertise. Problems arise if this sharing is unequal, and if significant tacit knowledge is either deliberately or accidentally withheld by either party, although implicit knowledge is provided.

This observation implies that both SMEs and polytechnics can derive more benefits, financial or non-financial, by jointly monetising the IP using the 'dressed' IP licensing approach. *SMEs seriously desired pre- and post-IPTC support from the polytechnics, and saw co-innovation as more than a marketing promise.* This phenomenon is consistent with SMEs' risk-averse characteristics described in Chapter 4.

### 6.4.3 Acquiring and protecting intellectual property

*Patent and non-patent IP are equally welcomed, but incomplete IP due diligence could potentially harm the IPTC partnership.*

**Patents.** You do not need a patent to make or to sell a product. They are complicated, annoying and expensive. But inventors and developers who think they have a product that will sell for many years generally benefit from a strong patent (Invention City Inc 2021a).

Big corporations patent most technology-infused innovations to improve the appropriability regime strength to gain a competitive advantage. This research found that technology giants like IBM and Nokia own many background patents on mobile payment and mapping technology, respectively. To avoid infringing relevant background patents owned by IBM and Nokia, new mobile application companies, such as Alibaba and Uber were obliged to conduct due diligence investigations to determine whether they had the freedom-to-operate (FTO) in the context of possibly patented background IP.

However, the desirability of using patenting as a competition strategy for a SME remains questionable. Both taking out a patent and performing due diligence can be costly.

In a real case scenario, one of the SMEs in this study had once taken a due diligence short cut by not engaging a patent agent to conduct the freedom-to-operate assessment of the licensed IP, only to find out later that the licensed patent did not cover the intended scope. This resulted in an IPTC problem. The IPTC partners blamed each other for neglecting the duty of IP assessment. Incomplete due diligence naturally strained the IPTC partnership.

Although a patent provides broad protection against unlawful replications, not all innovations are patentable, and non-patent IP (copyrighted software, hardware and electronic design artwork) was just as welcome by SMEs if the TRL level was high.

*Given this observation, polytechnics should give equal emphasis to both patent and non-patent IP to increase the IP take-up rate.* While patents can be used to create a temporary barrier against competitors, the associated costs and increased complexity may lead SMEs to value IP that doesn't necessarily need patenting, but is protected by simpler mechanisms, such as copyright.

While some of the research participants had selected patent IP for IP and economic protections, others had chosen non-patent IP for a variety of other reasons, and not all polytechnics sought patent protection for IP that resulted from polytechnic-SME co-innovation. Some patents were filed in anticipation of commercial potential, while a few were filed to fulfil predefined corporate KPIs, a case of debatable IP quality.

**Due diligence.** IPTC scholars point out that transferring a patent requires thorough due diligence or assessment of the claims. What was going to be protected (processes, compounds, features, or algorithm) and in which technology domain (chemical, pharmaceutical, electronics, or mechanical)? IP assessment leading to a patent makes an IPTC process problematic since both polytechnics and SMEs are usually not qualified to perform the assessment, and costly external IP assessment is therefore required.

These observations were thought-provoking. Establishing a patent costs more but will theoretically accord the IP owners straightforward rights to exclude competitors from replicating the inventive functions embedded in a new product. Hence, a patent should arguably give the IP owners a better financial return. However, the analysis in Chapter 4 countered this argument. *Analysis of the data found that non-patent IP outperformed patent IP when licensed to SMEs.*

### 6.4.4 Valuing and paying for IP

*Business-unfriendly IP valuation and payment structures could potentially harm an IPTC partnership.*

Although most SMEs considered the ability of the licensed IP to deter unauthorised replications an essential for attaining a competitive edge, the lack of awareness of IP variability was observably large. Furthermore, business knowledge related to IP valuation and the royalty payment structure was often poor among representatives of both the SMEs and the polytechnics, making it challenging to reach a mutually agreeable licensing deal. Hence, more IPTC development programs were installed by IPOS for both polytechnic and SME staff under the IP competency framework. *This finding implies that with the alignment of IPTC knowledge and knowhow, more realistic KPIs could be used to enhance the polytechnic-SME IPTC experience.*

### 6.4.5 Post IPTC support

*Although post IPTC support is not an IPTC norm, it was appreciated by certain SMEs.*

In a polytechnic, a staff member's performance is assessed on his or her capability to fulfil the primary mission (teaching), secondary mission (research), and third mission (IPTC). Therefore, it is understandable that polytechnics avoid embroiling themselves with post-licensing support, which is a task not critical to the primary mission of the polytechnic. Continued involvement with the licensee may interfere with core teaching and research activity.

Despite this, one request or suggestion made by the SMEs during the interviews was for post-IPTC co-innovation services to ready the licensed IP for large scale production. Such post-IPTC services included prototype refinements and validations, and market outreach support to address unanswered technical and usability uncertainties. *Gaining this sort of support from the polytechnics would allow SMEs to move the jointly developed prototypes nearer to the production stage – a cost and risk reduction measure for scaling up the production phase.*

### 6.4.6 Summary table (Table 6.1) of practical implications

**Table 6.1 Practical implications of the findings and recommendations to foster IPTC take-up rate**

| Practical Implications | What should be done? | For who? | Sources |
|---|---|---|---|
| A polytechnic's capability to supply relevant structural resources, including effective communication strategy and methods within a co-innovation model will encourage SME to proceed to the IP negotiation stage. | Ensure timely and proactive communication of relevant non-confidential information throughout the IPTC process. | Polytechnic | Documentary Research and Interview |
| | Adopt a collective effort to co-own of IP, reject out-the-door licensing method. | Polytechnic | Interview |
| | Avoid breach of confidentiality and trust in sharing enabling information | Polytechnic and SME | Documentary Research and Interview |
| | Avoid using an online collaborative platform to exchange information on challenges and solutions | Polytechnic and SME | Interview |
| | Ensure timely and proactive communication of relevant non-confidential information throughout the IPTC process. | Polytechnic | Documentary Research and Interview |
| A polytechnic's capability to offer a fair IP valuation facilitates an SME's decision to finalise the IPTC deal, hopefully leading to the desired competitive advantage. | Offer production-ready IP, patents or non-patent IPs. | Polytechnic | Documentary Research and Interview |
| | Clearly define expectation on IP strategy, and conduct IP due diligence to reduce litigation risks on future breach of a third-party IP right. | Polytechnic and SME | Interview |
| | Implement IP licensing as the more economical way to attain competitive advantage. | SME | Interview |
| | Improve IP valuation method to be more business-friendly | Polytechnic | Documentary Research and Interview |
| | Improve training to narrow the variability in IP awareness between technology- or non-technology SMEs. | Polytechnic and SME | Documentary Research and Interview |
| | Avoid misalignment of KPIs | Polytechnic and SME | Documentary Research and Interview |
| A polytechnic can reduce the financial and technical burdens of an SME IPTC partner in reducing the scaling-up investment with appropriate post-licensing supports to ensure a win-win long term relationship. | Involve in post-IPTC co-innovation services (regulatory testing, validation, networking and outreach). | Polytechnic and SME | Interview |
| | Take a long-term co-collaboration perspective (2-3 years) | Polytechnic and SME | interview |

## 6.5 Policy implications

This section reports on the analysis of the data in relation to the implications for polytechnic IPTC policy, and recommends policy guidelines to improve IPTC take-up rate.

### 6.5.1 Cross disciplinary learning

*Cross-disciplinary learning can take place through non-linear co-innovation policy.*

The research demonstrated that an IPTC partnership can be problematic due to incompatible knowledge between IPTC partners; for example, polytechnic TTO managers lack business knowledge, while SME managers lack technological knowledge. In today's fast-paced world, problems are multifaceted, and new knowledge and skill are created from experiential learning. People collaborate to transfer knowledge from one discipline to another – a cross-disciplinary learning approach to problem-solving. Polytechnics need to regard IPTC as a meaningful pathway for cross-disciplinary learning between business and technological domains.

Through co-innovation projects, polytechnic staff and learners can benefit from practice integrating classroom knowledge (gained from two or more modules of business, technology, project management, and social sciences) with experience to overcome real-life IPTC problems. While one can learn and teach many different polytechnic modules, only a few can directly contribute to taking a polytechnic's IP to the marketplace with a SME licensee.

The value of such direct involvement is that participants will acquire new collaborative and problem-solving skills while interacting with external stakeholders like SME licensees, regulators, agencies, intermediaries, vendors, manufacturers, and end-users. This stakeholder engagement, facilitated by SME licensees, will enhance the polytechnic staff and learners' body of knowledge. This by-product resulting from an IPTC partnership can be regarded as a non-monetary or in-kind contribution from the interaction with a SME. Since a primary mission of a polytechnic is training, understanding the IPTC partnership as a training opportunity helps to justify a polytechnic's increased support for IPTC activities from lab-to-production, during the pre- and post-IPTC phases.

### 6.5.2 Business-friendly risk and revenue sharing IPTC policy

*Besides the identified cross-disciplinary knowledge gap, polytechnic IP creators lack business sense*.

The lack of business sense among the IP creators was a key finding of this research. The IPTC partnership could be problematic due to:

- business-unfriendly IP valuation methods
- low TRL level of the licensed IP
- financial goal incompatibility between IPTC partners.

During the interviews, most SME managers were concerned about the upfront licensing fees imposed immediately after an IP license was finalised. They considered the time to pay licensing fees as critical. SMEs welcomed a revenue-sharing model in which fees were paid after the scaling-up phase, or when the product was experiencing the first profit with healthy traction. A royalty-free period for two years after the licensing deal would allow SMEs to channel their limited financial resources to other financial commitments required for scaling up (production prototyping, test-bedding, regulatory clearance and product-marketing) activities.

As opposed to upfront IP royalty fees, the SME participants offered several alternatives for sharing revenues *after* the first profit was made:

- deferment of royalty to facilitate SME's cashflow during the pre-production years
- equity sharing to share risks and profits as committed co-innovators
- bursary donation to recognise importance of education.

Although these licensee fee alternatives are not entirely novel, they are worth revisiting. For example, A*STAR RIs provided IPTC partners with royalty-free licensing deals for an initial three years (OECD/ERIA 2018) to provide time for scaling up activities. In another example, a private technology giant, Tesla, granted authentic competitors or complementors free access to Tesla's patented technologies to provide all involved opportunity to catch up (Jeyakodi & Ros

2019). Providing royalty-free or deferred royalty fee licensing deals can be closely linked to outcomes defined by policymakers with vision and sharp business acumen.

In this research, the participating polytechnics and SMEs engaged in direct co-innovation IPTC partnership to translate ideas nearer to the production phase. Together with the licensed IP (background and foreground), the efforts invested through this co-innovation could be quantified and converted into a company's equity later. In contrast to the upfront royalty and revenue-based royalty fees, this deferred and profit-based royalty fees alternative adopts a longer-term perspective, allowing the IPTC partner to use-first-and-pay-later, thereby sharing the risks and eventual profits.

Although the risk of IPTC failure is real, the risks of licensing-for-equity can be mitigated if the upfront fees deferred are not high, and the licensee has the requisite industry experience and market knowledge to market the licensed IP (e.g., veteran retailers). This research found that almost 70% of the SME managers interviewed were in their mid-career stage armed with market intelligence, an ingredient for IPTC success.

Risks and opportunities are negatively associated; however, risks can be managed or even converted into opportunities via legal contracts. If managed professionally, licensing-for-equity instead of the norm of licensing-for-cash can be an example of how polytechnics can create more spin-off companies (which are lacking now), contributing to Singapore's economic and innovation developments. Furthermore, these spin-off companies can create internship and career opportunities for polytechnics' students who are aspiring entrepreneurs.

### 6.5.3 Common IPTC policy across the polytechnic sector

*SMEs have a different understanding of IP contract clauses, especially the clauses on warranty and indemnification*

The earlier section discusses recommendations based on this research's revelations in relation to practical knowledge about the communication process, IP valuation methods, and the IPTC model.

Interestingly, the research also found that SMEs had a different understanding of IP contract clauses, especially the clauses on warranty and indemnification. Not all SMEs were willing to defend, indemnify and hold guiltless their polytechnic licensors. This is a complex legal issue. Some of the participant SMEs argued that polytechnics should be accountable for patent or other IP infringement cases even if they were not involved in the final product development – a disconcerting finding, given that the polytechnic as a non-product company, generally had little or no interest in working to ensure the commercial success of the IPTC deal.

Individual polytechnics addressed the issues of warranty and indemnification by using a term sheet summarising key commercial considerations using simple English. *Integrating all the practical knowledge makes it worth considering establishing a collective IP translator centre to share common practice and processes through consistent messaging to the industry.* Services provided through a one-stop platform would imply cost-saving and better efficiency than a decentralised one.

### 6.5.4 Summary of policy implications (Table 6.2)

**Table 6.2 Policy implications of the findings**

| Findings | Policy implications | What should the polytechnic do? | Guidelines for future action |
|---|---|---|---|
| The dynamic co-innovation model was a clear strategy option for SMEs without internal R&D capabilities to bring ideas from lab-to-production. | A polytechnic's capability to co-innovate with SMEs will increase IPTC take-up rate and narrow the cross-disciplinary knowledge gaps. | Uses the polytechnic-SME IPTC partnership as a cross-disciplinary learning platform for staff and students, hence the justification for co-innovation to bring ideas from lab-to-production. | Polytechnics should document lessons learnt from polytechnic-SME IPTC partnerships as case studies materials for polytechnics staff and learners to stay current with knowledge and skills. This case study materials can be regarded as an in-kind contribution received from SMEs towards the IPTC partnership. |
| Inability to reach a valuation agreement is problematic for a positive IPTC partnership. | A polytechnic's ability to remain business-friendly in deciding on the IP valuation and royalty payment method to mutually benefit all IPTC partners will increase the IPTC take-up rate. | Offers SMEs options to defer and switch to profit-based royalty payment (e.g., equity or bursary), challenging the industry norms of the upfront and revenue-based fees. | Polytechnics should allow more IPTC partners to opt for licensing-for-equity instead of the norm of licensing-for-cash. This change implies that polytechnic will have more spin-off companies to contribute to Singapore economic and innovation developments. |
| Inconsistent interpretation of IP licensing contract is problematic for a positive IPTC partnership. | A polytechnic's ability to simplify licensing agreement in clear and simple English will remove the negative impression that the IPTC process is tedious and time-consuming. | Offers SMEs an easy-to-understand term sheet summarizing key commercial considerations to gather inputs from SMEs before the negotiation. | Polytechnics should evaluate the feasibility of setting up an IP translator centre to align IPTC processes and practice for the five polytechnics. Such a go-to-centre will ensure consistent messaging in terms of IPTC policies, processes and practices. |

## 6.6 Strategic implications

This section analyses the findings' strategic implications and discusses the government's role in developing IPTC capability and other 'big picture' ideas to improve the city-state's competitive position.

The triple-helix innovation model argues that the bilateral interactions among government agencies (regulators and funding), local industries (product producers) and universities or polytechnics (IP producers) will foster more public-private IPTC. The literature confirms that Singapore was transformed from a technology adopter in the mid-1960s into a technology creator in the late 1990s. Although in theory, Singapore has more IP creators now, the findings from international innovation surveys suggest that Singapore needs to improve the innovation quality. As a result, the MNC-reliant RIE policies were recalibrated by the Economic Strategies Committee (ESC) to focus more on SME innovation outputs. This change implied that more local industries and public IP producers were better resourced to promote indigenous innovation capabilities, designing more homegrown products or services for the Asian region, hence meeting Singapore's goal of becoming Asia's innovation capital.

### 6.6.1 Increasing regard for IPTC

*IPTC expertise should be regarded as a competitive human resource.*

Besides investing heavily in RIE inputs, Singapore installed the 10-year IP Hub Master Plan (Government of Singapore and IPOS 2017) to improve Singapore's innovation outcomes through effective IPTC, including policy ingredients to increase IP expertise, improve the IP regime and create an IP savvy marketplace.

Problem-solving in IPTC requires cross-disciplinary competencies. For example, for an SME manager to negotiate an IP contract with a polytechnic IPTC manager, both parties must view each others' areas of expertise from one another's perspective, involving the intersection of knowledge between technology and business.

To boost the IP Hub Master Plan, IPOS implemented the comprehensive IP Competency Framework (Intellectual Property Office of Singapore 2019) to define various IP professional roles and their corresponding competencies required by the IP industry. The implications of this one-year-old IP Competency Framework promises to have a significant bearing on the demand for qualified IPTC experts from SMEs and polytechnics. A capability framework could supply a range of skilled professionals trained for various jobs at various levels, such as operations, executive, specialist and strategist, to provide cross-disciplinary advisories in areas such as IP legal (litigation), IP drafting and prosecution (protection and enforcement), IP technology (IPTC), IP intelligence and strategies (FTO), and IP valuation and finance (finance and insurance) to address the high level of variability in IP awareness identified by this research.

Singapore's goal to foster innovation outputs through design and commercialisation of ideas that were not invented in Singapore indicates that new knowledge is needed to inform the commercialisation of design IP enabled with contemporary technologies. *To stay relevant, IPOS should review and refine the existing IP competency framework to attain training capacity and procedural agility, if needed.*

### 6.6.2 A robust IP regime

*A stronger IP regime could be a competitive structural resource.*

Having a robust IP regime will insulate local SMEs from local and foreign competition, providing local SMEs with incentives to innovate. However, while this is true, IPTC partners must have access to a pool of qualified IP professionals who can ensure that IP is professionally prepared, registered, examined, and enforced. The effectiveness of a country's IP regime is therefore directly linked to the availability of relevant IPTC human resources.

The costs to engage these relevant services is prohibitive for some SMEs; especially if a patent is involved. This research has demonstrated that patenting appears to be a common strategy by which large corporations seek to protect their intellectual property, and that dealing appropriately with patented IP is a specialist activity and expensive. The participants in this research indicated that they wanted to use both patent and non-patent IP as a strategy to advance their products into the marketplace.

Singapore's market is small. Hence, the RIE policy encourages SMEs to think beyond Singapore to overcome the small home market constraint. To extend to regional markets, IPTC partners are expected to seek regional IP protection and enforcement with proper due-diligence.

This will inevitably increase the total IP costs, which ironically can be recovered through going regional or beyond.

It is, therefore, a chicken-and-egg problem. The ensuing implications of the need for regional perspectives in IPTC partnership products, embodied with patents are twofold. First, SMEs must have adequate cash flow, with or without public funding; and second, the IP regimes of the intended markets must be strong.

Since IP issues are complex and jurisdiction-specific, *the government could consider setting up a regional IPTC intermediary centre comprising IPTC experts that SMEs can consult for balanced advice to facilitate bilateral innovation flow within a region.* A balanced view of the pros and cons of investing in regional IP is prerequisite for IPTC success. This intermediary should be capable of providing a balanced advisory on FTO (infringement risks), ownership and transferability (IP ownership), and validity and enforceability (claims of IP rights).

### 6.6.3 Simplification of public funding schemes

*Public funding schemes must be simplified, with realistic KPIs and supported by quality assessors.*

When asked in the interviews, SME managers valued polytechnics' proactive sharing of information on accessible public funding that defrays the IP licensing costs and expected polytechnics' active participation in seeking funding to develop the IPTC projects further. The interviewees also perceived that access to public funding was complicated, time-consuming and KPI laden. Such findings could explain why SMEs were slow in securing various government grants to boost their innovation inputs (Wong, Ho & Singh 2006). Further reasons why SMEs were sluggish in seeking public funding could be linked to a newspaper article of Arnold (1999) arguing that the public fund's mediocre performance could be attributed to a top-down public funding policy that was contrived and lacking in quality assessors. Such frustrations also surfaced in the interview data.

However, according on Mahbubani (1999), a professor in the Practice of Public Policy and Dean of the Lee Kuan Yew School of Public Policy at the National University of Singapore, local agencies are agile learners, and RIE policies can be pivoted to match environmental conditions. Arnold's report supported Mahbubani's argument and notes that the public agencies have started to engage savvy venture capitalists to co-assess and co-invest in high-tech start-ups after acknowledging the agencies' underlying knowledge gap.

It is unclear at this stage what kinds of product offerings will propel Singapore closer to achieving its goal of being Asia's innovation capital – high-tech solutions or contemporary-technology ones. *Hence, public funders should consider scaffolding the existing IPTC funding to support the entire spectrum of IP types (patents and non-patent IPs) for scientific discoveries, technological solutions and business models.* This diversification confirms that IPTC is not only applicable to research universities but also to polytechnics. Unlike universities, polytechnics apply contemporary technologies to develop solutions to solve societal or industry problems

### 6.6.4 Summary of strategic implications (Table 6.3)

**Table 6.3 Strategic implications of the findings**

| Findings | Strategic implications | What should be done? | Ideas for improving Singapore's competitive position |
|---|---|---|---|
| High IP awareness variability was identified in this research. | IPOS's capability to level-up the nation IPTC expertise based on the newly established IP Competency Framework has fulfilled the demand for various qualified IPTC experts. | Diversify and develop the country's pools of competent IPTC professionals in IP legal, IP drafting and prosecution, IP technology, IP intelligence and strategies, and IP valuation and financial to narrow the cross-disciplinary competency gaps between business and technological domains | To stay relevant, IPOS should review and refine the existing IP competency framework to attain training agility of meeting Singapore's goal of becoming Asia's innovation capital that has a slant towards design-centric innovations, if needed. |
| Strong IP regime as a competitive structural resource for the local market. | IPOS's capability to install a robust national IP regime will insulate local SMEs from local and foreign competitions within Singapore jurisdiction, but not in the Asia region. IP protection is jurisdiction-specific, a patent filed in Singapore must be registered in those countries where the patented product will be marketed or made. | Develop a stronger regional IPTC alliance to ease transnational IPTC protection and enforcement to overcome the small home market constraint while strengthening the local IP regime. | The government could consider setting up a regional IPTC intermediary centre comprising IPTC experts that SMEs can tap on for a piece of balanced advice to facilitate bilateral innovation flow within the region. |
| The take-up rate of public funding scheme seemed slow. | Agencies' capability to offer IPTC funding supported by qualified assessors will help change public misperception. | Simplify public funding with realistic KPI and support the evaluation with qualified assessors. | Public funders should consider scaffolding the existing IPTC funding to support the entire spectrum of IP types (patents and non-patent IPs) for scientific discoveries, technological solutions and business models. |

## 6.7 Theory development implications

This section analyses the theoretical implications of the findings and discusses the theory-development contribution of the new knowledge provided by this research, and how it adds value to existing IPTC theories.

This case study began with documentary research into the innovation characteristics of IPTC stakeholders in Singapore, followed by a thematic analysis of SME managers' interview data. Data related to the management of IPTC processes were analysed and overarching themes were identified.

Both SMEs and polytechnics, with different organisational goals – financial gain versus education – were not constrained in making choices of whom to partner in IPTC. The IPTC experience hinged on the decision of who to partner and the way strategic resources and human capabilities were managed.

Secondary research showed that there was a good mix of firms collaborating with the polytechnic sector. These firms ranged from established ones (Eu Yan Sang) to start-ups (Nanoveu Pte Ltd). Products commercialised included products (mobility aids), processes (purple gold making), foods (sausage recipes) and software (machine control). This finding corresponded with the 13 case interviews completed during this research. Participants in the research came from established technology companies, established retailers and start-ups, and the products commercialised involved design and technology in hardware, software and process. Out of the 13 case interviews, some IPTC characteristics observed were:

- IP licensed, patented or non-patented, was mainly used for technology-aggregation, that is, the adding of new technologies (C & D) to existing technologies (A & B) to result in a product embedding all the existing and new technologies (ABCD).
- Term-sheets were used to ease the understanding of complex legal licensing contracts (LA).
- Besides LA, non-disclosure agreements (NDAs), research collaboration agreements (RCAs), or material transfer agreements (MTAs) were sometimes used as structural resources to manage IPTC partnership.
- The majority of SMEs were without internal R&D capability. Hence, they were seeking mutual dependence relationships with polytechnics to co-innovate the IP licensed.
- IPTC relationships became problematic or frustrating when there was incomplete IP due diligence, incomplete IPTC resources, conflicting organisational goals, and limited access to IPTC resources or human capabilities.
- Above all, most SMEs encountered challenges in scaling up activities.

Table 6.4 summarises examples of resources and human capability exchanged versus the themes identified in Chapter 5.

**Table 6.4 Example of strategic value adding resources as the means for IPTC partners**

| IPTC processes | Key themes | Structural resources | Tacit resources | Human capabilities |
|---|---|---|---|---|
| Marketing | Pragmatic IP marketing resources | Translational IP (polytechnic)*<br><br>Product/Market IP/Business Model<br><br>Proactive and effective communication process | Uncodified design and technology enabling knowledge<br><br>Confidential business and customer's insights<br><br>All related knowhow | Personalised and trusting communication<br><br>Market research capability<br><br>Cross-disciplinary marketing capabilities |
| | Dynamic IP co-innovation model | Stakeholders contact database<br><br>IPTC contract term-sheet (NDA, MTA, RCA, LA)# | | Interdependent or independent partnership<br><br>CI capability^ |
| Negotiation & deal Finalising | Appropriability regime | Translational IP*<br>Product/Market IP/Business Model<br>Reputational IP (co-branding)<br><br>Physical prototyping infrastructure | | Efficient licensing process<br><br>Equal IP due diligence capabilities<br><br>CI capability^ |
| | Inability to reach a valuation agreement | Affordable and quality translational IP<br><br>Business-friendly valuation methods<br><br>IPTC contracts (NDA, MTA, RCA, LA)# | | Business savvy IP creator & TTO managers<br><br>Technology savvy SME managers |
| Post-IPTC IP deployment | Scaling up challenges against post-IPTC success | Process IP for product making<br><br>Business-friendly stakeholders contact database | Uncodified production knowledge & knowhow | Business-friendly scaling up capability |
| | Co-innovation Transformational services | Production ready prototypes<br><br>Physical prototyping infrastructure | | Interdependent partnership<br><br>CI capability^ |

*Translational IP: Patents or non-patent IP offered by polytechnics
#NDA: non-disclosure agreement, LA: licensing agreement, RCA: research collaboration agreement, MTA: material transfer agreement
^CI: co-branding, co-innovation activities including prototyping, user-testing, networking capabilities.

### 6.7.1 Resource-based view (RBV)

According to Barney (1991), competitive advantage emanates from strategic resources that are beneficial for users, in limited supply, and difficult to copy or replace – the resource-based view (RBV) framework.

The resource-based view is a competition strategy focusing more on the resources inside a firm, and what competitive advantages they confer. Not all SMEs have the required strategic DTBC resources, many of which are linked to human capability, tacit knowledge and knowhow that need substantial financial input to develop over a long period. Firms with inadequate strategic resources can seek innovative ideas for commercialisation from their environment to attain competitive advantage (Somsuk 2010).

SME participants in this research had stopped looking inward for strategic resources but innovated by looking externally for strategic resources in today's open innovation environment. They made IPTC partnership decisions related to resources largely based on their vast working experience or deep market insights.

### 6.7.2 Resource dependency theory (RDT)

Resource dependency theory (RDT) is evident in this aspect of the study findings since RDT is associated with the need for organisations to acquire outside resources for innovation and commercial activity, with all the associated benefits and threats inter-organisational relationships entail. RDT focuses on inter-organisational relationship exchanges (Pfeffer & Salancik 1978), concentrating on how sourcing resources can lead to advantageous transactions, but equally disadvantageous dependences on other organisations.

According to RDT, relationships can be categorised into independent, dependent or interdependent. Interdependence occurs when there is ambiguity regarding control over IPTC partners' resources and capabilities for survival and competitive advantage.

Based on insights provided by the resource dependency theory and data from this current research, the management of a SME will search for IPTC partners who can provide the resources they need for their business going forward. The SME attempts to achieve freedom and certainty by developing a new product or service through external exchanges, usually obtaining and managing:

- an in-licensing agreement (structural resource) with either single or multiple IP producers (universities), IP translators (polytechnics) or a prior IP owner (private firms)
- an outsourcing contract (structural resource) with single or multiple product producers (contract manufacturers).

With appropriate contract arrangements, a SME can achieve freedom-to-develop a new product or service by leveraging the IP environment accessible to it, especially with polytechnic IP translators, when they are available.

On the other hand, a polytechnic that is not a product producer may understand that it has a gap in business knowledge and customer insight. An IPTC project will be problematic without validated business and market insights (Invention City Inc 2021a). Through certain forms of contract-based alliances (NDA: non-disclosure agreement, LA: licensing agreement, RCA: research collaboration agreement, MTA: material transfer agreement) or standard operating procedures, a SME can provide this business knowledge and customer insight, and a SME manager can negotiate a deal that gives both parties a certain degree of autonomy and control over exchanged resources.

Under a typical contract-based alliance, a SME manager takes a polytechnic's IP through a licensing agreement, whereby the IP rights are exchanged with royalty payments. Through the licensing contract, a polytechnic is commonly isolated from legal risks associated with IP commercialisation by indemnification and non-warranty clauses.

Once IP is transferred to a SME, the SME, especially a research-intensive one, is expected to be resource independent from the polytechnic and manage alternative suppliers of resources in order to scale up activities – a 'naked' IP licensing approach. In this straightforward relationship, SMEs can seek resource independence from polytechnics by developing the licensed IP using in-house R&D capability or outsourcing it to an external IPTC partner. The external IPTC partnership can include another polytechnic or other private IP translators.

Research-intensive and well-resourced SMEs have the choice of IPTC relationship, independent or otherwise.

From the polytechnic's perspective, this 'naked' licensing approach is the most desirable outcome, as neither party is constrained, and both parties' goals can be realised independently. Using this approach, polytechnics can fulfil the KPIs imposed by funding agencies on the number of licensing deals without being involved in any post-licensing activity, while SMEs enjoy the autonomy to translate the licensed IP with the choice of IPTC partners.

### 6.7.3 The resource-based view vs resource dependency theory

The resource-based view (RBV) focusses on a firm strategically exploiting *its own* resources, while resource dependence theory (RDT) considers the procurement of *external resources* for strategic reasons. Of the two outlooks, RBV is more suited for explaining the IPTC phenomenon where there is a 'naked' licensing arrangement involving research-intensive or well-resourced SMEs.

Research participants in this study discussed the types of strategic resources exchanged during the operation of their businesses. These SMEs were resource dependent. The resources they sought could be categorised into design (D), technology (T), business (B), and customer (C) types. Combined resources, knowledge, knowhow and human capabilities are, therefore, labelled DTBC resources. Table 6.5 lists examples of DTBC resources exchanged between polytechnics and SMEs.

**Table 6.5 Examples of design (D), technology (T), business (B), and customer (C) resources**

| Label | Descriptor | Structural resources, knowledge and knowhow | Human capabilities |
|---|---|---|---|
| D | Design | Prototype drawings, control algorithm | • Co-innovation capability<br>• Technology savvy SME managers<br>• Equal IP due diligence capabilities |
| T | Technology | Enabling prototyping software, system integration knowhow, | |
| B | Business | Business models | Business savvy IP creator and TTO managers |
| C | Customer | Customer insights | • Market research capability<br>• User experience research capability |

RDT recognises that not all SMEs are research-intensive or sufficiently well-resourced to have full control over the exchanged resources and capabilities. Many SMEs will have partial control over the complete range of DTBC resources, but must consider interdependent IPTC partnerships as an option to commercialise their products.

For example, a polytechnic will have full control over the design and technology aspects of the licensed IP, but little or zero knowledge related to businesses and customers – hence, a partial control of DTBC resources. Similarly, a SME will likely have partial control over the complete DTBC resources in reverse fashion. Most SMEs will tend to have dominant control over BC resources.

Consequently, a SME will elect to enter into an interdependent relationship with the polytechnic either using a short-term IP licensing contract or a longer-term joint-venture co-innovation contract to manage the SME's resource dependencies on polytechnics. Several SMEs confirmed the need for polytechnics to provide post-licensing co-innovation supports in the interview.

Table 6.6 shows that the choice of IPTC partnership can be influenced by the level of control of the partners over the complete range of DTBC resources. Cross-disciplinary DTBC resources can be critical to the choice of IPTC partners. Understanding the polytechnic-SME IPTC context adds to the scope of RDT.

Under this enhanced model, the power of an IPTC partner is linked to the level of the complete range of DTBC resources from design to the customers' acceptance of the resulting product. For example, a SME that is fully resourced with DTBC may choose to have an independent relationship with a DTBC-partially or fully resourced polytechnic. A fully DTBC resourced SME is able to seek alternative IPTC partners if their original choice is unable to offer the required resources.

When IPTC partners are both DTBC-partially resourced, they can share an interdependent relationship, but poorly resourced SMEs may be forced into a dependent relationship if the target polytechnic provides the majority of the required DTBC resources and capabilities. When both potential IPTC partners have nothing to offer, each must consider building up their internal resources based on the understanding of RBV concept.

Interdependency supports co-innovation and co-branding efforts, and will ideally bring the two partners together a in rewarding, balanced, long-term relationship in response to their resource inadequacies. The benefits of an interdependent partnership (e.g., JV) include deferred royalty payment for SMEs, an improved opportunity for polytechnics to own shares of a spin-off company, and increased economic and innovation activities for the Singapore RIE ecosystem. *It is advantageous in terms of competition for SMEs to look for a non-competing interdependent partner, polytechnics included, to translate their product IP.* Future research on the viability of long-term interdependent relationships will determine the accuracy of this hypothesis.

**Table 6.6 An enhanced RDT model of how DTBC resources influence the IPTC relationship**

| Resources and capability in design, technology, business and customers (DTBC) | All resources controlled by a SME | Resources partially controlled by a SME | Resources not controlled by a SME |
|---|---|---|---|
| All resources controlled by a polytechnic | Independent | Interdependent | Dependent |
| Resources partially controlled by a polytechnic | Independent | Interdependent | Dependent |
| Resources not controlled by a polytechnic | Seek alternative partnership | Seek alternative partnership | No relationship |

### 6.7.4 Appropriability regime (AR)

Besides RBV, within an organisation, the appropriability regime (AR) is another theory that explains the means used by IPTC partners to strengthen their DTBC resources. The appropriability regime consists of all the mechanisms partners put in place to protect their knowledge and innovations in order to benefit exclusively and not lose the rewards of their IP and development work to imitators.

From the structural resource perspective, it was interesting to note that SMEs and polytechnics in this research selectively protected their incremental technology assets from imitation by coupling multiple legal mechanisms (e.g., patents, registered designs, trade secrets, and copyrights) with immobile tacit process knowledge.

This finding demonstrates the AR in action in the polytechnic-SME IPTC context. Many SMEs would like patents, but raised concerns over the prohibitive costs. In the absence of in-depth IP knowledge, a patent can potentially be used as a powerful tool when both IP owners and potential IP right infringers are equally informed or misinformed. It should be remembered, however, that what constitutes a patent infringement is a question for patent attorneys and the court to deliberate on, and should not fall under the jurisdiction of a SME or TTO manager. If, however, neither the IP owners nor the potential IP rights infringers have much patent knowledge, and have not consulted a patent expert, a costly infringement suit can clear any uncertainty. Meanwhile, the wait-and-see approach gives the SME perceived hope and raises fears for potential infringers.

However, this thesis challenges the general acceptance that a tight IP legal mechanism (e.g., patents) and difficult to replicate tacit knowledge will produce a strong AR (Teece 1986). Using a fee-paying database (Innography), the researcher found that only 3% and 15% of the polytechnic sector patents and university patents were considered strong, respectively. This finding suggests that polytechnics' incremental technologies have a weaker AR than the university's radical ones.

In contrast, the secondary findings of this research also show that many commercially successful innovations were either users or aggregators of contemporary technologies, for example, the Claudio Ballard's digital scanner; and certain business model innovations did not use radical technologies (e.g., Uber taxi service and Airbnb). For Uber and Airbnb, knowledge about their customers was their key competitive advantage, not patents. This phenomenon shows that a product can still be successfully commercialised based on aggregation of contemporary technologies that have relatively weak IP rights.

Tacit knowhow and human capability within the firm, including strategic and/or innovative thinking, along with product placement mean that aggregators can use weakly protected IP to their advantage, while creating more weakly protected IP, but also a dominant business. If

SMEs were to focus on merely radical technologies with strong IP rights to innovate, the majority would miss many profit-making opportunities. In reality, patent strength assessment is complex and subjective; it involves many variables (number of references, number of citations, number of claims and jurisdiction). Although the appropriability regime model is meant to be a broad self-assessment barometer, further investigation is needed to explain the phenomenon where a new product competes using IP that was generated using contemporary technologies or processes that are tested and proven to be reliable.

### 6.7.5 Dynamic capability (DC)

Besides RBV and AR, within an organisation, dynamic capabilities (DC) is another theory that explains the means used by IPTC partners to strengthen their DTBC resources. The theory relates to the ability of a business to adapt to a changing business environment. A quick response to sudden developments and a capacity to reconfigure their resources and strategies are considered essential in a global competitive environment. DC can be seen as a competitive advantage.

From a human capability perspective, although SMEs could rapidly react to emerging threats and unexpected opportunities in their environments, the polytechnics, due to their work culture (hierarchical structure, teaching-first-IPTC-last), had difficulty deploying the required resources to meet the dynamic demand of the IPTC project. Consequently, the SMEs were compelled to outsource to specialised contractors those jobs for which the SMEs had limited capability.

Leih and Teece (2016); (Schoemaker, Heaton & Teece 2018) have argued that firms should outsource their ordinary capabilities, such as efficient manufacturing and effective marketing, to external specialised contractors to sustain their core capabilities. According to the research participants, such contractors include other IP translators, regulatory consultants and product manufacturers.

Some SMEs, however, expected the polytechnics to co-innovate and flexibly manage (deploy, reconfigure and coordinate) the polytechnic's resources, competences and intellectual assets throughout the entire IPTC journey, as if the poly's dynamic capabilities equalled those of the SME.

The co-innovation capability of an agile SME and a bureaucratic polytechnic necessitate further investigation into their operation as an integrated entity.

### 6.7.6 The missing piece

To articulate the need for the polytechnic to extend their IPTC services after the IP license is finalised, the researcher added an additional process to the existing university IPTC model found in the literature. Figure 6.2 shows that the post-licensing IP development as the missing piece appended to the adapted IPTC model.

According to the linearised IPTC model adapted from Bradley, Hayter & Link (2013, p5), licensing activities can be subdivided into intra- and inter-organisational processes related to the promotion and securing of the license.

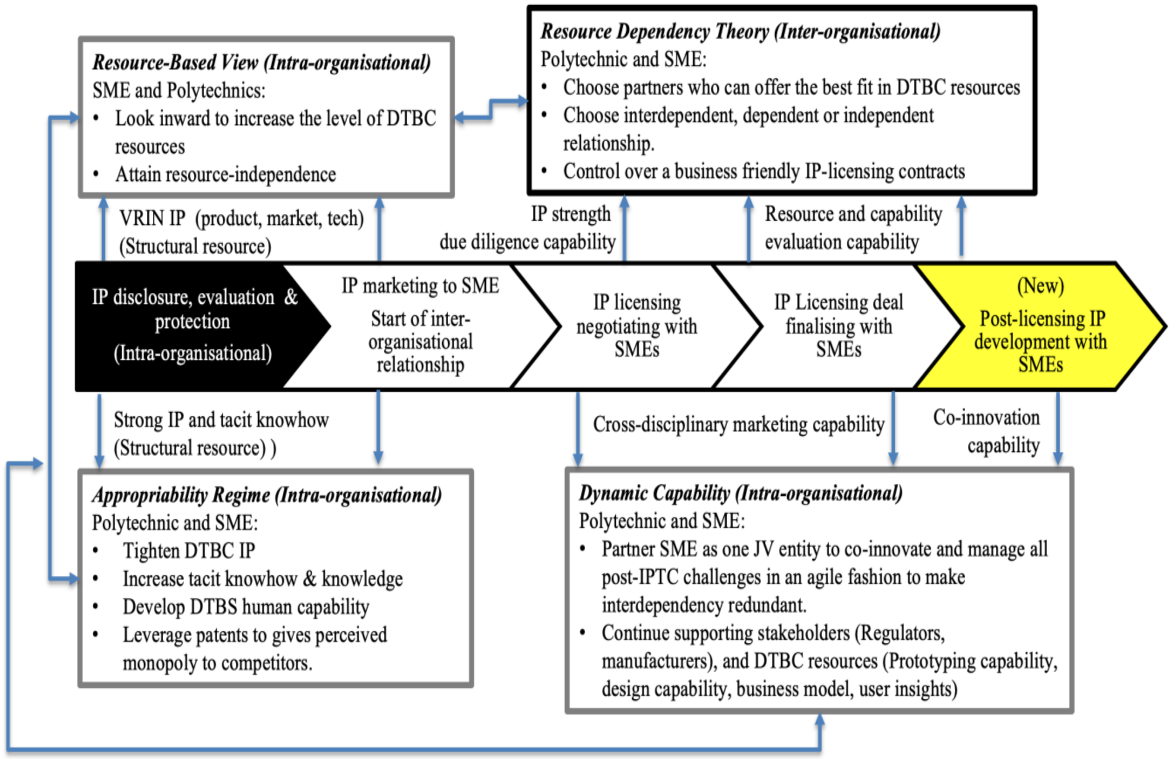



**Figure 6.2 Modified IPTC model. Adapted by the researcher based on a university IPTC model by Bradley, Hayter & Link 2013, p. 5.**

This thesis challenges the general acceptance that IP licensing should ideally adopt an 'out-the-door' IPTC approach – straightforward 'naked' technology licensing. This logic is understandable because polytechnics, like universities, as non-product organisations, would tend to avoid unwanted IP infringement or product liability problems in the future. As argued earlier, only research-intensive or well-resourced SMEs can afford the 'naked' licensing approach. In the SME IPTC environment, many other DTBC-partially resourced SMEs would consider partnering polytechnics as their targeted non-competing IPTC partners.

This research suggests that having polytechnics provide further IP development after a licensing deal is secured is desirable and a missing piece in the IPTC relationship. Adding this piece has the potential to enhance the dynamic capabilities of both the SME and the (bureaucratic) polytechnic.

### 6.7.7 In summary

The outcomes of this research accord with a number of theories about business and business relationships. The theories that support this understanding of this research are:

- RDT, resource dependency theory
- RBV, resource-based view
- DC, dynamic capability
- AR, appropriability regime

Their applicability varies according to the SME's resource-dependency:

- For a research-intensive SMEs who are inward-looking, RBV, DC and AR support the broad explanation of their choice of an independent IPTC partnership.
- For SMEs, research-intensive or not, who must search for their required DTBC resources, RDT is the leading theory that supports the explanation of an inter-organisation IPTC partnership.
- At the organisational level, polytechnics or SMEs will separately manage their means to secure strategic resources internally. This behaviour can be explained broadly by RBV, DC and AR; hence, a two-level strategy to secure and deploy strategic resources by combining inward and outward-looking approaches [(RBV+DC+AR) + RDT].

These theories map graphically into the IPTC processes, as is demonstrated in Figure 6.2. Listed below are some key points:

- RBV explains why some SMEs look inwardly to develop and increase their DTBC resources. Strategic resources developed internally within SMEs or polytechnics can delay competition if they demonstrate strong AR characteristics and execution is supported by DC capability.
- Although RBV explains the behaviour of research-intensive or well-resourced SMEs in opting for an independent IPTC relationship with the IP provider, RBV needs to be integrated with RDT to explain the behaviour of those SMEs that opt for an interdependent relationship. A SME may, theoretically, encompass internal resources, tacit IP or implicit IP that are valuable, rare, inimitable, non-substitutable (VRIN)

without having the full complement of resources to exploit it (like being able to invent the wheel, but not quite appreciating how much an axle would contribute). Using the resource-based view to understand the situation will help IPTC partners to finalise the types of relationships they can form, as explained by RDT.

- RDT appeared from the data analysis to be the dominant theory explaining the behaviour of the SMEs and polytechnics when they sought IPTC. Interdependence, dependence, or independence can be linked to the control that each IPTC partner has over the DTBC resources, reinforcing our understanding of RDT theory.
- Complementing RBV, SMEs and polytechnics avoided competition by strengthening their IP rights using patents and other non-patent IP protection, a behaviour that the AR model can explain. While it is unclear about the licensed IP's strength until it is challenged by a potential infringement, it seems that SMEs perceive that protected IP, especially patented, can lift the SME's AR. Further study is recommended to determine what effect technology-aggregation IP has on the strength of the ARs of IPTC partners.
- Complementing RBV and AR, some SMEs and polytechnics may consider co-innovation after a licensing deal is finalised to mitigate the risk of IPTC failures due to resource interdependency. This dynamic capability achieved through co-innovation will strengthen the market position of the jointly developed innovations and increase IPTC success. Theoretically, DC can indirectly influence the choice of IPTC partnership by increasing the VRIN resources explained in RBV. (Inventing the wheel requires the right materials and the right set of skills distributed among the right set of inventors and carpenters. Inventing the axle requires the same. Interdependent teams can then put them together under a wagon or cart applying their joint dynamic capabilities.)

## 6.8 Originality of contribution

This research found that resources that promote the IPTC take-up rate are cross-disciplinary, connecting the business world to the research world. Polytechnics supply innovative designs, and technologies, while SMEs provide dominant resources in business and customer insight -

DTBC resources. A partnership between a SME and a polytechnic brings innovation in design and technology together with business, market knowledge and customer awareness.

At the strategic decision level, an enhanced RDT model will facilitate an understanding of how a SME could choose an IPTC partnership based on how much control it could exert over the combined DTBC resources.

At the operations level, it is useful to apply the two-level strategy to secure, develop and deploy strategic resources by combining inward and outward-looking organisational approaches. While the resource-based view, dynamic capability and appropriability regime theories consider the intra-organisational aspects of business activity, involving a SME's internal mechanisms for increasing strategic resources, resource dependency theory focusses on the need of a business to acquire resources externally. If the resources are difficult to obtain or control, the SME becomes vulnerable in terms of power, authority and reward.

On the whole, AR focusses on mechanisms through which one's IP can be protected, such as patents. This thesis challenges AR's general acceptance, which leans towards a tight legal mechanism (e.g., patents) to delay imitation. Future business models and incremental innovations should be users of contemporary technologies. Thus, moving forward, more non-patent IP, which is lesser-known for its protection strength than patents, will play a more significant role in IPTC.

This thesis also challenges the general acceptance that polytechnic IPTC should ideally adopt an 'out-the-door' IPTC approach after the license is secured – a straightforward 'naked' technology licensing approach. A new post-licensing process should be added to the existing IPTC model if innovation and success are to be accelerated.

*Both SMEs and polytechnics should consider post-licensing collaboration to reduce risk of IPTC failure by forming an interdependent partnership*. This post-IPTC support concept may not hold for university IPTC where the technologies involved are usually more radical and sophisticated, and where different strategic resources and a more extended timeframe are needed to translate the ideas nearer to the marketplace. Polytechnics possess such strategic resources.

## 6.9 Future research

Further research is recommended in the following areas:

- Taking a patented technology that is widely perceived as more substantial in IP rights protection to the marketplace will not guarantee commercial success. This study has shown that certain business models and incremental innovations that aggregate contemporary technologies that are lesser-known for their IP strength can be successfully commercialised. Therefore, future research needs to focus on investigating and explaining the ways in which a new product competes using aggregation of contemporary technologies.
- A polytechnic, a public training provider, focuses more on teaching and R&D, and may pay less attention to IPTC. On the one hand, SMEs, who are agile, but inadequately resourced, will seek long-term interdependence IPTC partnerships with polytechnics. On the other hand, polytechnics, who are less agile, but better-resourced, may be selective in their choice of IPTC partners. This conflict in the circumstances of two potential partners in an IPTC warrants further investigation to determine what factors (monetary or nonmonetary) influence a polytechnic to consider a long-term interdependent IPTC partnership with a SME.
- Although a polytechnic is competent in IP development, it lacks core and fundamental technologies that universities commonly produce. Hypothetically, polytechnics can complement universities to translate IP for SME acceptance. Therefore, future research into IPTC partnerships between universities and polytechnics could provide insights into the strategic implications of cooperation and possible beneficial outcomes.

# Appendices

# Appendix 1 Human Research Ethics Committee approval

THE UNIVERSITY of ADELAIDE

**RESEARCH BRANCH**
OFFICE OF RESEARCH ETHICS, COMPLIANCE AND INTEGRITY

**SABINE SCHREIBER**
**SECRETARY**
**HUMAN RESEARCH ETHICS COMMITTEE**
THE UNIVERSITY OF ADELAIDE
SA 5005
AUSTRALIA

TELEPHONE +61 8 8313 6028
FACSIMILE +61 8 8313 7325
email: sabine.schreiber@adelaide.edu.au
CRICOS Provider Number 00123M

22 November 2012

Dr A O'Connor
Entrepreneurship, Commercialisation and Innovation Centre

Dear Dr O'Connor

**PROJECT NO: H-2012-141**
***An exploratory study of Polytechnic - Small-Medium-Enterprises (SMEs) Technology Transfer (TT) processes***

I write to advise you that on behalf of the Human Research Ethics Committee I have approved the above project. Please refer to the enclosed endorsement sheet for further details and conditions that may be applicable to this approval. Ethics approval is granted for a period of three years subject to satisfactory annual progress reporting. Ethics approval may be extended subject to submission of a satisfactory ethics renewal report prior to expiry.

**The ethics expiry date for this project is: 31 October 2015**

Where possible, participants taking part in the study should be given a copy of the Information Sheet and the signed Consent Form to retain.

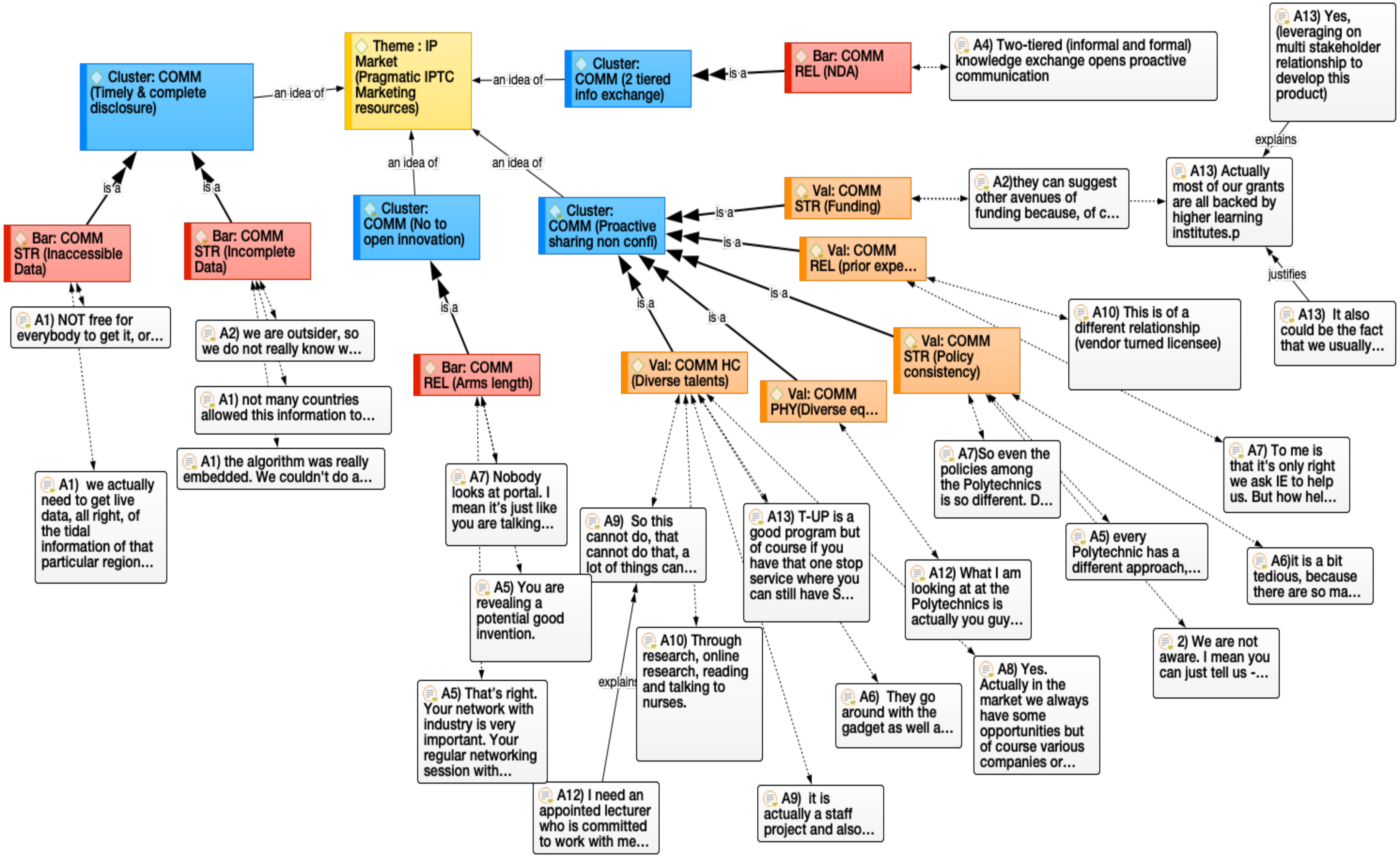
Please note that any changes to the project which might affect its continued ethical acceptability will invalidate the project's approval. In such cases an amended protocol must be submitted to the Committee for further approval. It is a condition of approval that you immediately report anything which might warrant review of ethical approval including (a) serious or unexpected adverse effects on participants (b) proposed changes in the protocol; and (c) unforeseen events that might affect continued ethical acceptability of the project. It is also a condition of approval that you inform the Committee, giving reasons, if the project is discontinued before the expected date of completion.

A reporting form for the annual progress report, project completion and ethics renewal report is available from the website at http://www.adelaide.edu.au/ethics/human/guidelines/reporting/

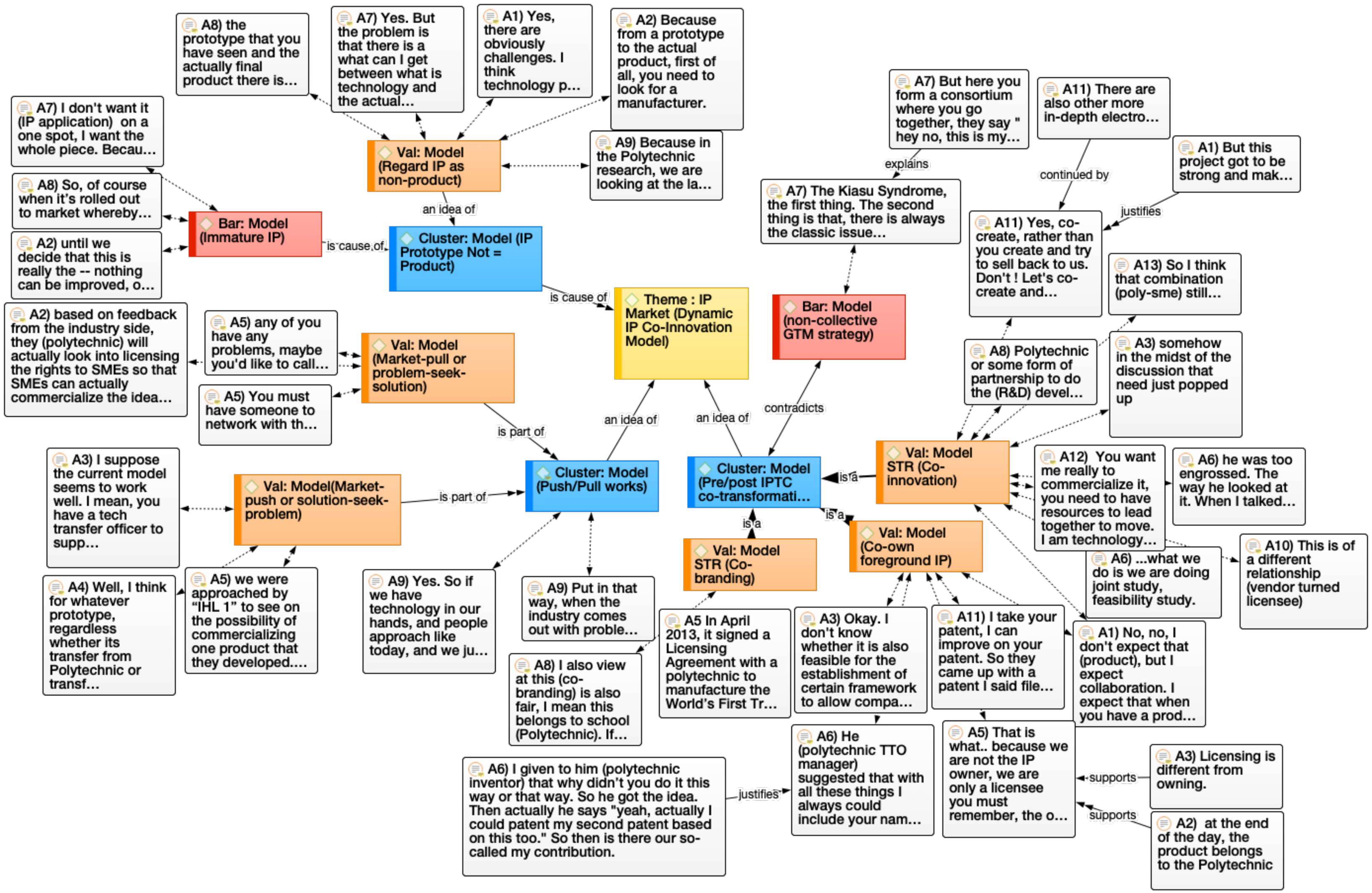
Yours sincerely

**Dr John Semmler**
**Acting Convenor**
**Human Research Ethics Committee**

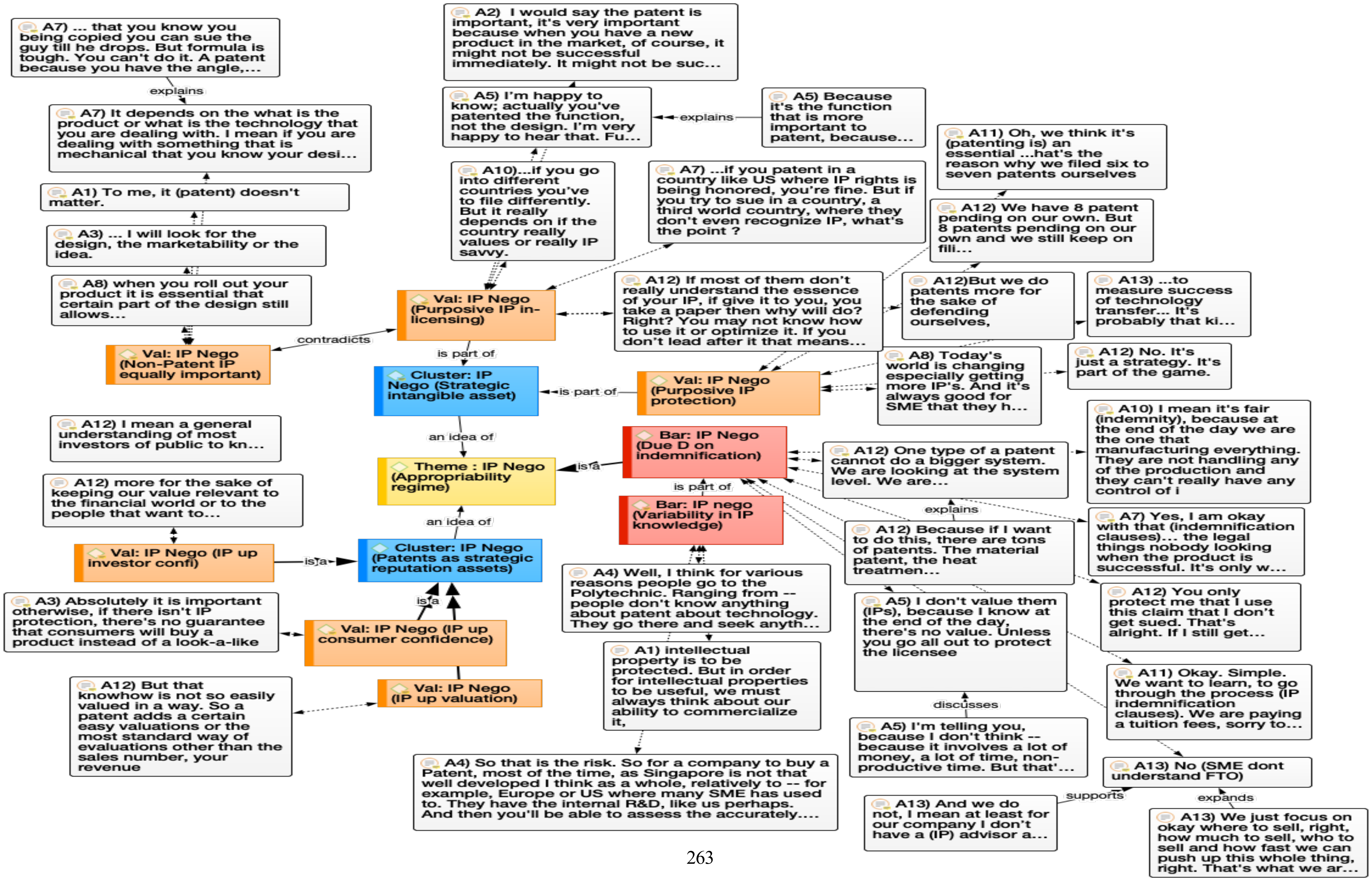
## Appendix 2 TA map on IPTC marketing communication resources



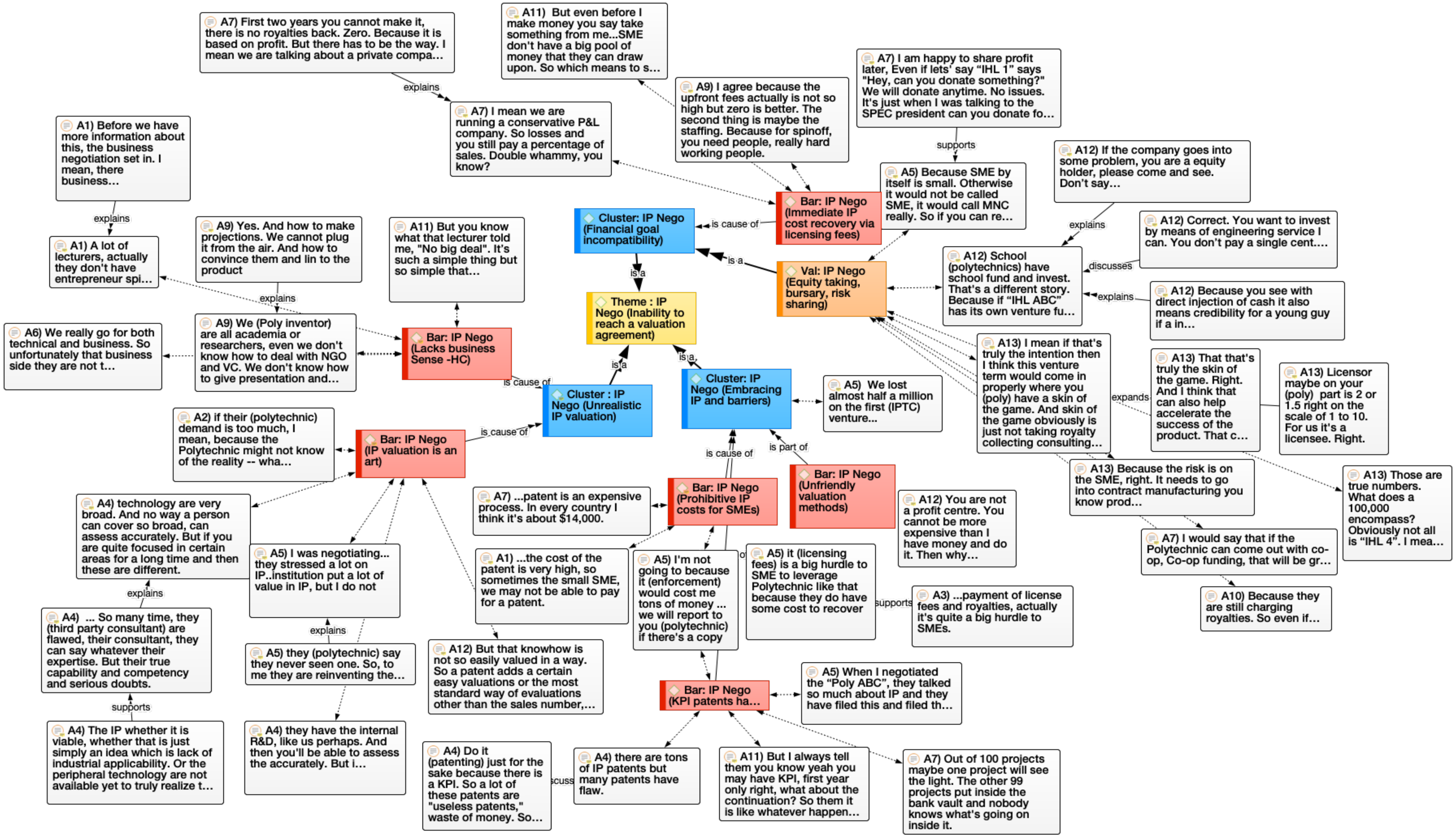
# Appendix 3 TA map on IPTC marketing innovation model



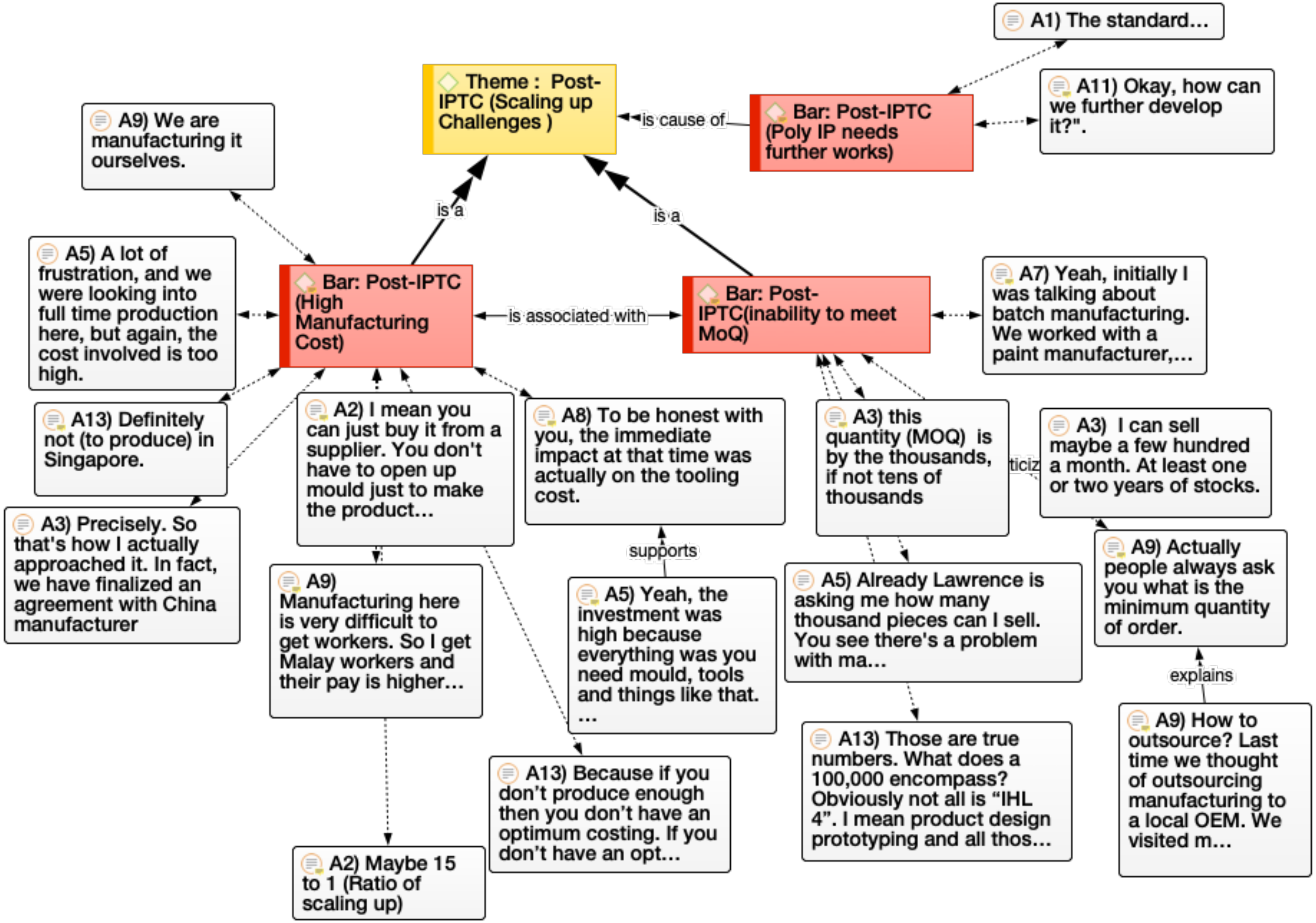
## Appendix 4 TA map on negotiating resources for appropriability regime



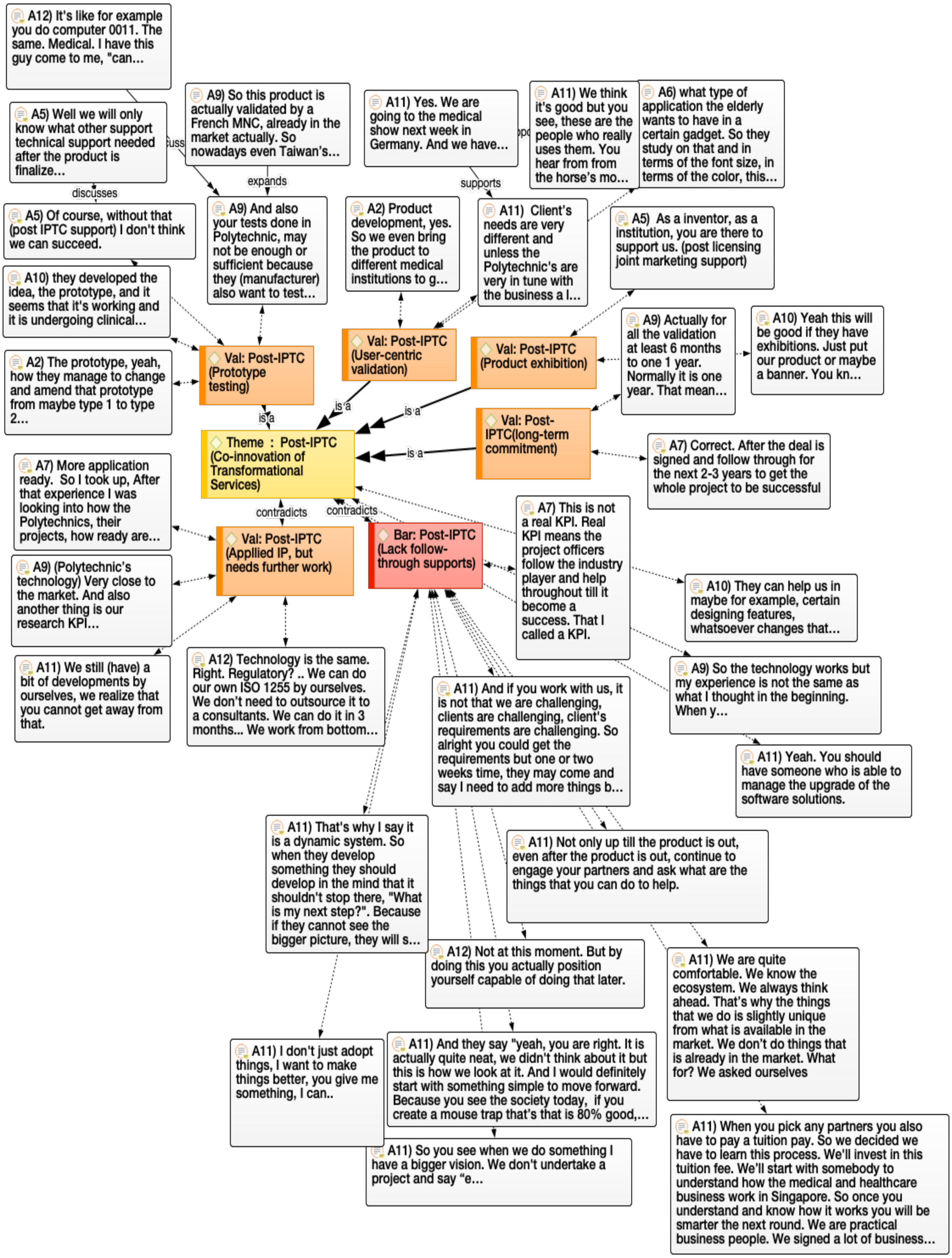
## Appendix 5 TA map on negotiation resources to reach valuation agreement



## Appendix 6 TA map on post-IPTC resources for scaling up challenges



# Appendix 7 TA map on post-IPTC co-innovation supports



## References


A*STAR 2015, *Science, Technology & Enterprise Plan 2015* A*Star, Singapore, viewed 15 Jan 2015, <http://www.a-star.edu.sg/Portals/0/media/otherpubs/STEP2015_1Jun.pdf>.

Abramson, HN, Encarnacao, J & Reid, PP 1997, *Technology transfer systems in the United States and Germany: Lessons and perspectives*, National Academies Press, ProQuest Ebook Central, viewed 18 October 2017.

Abreu, M, Grinevich, V, Hughes, A & Kitson, M 2009, *Knowledge exchange between academics and the business, public and third sectors*, University of Cambridge, Imperial College, London.

Accounting and Corporate Regulatory Authority 2018, *Business filing portal of ACRA*, 30 Dec 2018, <https://www.bizfile.gov.sg/ngbbizfileinternet/faces/oracle/webcenter/portalapp/pages/BizfileHomepage.jspx#%40%3F_adf.ctrl-state%3Dij4hkptqw_128>.

Agrawal, A & Henderson, R 2002, 'Putting patents in context: Exploring knowledge transfer from MIT', *Management Science*, vol. 48, no. 1, pp. 44-60.

Ahn, MJ & York, A 2010, 'A resource-based view of innovation, technology transfer and commercialization', in *The Proceedings of the Conference of the United States Association for Small Business and Entrepreneurship,* United States Association for Small Business and Entrepreneurship, USA, p. 1106.

Akio, T 2005, 'The critical assessment of the resource-based view of strategic management', *Ritsumeikan International Affairs*, vol. 3, pp. 125-150.

Aldrich, HE & Pfeffer, J 1976, 'Environments of organizations', *Annual Review of Sociology*, vol. 2, no. 1, pp. 79-105.

Allen, J 2014, 'Does university patent licensing pay off?', *IPWatchdog Inc.*, viewed 11 April 2017, <http://www.ipwatchdog.com/2014/01/27/does-university-patent-licensing-pay-off/id=47655/>.

Andes, S 2016, *Technology transfer 2.0: Finding economic value in university R&D*, viewed 6 September 2017 <https://www.brookings.edu/blog/metropolitan-revolution/2016/06/07/technology-transfer-2-0-finding-economic-value-in-university-rd/>.

Ang, MHJ 2006, *Curriculum vitae of Marcelo H. Jr. Ang*, Department of Mechanical Engineering, National University of Singapore, viewed 21 Oct 2018, <http://guppy.mpe.nus.edu.sg/~mpeangh/cv.pdf>.

Ansoff, H 1957, 'Strategies for diversification', *Harvard Business Review*, September-October, pp. 113-125.

Antikainen, MJ & Vaataja, HK 2010, 'Rewarding in open innovation communities–How to motivate members', *International Journal of Entrepreneurship and Innovation Management*, vol. 11, no. 4, pp. 440-456.

Argote, L & Ingram, P 2000, 'Knowledge transfer: A basis for competitive advantage in firms', *Organizational Behavior and Human Decision Processes*, vol. 82, no. 1, pp. 150-169.

Arnold, W 1999, 'Where the start-up dance is still hard to do', *New York Times*, vol. 149, 19 September 1999, viewed 15 Jan 2015, (electronic Dow Jones Factiva's global news).

Aronson, J 1995, 'A pragmatic view of thematic analysis', *The Qualitative Report*, vol. 2, no. 1, pp. 1-3.

Arya, B & Lin, Z 2007, 'Understanding collaboration outcomes from an extended resource-based view perspective: The roles of organizational characteristics, partner attributes, and network structures', *Journal of Management*, vol. 33, no. 5, pp. 697-723.

AUTM 2014, *What is technology transfer?*, viewed 10 July 2014, <http://www.autm.net/autm-info/about-tech-transfer/about-technology-transfer/>.

AUTM 2015, *Highlights of AUTM's U.S. Licensing Activity Survey FY2014*, viewed 10 Dec 2016, <http://www.autmvisitors.net/sites/default/files/documents/FY2014%20Highlights.pdf>.

Barney, JB 1986, 'Strategic factor markets: Expectations, luck, and business strategy', *Management Science*, vol. 32, no. 10, pp. 1231-1241.

Barney, JB 1991, 'Firm resources and sustained competitive advantage', *Journal of Management*, vol. 17, no. 1, pp. 99-120.

Battistella, C & Nonino, F 2012, 'What drives collective innovation? Exploring the system of drivers for motivations in open innovation, Web-based platforms', *Information Research*, vol. 17, no. 1, pp. 17-11.

Bauer, SM & Flagg, JL 2010, 'Technology transfer and technology transfer intermediaries', *Assistive Technology Outcomes and Benefits*, vol. 6, no. 1, pp. 129-150.

Baxter, P & Jack, S 2008, 'Qualitative case study methodology: Study design and implementation for novice researchers', *The Qualitative Report*, vol. 13, no. 4, pp. 544-559.

Bekkers, R & Freitas, IMB 2008, 'Analysing knowledge transfer channels between universities and industry: To what degree do sectors also matter?', *RESEARCH POLICY*, vol. 37, no. 10, pp. 1837-1853.

Bernard, HR 2006, *Research methods in anthropology: Qualitative and quantitative approaches* 4th edn, AltaMira Press, USA.

Bettis, RA & Hitt, MA 1995, 'The new competitive landscape', *Strategic Management Journal*, vol. 16, no. S1, pp. 7-19.

Bhargava, R 2013, 'A structured approach to innovation through 'La Salle Matrix Thinking' ', *International Journal of Business Management & Research (IJBMR),* vol. 3, pp. 19-32

Birger, F, Lee, SK & Goh, CB 2008, *Toward a better future: Education and training for economic development in Singapore since 1965*, World Bank Publications, Washington DC.

Bjerke, B 1998, 'Entrepreneurship and SMEs in the Singaporean context', in *Competitiveness of the Singapore economy: A strategic perspective*, vol. 1998, Singapore University Press, Singapore, pp. 249-293.

Bozeman, B, Rimes, H & Youtie, J 2014, 'The evolving state-of-the-art in technology transfer research: Revisiting the contingent effectiveness model', *RESEARCH POLICY*, vol. 44, pp. 34-49.

Bradley, SR, Hayter, CS & Link, A 2013, 'Models and methods of university technology transfer', *Foundations and Trends in Entrepreneurship*, vol. 9, no. 6, pp. 1-73.

Braun, V & Clarke, V 2006, 'Using thematic analysis in psychology', *Qualitative Research in Psychology*, vol. 3, no. 2, pp. 77-101.

Braun, V & Clarke, V 2012, 'Thematic analysis', in HE Cooper, PM Camic, DL Long, A Panter, DE Rindskopf & KJ Sher (eds), *APA handbook of research methods in psychology, Vol 2: Research designs*, American Psychological Association, pp. 57-71.

Braun, V & Clarke, V 2013, *Successful qualitative research: A practical guide for beginners*, Sage.

Braun, V & Clarke, V 2014, 'Thematic analysis', in AC Michalos (ed.), *Ecyclopaedia of quality of life and well-being research*, vol. 24, Springer Dordrecht, Netherlands, pp. 6626-6628.

Braun, V & Clarke, V 2019, 'Reflecting on reflexive thematic analysis', *Qualitative Research in Sport, Exercise and Health*, vol. 11, no. 4, pp. 589-597.

Bray, MJ & Lee, JN 2000, 'University revenues from technology transfer: Licensing fees vs. equity positions', *Journal of Business Venturing*, vol. 15, no. 5, pp. 385-392.

Brown, T & Wyatt, J 2015, 'Design thinking for social innovation', *Annual Review of Policy Design*, vol. 3, no. 1, pp. 1-10.

Business Wire 2017, 'Unilever foundry launches in Ireland in partnership with Dogpatch Labs', *Business Wire*, 13 July 2017, viewed 01 Dec 2017, (electronic Dow Jones Factiva's global news).

C2 Creative Communications 2019, *Thank you for supporting IP Week @ SG 2019!*, viewed 15 Sep 2019 <https://www.ipweek2019.sg/partners.html>.

Campbell, AF 2005, 'The evolving concept of value add in university commercialisation', *Journal of Commercial Biotechnology*, vol. 11, no. 4, pp. 337-345.

Cannon, S & Summers, LH 2014, 'How Uber and the sharing economy can win over regulators', *Harvard Business Review*, vol. 13, no. 10, pp. 24-28.

Cardoso, M, Carvalho, JV & Ramos, I 2009, 'Open innovation communities… or should it be "Networks"', in *Web 2.0*, Springer, pp. 1-22.

Casciaro, T & Piskorski, MJ 2005, 'Power imbalance, mutual dependence, and constraint absorption: A closer look at resource dependence theory', *Administrative Science Quarterly*, vol. 50, no. 2, pp. 167-199.

Cassell, C, Symon, G, Buehring, A & Johnson, P 2006, 'The role and status of qualitative methods in management research: an empirical account', *Management Decision*, vol. 44, no. 2, pp. 290-303.

Chan, LM 2008, 'Polytechnic education', in *Toward a better future: Education and training for economic development in Singapore since 1965*, The World Bank and National Institute of Education, USA, pp. 135-148.

Chandy, RK & Tellis, GJ 2000, 'The incumbent's curse? Incumbency, size, and radical product innovation', *Journal of Marketing*, vol. 64, no. 3, pp. 1-17.

Charmaz, K 2006, *Constructing grounded theory*, Sage Publications, London.

Chen, J, Zhu, Z & Xie, HY 2004, 'Measuring intellectual capital: A new model and empirical study', *Journal of Intellectual Capital*, vol. 5, no. 1, pp. 195-212.

Chesbrough, H 2008, 'Orchestrating appropriability: towards an endogenous view of capturing value from innovation investments', in S Shane (ed.), *The handbook of technology and innovation management*, John Wiley & Sons, pp. 335-364.

Chesbrough, HW 2003, 'The era of open innovation', *MITSloan Management Review*, vol. 44, no. 3, pp. 34-41.

Chew, C 2009, 'From lab to life', *The Straits Times*, 17 October 2009, viewed 15 June 2013, (electronic Dow Jones Factiva's global news).

Chew, C 2018, '24 brands for good recipients recognised for making a positive social impact', *ACROFAN or PRNewswire*, 30 July 2018, viewed 1 Aug 2018, (electronic Dow Jones Factiva's global news).

Chew, R 2010, 'Developments of SMEs in Singapore's services and wholesale and retail sectors: Issues and prospects', *International Journal of Business and Globalisation*, vol. 4, no. 3, pp. 279-298.

Chia, Y-M 2014, 'Reinventing the wheelchair', *Straits Times*, 10 February 2014, viewed 30 Mar 2016, (electronic Dow Jones Factiva's global news).

Choudhury, AR 2017, 'Singtel partners polytechnics to help heritage SMEs', *The Business Times*, 31 May 2017, viewed 01 Dec 2017, (electronic Dow Jones Factiva's global news).

Chua, ST 2002, ‘How MNCs helped start-up SMEs’, in *Heart Work,* Singapore Economic Development Board (EDB) and EDB Society Singapore, pp. 54-59.

Chung, S 2002, ‘Building a national innovation system through regional innovation systems’, *Technovation*, vol. 22, no. 8, pp. 485-491.

Cohen, WM & Levinthal, DA 1990, ‘Absorptive capacity: A new perspective on learning and innovation’, *Administrative Science Quarterly*, pp. 128-152.

Collier, A, Gray, BJ & Ahn, MJ 2011, ‘Enablers and barriers to university and high technology SME partnerships’, *Small Enterprise Research*, vol. 18, no. 1, pp. 2-18.

Collis, DJ & Montgomery, CA 1995, ‘Competing on resources: Strategy in the 1990s’, *Harvard Business Review*, vol. 73 (July-August), pp. 118-128.

Cornell University, INSEAD & WIPO 2019, The Global Innovation Index 2019: Creating Healthy Lives—The Future of Medical Innovation, 12th edn, Ithaca, Fontainebleau, and Geneva, viewed 1 Mar 2021, <https://www.wipo.int/edocs/pubdocs/en/wipo_pub_gii_2019.pdf>

Cousins, S, Gerkey, B, Conley, K & Garage, W 2010, ‘Sharing software with ROS’, *IEEE Robotics & Automation Magazine*, vol. 17, pp. 12-14.

Creswell, JW 2007, *Qualitative inquiry and research design: Choosing among five approaches*, 2nd edn, Sage Publications.

Cripps, D, Anderson, D, Spiller, ML, Coghlan, J & Yencken, J 1999, *University research: Technology transfer and commercialisation practices*, Australian Research Council.

Cunningham, JA, Menter, M & Young, C 2017, ‘A review of qualitative case methods trends and themes used in technology transfer research’, *The Journal of Technology Transfer*, vol. 42, no. 4, pp. 923-956.

D’Este, P & Patel, P 2007, ‘University–industry linkages in the UK: What are the factors underlying the variety of interactions with industry?’, *RESEARCH POLICY*, vol. 36, no. 9, pp. 1295-1313.

Damanpour, F 2017, ‘Organizational innovation’, in *Oxford research encyclopedia, business and management*, Oxford University Press, USA, p. 47.

Danube Universities 2013, *Budapest University of Technology and Economics*, viewed 6 September 2017, <http://danubeuniversities.eu/universities/budapest-university-of-technology-and-economics/>.

Davenport, TH & Prusak, L 1998, *Working knowledge: How organizations manage what they know*, Harvard Business Press.

Davis, GF & Adam Cobb, J 2010, ‘Chapter 2 Resource dependence theory: Past and future’, in *Stanford’s organization theory renaissance, 1970–2000*, Emerald Group Publishing Limited, pp. 21-42.

Davis, JL & Harrison, SS 2002, *Edison in the boardroom: How leading companies realize value from their intellectual assets*, vol. 28, John Wiley & Sons.

De Wet, G 1995, 'Technology space maps for technology management and audits', *Management of Technology*, vol. 3, pp. 1235-1243.

De Wet, G 1999, 'Emerging from the technology colony: A view from the South', PICMET '99: *Portland International Conference on Management of Engineering and Technology.* , vol. Proceedings Vol-1: Book of Summaries (IEEE Cat. No.99CH36310). viewed 15 May 2021,

<https://www.semanticscholar.org/paper/Emerging-from-the-technology-colony%3A-a-view-from- Wet/81fb491b90dcdd2d1ef221b36be3e569f371b8f5>.

Decter, MH 2009, 'Comparative review of UK-USA industry-university relationships', *Education+ Training*, vol. 51, no. 8/9, pp. 624-634.

Den Ouden, E 2011, Innovation design: Creating value for people, organizations and society, Springer Science & Business Media.

Deng, Z, Lev, B & Narin, F 1999, 'Science and technology as predictors of stock performance', *Financial Analysts Journal*, vol. 55, no. 3, pp. 20-32.

Department of Statistics, MoTI, Republic of Singapore 2013, *Yearbook Of Statistics Singapore 2013*, Singapore, viewed 18 Dec 2014, <http://www.singstat.gov.sg/publications/publications_and_papers/reference/yearbook_2013/yos2013.pdf>.

Dodgson, M 1993, 'Organizational learning: A review of some literatures', *Organization Studies*, vol. 14, no. 3, pp. 375-394.

Dos Santos, MER & Torkomian, ALV 2013, 'Technology transfer and innovation: The role of the Brazilian TTOs', *International Journal of Technology Management & Sustainable Development*, vol. 12, no. 1, pp. 89-111.

Drees, JM & Heugens, PP 2013, 'Synthesizing and extending resource dependence theory: A meta-analysis', *Journal of Management*, vol. 39, no. 6, pp. 1666-1698.

Dubickis, M & Gaile-Sarkane, E 2015, 'Perspectives on innovation and technology transfer', *Procedia-Social and Behavioral Sciences*, vol. 213, pp. 965-970.

Economic Strategies Committee 2010, *Report of the economic strategies committee – High skilled people, innovative economy, distinctive global city*, viewed 23 Oct 2018, <https://www.mof.gov.sg/Portals/0/MOF%20For/Businesses/ESC%20Recommendations/ESC%20Full%20Report.pdf>.

Edquist, C & Hommen, L 2008, 'Comparing national systems of innovation in Asia and Europe: Theory and comparative framework', in *Small country innovation systems: Globalisation, change and policy in Asia and Europe: Theory and comparative framework*, Edward Elgar., pp. 1-28.

Edvinsson, L & Sullivan, P 1996, 'Developing a model for managing intellectual capital', *European Management Journal*, vol. 14, no. 4, pp. 356-364.

Eriksson, K & Lindström, UÅ 1997, 'Abduction—a way to deeper understanding of the world of caring', *Scandinavian Journal of Caring Sciences*, vol. 11, no. 4, pp. 195-198.

Etzkowitz, H 1998, 'The norms of entrepreneurial science: Cognitive effects of the new university–industry linkages', *RESEARCH POLICY*, vol. 27, no. 8, pp. 823-833.

Etzkowitz, H 2002, *MIT and the rise of entrepreneurial science*, London and New York, Routledge, viewed 25 October 2017, <http://www.tandfebooks.com.proxy.library.adelaide.edu.au/ISBN/9780203216675>.

Etzkowitz, H 2003, 'Innovation in innovation: The triple helix of university-industry-government relations', *Social Science Information*, vol. 42, no. 3, pp. 293-337.

Evans, JD & Johnson, RO 2013, 'Tools for managing early-stage business model innovation', *Research-Technology Management*, vol. 56, no. 5, pp. 52-56.

Florida, R 2003, 'Cities and the creative class', *City & Community*, vol. 2, no. 1, pp. 3-19.

Flyvbjerg, B 2011, 'Case study', in NK Denzin & YS Lincoln (eds), *Handbook of qualitative research*, 4th edn, Sage, London, pp. 301-316.

Galbraith, CS, Ehrlich, SB & DeNoble, AF 2006, ‘Predicting technology success: Identifying key predictors and assessing expert evaluation for advanced technologies’, *The Journal of Technology Transfer*, vol. 31, no. 6, pp. 673-684.

Geiger, RL 2006, ‘The quest for ‘economic relevance’ by US research universities’, *Higher Education Policy*, vol. 19, no. 4, pp. 411-431.

Geuna, A & Muscio, A 2009, ‘The governance of university knowledge transfer: A critical review of the literature’, *Minerva*, vol. 47, no. 1, pp. 93-114.

Goh, CB & Gopinathan, S 2008, ‘The development of education in Singapore since 1965’, in *Toward a better future: Education and training for economic development in Singapore since 1965*, The World Bank and National Institute of Education, USA, pp. 12-38.

Government of Singapore 2017a, *Intellectual Property Policy*, 15 July 2017, <https://www.mlaw.gov.sg/content/minlaw/en/our-work/intellectual-property-policy.html>.

Government of Singapore 2017b, *Search for UEN* 30 JUN 2017, <https://www.uen.gov.sg/ueninternet/faces/pages/uenSrch.jspx?_afrLoop=732206699778969&_afrWindowMode=0&_adf.ctrl-state=qyrvq56ea_4>.

Government of Singapore 2020, *DPM Heng Swee Keat at the RIE2025 Press Conference*, 13 December 2020, <https://www.pmo.gov.sg/Newsroom/DPM-Heng-Swee-Keat-Opening-Remarks-at-the-RIE2025-Press-Conference>.

Government of Singapore and IPOS 2017, *Update to the IP hub masterplan, May 2017, Singapore*, viewed 10 Oct 2017, <https://www.ipos.gov.sg/docs/default-source/about-ipos-doc/full-report_update-to-ip-hub-master-plan_final.pdf>.

Graff, GD 2007, ‘Echoes of *Bayh-Dole*? A survey of IP and technology transfer policies in emerging and developing economies’, *Intellectual property management in health and agricultural innovation: A handbook of best practices, MIHR, Oxford (UK), and PIPRA, Davis (CA)*, pp. 169-195.

Gray, D, Micheli, P & Pavlov, A 2015, *Measurement madness: Avoiding performance management pitfalls*, John Wiley & Sons, ProQuest Ebook Central, viewed 27 April 2018.

Gulbrandsen, M & Slipersaeter, S 2007, ‘The third mission and the entrepreneurial university model, chapter 4’, in *Universities and strategic knowledge creation*, Edward Elgar Publishing, USA, pp. 112-143.

Gummesson, E 2006, ‘Qualitative research in management: Addressing complexity, context and persona’, *Management Decision*, vol. 44, no. 2, pp. 167-179.

Gunsel, A 2015, ‘Research on effectiveness of technology transfer from a knowledge based perspective’, *Procedia-Social and Behavioral Sciences*, vol. 207, pp. 777-785.

Haas, AR 1999, *Trends in articulation arrangements for technical and vocational education in the South East Asian Region*, RMIT University, Australia.

Hagiu, A, Yoffie, D & Wagonfeld, AB 2009, ‘Intellectual ventures’, *HBS Case*, pp. 710-423.

Han, FK, Zuraidah, I, Chua, MH, Lim, L, Low, I, Lin, R & Chan, R 2011, Lee Kuan Yew: Hard Truths To Keep Singapore Going, Straits Times Press, Singapore.

Harmon, B, Ardishvili, A, Cardozo, R, Elder, T, Leuthold, J, Parshall, J, Raghian, M & Smith, D 1997, ‘Mapping the university technology transfer process’, *Journal of Business Venturing*, vol. 12, no. 6, pp. 423-434.

Hellström, T 2008, ‘Transferability and naturalistic generalization: New generalizability concepts for social science or old wine in new bottles?’, *Quality & Quantity*, vol. 42, no. 3, pp. 321-337.

High, P 2014, ‘Innovator Sir James Dyson turns everyday products into gold’, *Forbes*, 24 Feb 2014, viewed 2 May 2019, <https://www.forbes.com/sites/peterhigh/2014/02/24/innovator-sir-james-dyson-turns-every-day-products-into-gold/#23a8f2dc2352>.

Hillman, AJ, Withers, MC & Collins, BJ 2009, ‘Resource dependence theory: A review’, *Journal of Management*, vol. 35, no. 6, pp. 1404–1427.

Hsieh, H-F & Shannon, SE 2005, ‘Three approaches to qualitative content analysis’, *Qualitative Health Research*, vol. 15, no. 9, pp. 1277-1288.

Inland Revenue Authority of Singapore 2007, *Productivity and innovation credit scheme*, viewed 16 August 2013, <http://www.iras.gov.sg/irashome/picredit.aspx>.

Innography Inc 2014, *Measuring the strength of patents*, viewed 12 May 2016, , <https://www.innography.com/blog/post/measuring-the-strength-of-patents>.

Innography Inc 2016, *Patent scout*, *USA*, <https://app.innography.com/home/>.

Intellectual Property Office of Singapore 2013, *Patent search*, <http://www.epatents.gov.sg/PE/>.

Intellectual Property Office of Singapore 2019, *Careers in IP*, 10 Jan 2019, <https://www.ipos.gov.sg/ip-careers/careers-in-ip>.

Invention City Inc 2021a, *Patent stories – Real world examples of how patents are useful*, viewed 15 Feb 2021, <https://www.inventioncity.com/new-inventions/patent-stories-real-world-examples-of-how-patents-are-useful>.

Invention City Inc 2021b, *SqueezeDriver® - ICQ 96*, viewed 15 Feb 2021, <https://www.inventioncity.com/new-inventions/the-squeezedriver-story>.

IPI-Singapore 2018, *Services*, viewed 15 May 2018, <https://www.ipi-singapore.org/services>.

IPI-Singapore 2019, *Discover, connect & collaborate at TECHINNOVATION 2019,* viewed 15 Sep 2019, <https://www.techinnovation.com.sg>.

Isabelle, DA 2013, ‘Key factors affecting a technology entrepreneur’s choice of incubator or accelerator’, *Technology Innovation Management Review*, vol. 3, no. 2, p. 16.

Ishak, NM & Bakar, AYA 2014, ‘Developing sampling frame for case study: Challenges and conditions’, *World Journal of Education*, vol. 4, no. 3, p. 29.

Jasinski, AH 2009, ‘Barriers for technology transfer: The case of a country in transition’, *Journal of Technology Management in China*, vol. 4, no. 2, pp. 119-131.

Jewell, C 2012, *Singapore: A home for innovation*, <http://www.wipo.int/wipo_magazine/en/2012/05/article_0004.html>.

Jeyakodi, D & Ros, M 2019, *The innovation matrix: Three moves to design a winning strategy for innovation and intellectual property*, BIS Publishers.

Joffe, H 2012, ‘Thematic analysis’, in D Harper, A Thompson & Chichester (eds), *Qualitative research methods in mental health and psychotherapy: A guide for students and practitioners*, Wiley-Blackwell, pp. 209-223.

Jones, P, Patz, R, Thomas, B & McCarthy, S 2014, ‘Micro-sized enterprises, innovation and universities: A Welsh perspective’, *Industry and Higher Education*, vol. 28, no. 1, pp. 39-49.

Kan, F 2018, ‘Making a social impact through innovation’, *Business Times Singapore*, 8 August 2018, viewed 1 Aug 2018, (electronic Dow Jones Factiva’s global news).

Keller, RT & Chinta, RR 1990, 'International technology transfer: strategies for success', *Academy of Management Perspectives,* vol. 4, no. 2, pp. 33-43.

Kerrigan, JE & Brasco, CJ 2002, ‘The technology transfer revolution: Legislative history and future proposals’, *Public Contract Law Journal*, pp. 277-291.

Kline, SJ & Rosenberg, N 1986, ‘An overview of innovation’, in RLN Rosenberg (ed.), *The positive sum strategy. Harnessing technology for economic growth.*, Washington, DC, pp. 275-306.

Knight, J 2011, ‘Education hubs: A fad, a brand, an innovation?’, *Journal of Studies in International Education*, vol. 15, no. 3, pp. 221-240.

Kogut, B & Zander, U 1993, ‘Knowledge of the firm and the evolutionary theory of the multinational corporation’, *Journal of International Business Studies*, vol. 24, no. 4, pp. 625-645.

Konig, W 1996, ‘Science-based industry or industry-based science? Electrical engineering in Germany before World War I’, *Technology and Culture*, vol. 37, no. 1, pp. 70-101.

Korhonen, J, Honkasalo, A & Seppälä, J 2018, 'Circular economy: the concept and its limitations', *Ecological economics*, vol. 143, pp. 37-46.

Kovács, G & Spens, KM 2005, ‘Abductive reasoning in logistics research’, *International Journal Of Physical Distribution & Logistics Management*, vol. 25, no. 2, pp. 132-144.

Kumar, S, Luthra, S & Haleem, A 2015, ‘Benchmarking supply chains by analyzing technology transfer critical barriers using AHP approach’, *Benchmarking: An International Journal*, vol. 22, no. 4, pp. 538-558.

Kundríková, J 2015, ‘Academic entrepreneurship using technology transfer and its organizational forms’, *Journal of Information, Control and Management Systems*, vol. 13, pp. 55-62.

Lai, A & Maclean, R 2011, ‘Managing human capital in world cities: The development of Hong Kong into an education hub’, *Asia Pacific Journal of Education*, vol. 31, no. 3, pp. 249-262.

Landau, R & Rosenberg, N 1986, *Positive sum strategy: Harnessing technology for economic growth*, National Academies Press, ProQuest Ebook Central, viewed 10 December 2017.

Lane, JP & Flagg, JL 2010, ‘Translating three states of knowledge–discovery, invention, and innovation’, *Implementation Science*, vol. 5, no. 1, p. 9.

LaSalle, RJ 2014, ‘La Salle Matrix Thinking’ – A structured approach to Innovation – ‘Opportunity Capture’ and Systematic Thinking, RMIT, 20 May 2021, < https://www.researc\hgate.net/publication/260183784_La_Salle_Matrix_Thinking_-_A_structured_approach_to_Innovation_-_Opportunity_Capture_and_Systematic_Thinkin>

Lavie, D 2006, ‘The competitive advantage of interconnected firms: An extension of the resource-based view’, *Academy of Management Review*, vol. 31, no. 3, pp. 638-658.

Lee, J & Win, H 2004, ‘Technology transfer between university research centers and industry in Singapore’, *Technovation*, vol. 24, no. 5, pp. 433-442.

Lee, M-C, Chang, T & Chien, W-TC 2011, ‘An approach for developing concept of innovation readiness levels’, *International Journal of Managing Information Technology (IJMIT)*, vol. 3, no. 2, pp. 18-38.

Lee, NH 2002, ‘Profile of the ‘Enterprise-50’ companies and other SMEs in Singapore’, *Singapore Management Review*, vol. 24, no. 1, p. 27.

Lee, SK, Goh, CB, Fredriksen, B & Tan, JP 2008, *Toward a better future: Education and training for economic development in Singapore since 1965*, The World Bank and National Institute of Education, USA.

Lee, YS & Png, CB 2011, 'Enterprise and entrepreneurship: Critical engines of economic growth', in *Heart Work: EDB & partners, new frontiers for the Singapore economy*, vol. 2, Straits Times Press, Singapore, pp. 166-177.

Leih, S & Teece, D 2016, 'Campus leadership and the entrepreneurial university: A dynamic capabilities perspective', *Academy of Management Perspectives*, vol. 30, no. 2, pp. 182-210.

Lerner, J & Tirole, J 2004, *The economics of technology sharing: Open source and beyond*, National Bureau of Economic Research, Cambridge, Massachusetts.

Leung, L 2015, 'Validity, reliability, and generalizability in qualitative research', *Journal of Family Medicine and Primary Care*, vol. 4, no. 3, p. 324.

Lev, B 2000, *Intangibles: Management, measurement, and reporting*, Brookings Institution Press, ProQuest Ebook Central, viewed 21 October 2017.

Leydesdorff, L & Etzkowitz, H 1996, 'Emergence of a triple helix of university—industry—government relations', *Science and Public Policy*, vol. 23, no. 5, pp. 279-286.

Leydesdorff, L 2012, 'The triple helix, quadruple helix,…, and an N-tuple of helices: explanatory models for analyzing the knowledge-based economy?', *Journal of the knowledge economy*, vol. 3, no. 1, pp. 25-35.

Leydesdorff, L, Etzkowitz, H & Kushnir, D 2016, 'Globalization and growth of US university patenting (2009–2014)', *Industry and Higher Education*, vol. 30, no. 4, pp. 257-266.

Liaw, W-C 2009, '$25m for polys to grow fruits of research', *The Straits Times*, 12 May 2009, viewed 8 Jan 2016, (electronic Down Jones Factiva's global news).

Lichtenthaler, U, Ernst, H & Conley, J 2011, 'How to develop a successful technology licensing program', *MIT Sloan Management Review*, vol. 52, no. 2, pp. 17-19.

Lim, D 2015, 'Patent holdups', in RD Blair & DD Sokol (eds), *The Cambridge handbook of antitrust, intellectual property, and high tech*, Cambridge University Press, Cambridge, pp. 245-270.

Lim, H 2008, 'SMEs development policy environment and challenges in Singapore', in H Lim (ed.), *SME in Asia and Globalization*, ERIA, Singapore, pp. 267-286.

Lim, M 2009, 'Technology transfer - Singapore perspective. Model approaches for policymakers: submitted by Singapore', paper presented at APEC 2009/SOM1/IPEG/SEM/009 Session: 4b From mind to market: The highs and lows of technology transfer, Singapore, 23-24 February 2009.

Lim, P 2017, *From the CE Office*, viewed 15 May 2017 <https://www.etpl.sg/introduction/from-the-ce-office>.

Lin, BW 2003, 'Technology transfer as technological learning: a source of competitive advantage for firms with limited R&D resources', *R&D Management*, vol. 33, no. 3, pp. 327-341.

Lin, CT 2002, 'Training a New Breed of Technologists', in *Heart Work,* Singapore Economic Development Board (EDB) and EDB Society Singapore, pp. 76-91.

Link, AN, Siegel, DS & Van Fleet, DD 2011, 'Public science and public innovation: Assessing the relationship between patenting at US National Laboratories and the *Bayh-Dole Act*', *RESEARCH POLICY*, vol. 40, no. 8, pp. 1094-1099.

Lipinski, J, Minutolo, MC & Crothers, LM 2008, 'The complex relationship driving technology transfer: The potential opportunities missed by universities', *Journal of Behavioral and Applied Management*, vol. 9, no. 2, p. 112.

Liu, FT 2015, *Thirty years, hundred stories: Engineering accomplishments in Singapore as told by the NTI pioneer engineering class of 85*, Nanyang Technological University/ISEAS – Yusof Ishak Institute, Singapore.

Lockett, A, Wright, M & Wild, A 2013, 'The co-evolution of third stream activities in UK higher education', *Business History*, vol. 55, no. 2, pp. 236-258.

London Business School 2014, 'Startup stats', *Business Strategy Review*, no. 2, 1 June 2014, pp. 70-71.

Mahbubani, K 1999, 'Like Silicon Valley, Singapore needs time', *New York Times*, September 26, 1999.

Mankins, JC 1995, *Technology readiness levels – A white paper*, Advanced Concepts Office, Office of Space Access and Technology, NASA.

Markman, GD, Gianiodis, PT, Phan, PH & Balkin, DB 2005, 'Innovation speed: Transferring university technology to market', *RESEARCH POLICY*, vol. 34, no. 7, pp. 1058-1075.

Marsili, O 2001, *The anatomy and evolution of industries: Technological change and industrial dynamics*, Edward Elgar, Cheltenham, UK and Northampton, MA, USA.

Mathews, JA 2003, 'Competitive dynamics and economic learning: An extended resource-based view', *Industrial and Corporate Change*, vol. 12, no. 1, pp. 115-145.

Mathews, M 2018, 'First national level skills development framework for the IP sector to be launched in August', *Channel News Asia*, Singapore, viewed 04 Mar 2019, <https://www.channelnewsasia.com/news/singapore/first-skills-development-framework-intellectual-property-11308556>.

Maxwell, JA 1997, 'Designing a qualitative study', *The SAGE handbook of applied social research methods*, vol. 2, pp. 214-253.

May, T 2011, *Social research*, 4th edn, McGraw-Hill Education (UK), ProQuest Ebook Central, viewed 8 Mar 2019.

May, T & Perry, B 2011, 'Case study research ', in *Social Research*, 4th edn, McGraw-Hill Education (UK), ProQuest Ebook Central.

Mazloomi Khamseh, H & Jolly, DR 2008, 'Knowledge transfer in alliances: Determinant factors', *Journal of Knowledge Management*, vol. 12, no. 1, pp. 37-50.

Mazurkiewicz, A & Poteralska, B 2015, 'Barriers to technology transfer at R&D organisations', in *Proceedings of the European Conference on Innovation and Entrepreneurship,* Academic Conferences International Limited, pp. 449-457.

Melrose, S 2009, 'Naturalistic generalization', *Encyclopedia of case study research*.

Menkhoff, T & Wah, CY 2008, 'Technological change management strategies in Asian small-scale businesses: Trends in Singapore', in *Internationales Asien Forum. International Quarterly for Asian Studies,* Arnold Bergsträsser Institut, vol. 39, p. 305.

Metzger, MD 2000, 'University policies and their influence on the organized research unit and technology transfer', PhD thesis, The University of Michigan, USA.

Meyer-Krahmer, F & Schmoch, U 1998, 'Science-based technologies: University–industry interactions in four fields', *RESEARCH POLICY*, vol. 27, no. 8, pp. 835-851.

Milton-Smith, J 2001, 'The role of SMEs in commercialising university research & development: The Asia-Pacific experience', *Small Business Economics*, vol. 16, no. 2, pp. 141-148.

Ministry of Trade & Industry 2006, *The Science and Technology Plan 2010*, viewed 10 July 2013, <http://www.mti.gov.sg/ResearchRoom/Documents/app.mti.gov.sg/data/pages/885/doc/S%20And%20T%20Plan%202010.pdf>.

Ministry of Trade & Industry 2013, *RIE 2015*, viewed 13 July 2013, <http://www.nrf.gov.sg/docs/default-source/Publications/rie2015.pdf?sfvrsn=0>.

Mintzberg, H, Lampel, J & Ahlstrand, B 2017, Strategy Safari, *getAbstract,* viewed 30 May 2021.

Mok, KH 2015, 'The quest for global competitiveness: Promotion of innovation and entrepreneurial universities in Singapore', *Higher Education Policy*, vol. 28, no. 1, pp. 91-106.

Mowery, DC 2009, 'Plus ca change: Industrial R&D in the "third industrial revolution"', *Industrial and Corporate Change*, vol. 18, no. 1, pp. 1-50.

Mowery, DC, Nelson, RR, Sampat, B & Ziedonis, AA 1999, 'The effects of the *Bayh-Dole Act* on US university research and technology transfer: An analysis of data from Columbia University, the University of California, and Stanford University', *RESEARCH POLICY*, vol. 29, pp. 729-740.

Mowery, DC, Oxley, JE & Silverman, BS 1996, 'Strategic alliances and interfirm knowledge transfer', *Strategic Management Journal*, vol. 17, no. S2, pp. 77-91.

Mowery, DC, Sampat, BN & Ziedonis, AA 2004, *Ivory tower and industrial innovation: University-industry technology transfer before and after the Bayh-Dole Act*, Stanford University Press, ProQuest Ebook Central, viewed 24 October 2017.

Nanyang Polytechnic 2011, *Centre for Technology Innovation & Commercialisation (CTIC) – Success stories*, viewed 12 October 2013, <http://www.nyp.edu.sg/ctic/success-stories/engineering/electrical-n-electronics>.

Nanyang Polytechnic 2012, *Annual Report 2012/2013*, viewed 18 July 2013, <http://www.nyp.edu.sg/nyp/slot/u100/about%20nyp/annualreport_2012/1_ENTIRE_PUBLICATION_NYP_Annual_Report_2012-2013.pdf>.

Nanyang Polytechnic 2013, *Our vision and mission*, viewed 15 July 2015, <http://www.nyp.edu.sg/about-nyp/corporate-profile/our-vision-and-mission>.

Ndonzuau, FN, Pirnay, F & Surlemont, B 2002, 'A stage model of academic spin-off creation', *Technovation*, vol. 22, no. 5, pp. 281-289.

Newell, S 2005, 'Knowledge transfer and learning: Problems of knowledge transfer associated with trying to short-circuit the learning cycle', *JISTEM-Journal of Information Systems and Technology Management*, vol. 2, no. 3, pp. 275-289.

Ng, FSD 2008, 'Strategic management of educational development in Singapore (1965–2005)', in *Toward a better future: Education and training for economic development in Singapore since 1965*, The World Bank and National Institute of Education, USA, pp. 39-68.

Ng-Loy, WL 2008, *Law of intellectual property of Singapore*, Thomson Sweet & Maxwell Asia.

Ngee Ann Polytechnic 2010, *Licensing opportunities,* viewed 8 October 2013, <http://www.np.edu.sg/tlo/industry/Pages/LicensingOpp.aspx>.

Ngee Ann Polytechnic 2011, *Commercialization,* viewed 2 December 2013, <http://www.np.edu.sg/NPEnterprise/Commercialisation/Pages/default.aspx>.

Ngee Ann Polytechnic 2015, *About Ngee Ann Polytechnic*, viewed 15 July 2015, <http://www.np.edu.sg/home/aboutnp/Pages/about_np.aspx>.

Nonaka, I 1994, 'A dynamic theory of organizational knowledge creation', *Organization Science*, vol. 5, no. 1, pp. 14-37.

NTU 2012, *Vision & mission*, viewed 15 Aug 2015, <http://www.ntu.edu.sg/AboutNTU/CorporateInfo/Pages/visionmission.aspx>.

NUS 2015, *Mission, vision, core values & strategic thrusts*, viewed 15 Aug 2015, <http://www.nus.edu.sg/iro/home/mission.html>.

OECD 1997, *National innovation systems*, Paris.

OECD 2010, ‘Singapore: Rapid improvement followed by strong performance’, in *Strong performers and successful reformers in education: Lessons from PISA for the United States*, pp. 159-175.

OECD 2015, *Frascati manual 2015*.

OECD & Eurostat 2018, *Oslo manual 2018*.

OECD/ERIA 2018, *SME policy index: ASEAN 2018: Boosting competitiveness and inclusive growth*, OECD Publishing, Paris/Economic Research Institute for ASEAN and East Asia, Jakarta., viewed 23 Oct 2018, <https://doi.org/10.1787/9789264305328-en>.

Ong, JW, Ismail, HB & Goh, GGG 2010, ‘The competitive advantage of small and medium enterprises (SMEs): The role of entrepreneurship and luck’, *Journal of Small Business & Entrepreneurship*, vol. 23, no. 3, pp. 373-391.

ONMEDIO 2018, *Silver eco & ageing well international awards*, viewed 11 Aug 2018, <http://www.silvereco.org/awards/winners/>.

O'shea, RP, Allen, TJ, Chevalier, A & Roche, F 2005, 'Entrepreneurial orientation, technology transfer and spinoff performance of US universities', *Research Policy*, vol. 34, no. 7, pp. 994-1009.

Palinkas, LA, Horwitz, SM, Green, CA, Wisdom, JP, Duan, N & Hoagwood, K 2015, ‘Purposeful sampling for qualitative data collection and analysis in mixed method implementation research’, *Administration and Policy in Mental Health and Mental Health Services Research*, vol. 42, no. 5, pp. 533-544.

Parker, S 2014, ‘Game of phones: Tech kings clash in smartphone patent wars’, *The New Economy*, 27 March 2014, viewed 25 Jan 2018, <https://www.theneweconomy.com/technology/game-of-phones-tech-kings-clash-in-smartphone-patent-wars>.

Patsnap 2016, *Patsnap patent search and analysis*, vol. 2016, no. 13 Sept, <http://www.patsnap.com>.

Pavitt, K 1984, ‘Sectoral patterns of technical change: towards a taxonomy and a theory’, *RESEARCH POLICY*, vol. 13, no. 6, pp. 343-373.

Pazos, DR, López, SF, González, LO & Sandiás, AR 2012, ‘A resource-based view of university spin-off activity: New evidence from the Spanish case’, *Revista Europea de Dirección y Economía de la Empresa*, vol. 21, no. 3, pp. 255-265.

Peräkylä, A & Ruusuvuori, J 2011, ‘Analyzing talk and text’, in NK Denzin & YS Lincoln (eds), *The SAGE handbook of qualitative research*, 4th edn, Sage, London, pp. 529-524.

Perkmann, M, Tartari, V, McKelvey, M, Autio, E, Broström, A, D’Este, P, Fini, R, Geuna, A, Grimaldi, R & Hughes, A 2013, ‘Academic engagement and commercialisation: A review of the literature on university–industry relations’, *RESEARCH POLICY*, vol. 42, no. 2, pp. 423-442.

Perkmann, M & Walsh, K 2007, ‘University–industry relationships and open innovation: Towards a research agenda’, *International Journal of Management Reviews*, vol. 9, no. 4, pp. 259-280.

Peteraf, MA & Barney, JB 2003, ‘Unraveling the resource-based tangle’, *Managerial and Decision Economics*, vol. 24, no. 4, pp. 309-323.

Pfeffer, J & Salancik, GR 1978, *The external control of organizations: A resource dependence perspective*, Stanford University Press.

Phan, PH & Siegel, DS 2006, ‘The effectiveness of university technology transfer’, *Foundations and Trends® in Entrepreneurship*, vol. 2, no. 2, pp. 77-144.

Pike, S, Roos, G & Marr, B 2005, ‘Strategic management of intangible assets and value drivers in R&D organizations’, *R&D Management*, vol. 35, no. 2, pp. 111-124.

Pisano, GP & Teece, DJ 2007, 'How to capture value from innovation: Shaping intellectual property and industry architecture', *California Management Review*, vol. 50, no. 1, pp. 278-296.

Porter, ME 1985a, *Competitive advantage: Creating and sustaining superior performance*, The Free Press, New York.

Porter, ME 1985b, 'Technology and competitive advantage', *Journal of Business Strategy*, vol. 5, no. 3, pp. 60-78.

Powell, W 1990, 'Neither market nor hierarchy: Network forms of organization', *Research in Organizational Behavior*, vol. 12, pp. 295-336.

Powers, JB 2003, 'Commercializing academic research: Resource effects on performance of university technology transfer', *The Journal of Higher Education*, vol. 74, no. 1, pp. 26-50.

Quinn, JB & Hilmer, FG 1994, 'Strategic outsourcing', *Sloan Management Review*, vol. 35, no. 4, p. 43.

Rasmussen, E 2006, 'Models for university technology transfer operation: patent agency and 2g', *International Journal of Technology Transfer and Commercialisation*, vol. 5, no. 4, pp. 291-307.

Rauch, DE & Schleicher, D 2015, 'Like Uber, but for local government law: The future of local regulation of the sharing economy', *Ohio St. LJ*, vol. 76, p. 901.

Razak, AA & White, GR 2015, 'The triple helix model for innovation: A holistic exploration of barriers and enablers', *International Journal of Business Performance and Supply Chain Modelling*, vol. 7, no. 3, pp. 278-291.

Republic Polytechnic 2011, *Projects & collaborations with the industries*, viewed 1 Oct 2013, <http://www.rp.edu.sg/schoolscentres/sas/industry/projcollab.aspx>.

Republic Polytechnic 2012, *Annual report 2012/13*, viewed 15 August 2013, <http://www.rp.edu.sg/uploadedFiles/Contents/RP/About_RP/08Corporate_Material_and_References/Annual_Reports/RP_Annual_Report_2013.pdf>.

Republic Polytechnic 2013, *RP technology yearbook*, viewed 13 October 2013, <http://www.rp.edu.sg/tdc/technology_yearbook.asp\>.

Republic Polytechnic 2015, *RP's vision, mission, logo and core values*, 15 July 2015, <http://www.rp.edu.sg/Mission_And_Vision.aspx>.

Rogers, EM, Takegami, S & Yin, J 2001, 'Lessons learned about technology transfer', *Technovation*, vol. 21, no. 4, pp. 253-261.

Rombach, D & Achatz, R 2007, 'Research collaborations between academia and industry', in *2007 Future of software engineering,* IEEE Computer Society, pp. 29-36.

Rooksby, JH 2012, 'Innovation and litigation: Tensions between universities and patents and how to fix them', *Yale Journal of Law & Technology,* vol. 15, no. 2, pp. 312-404.

Rothwell, R & Gardiner, P 1985, 'Invention, innovation, re-innovation and the role of the user: A case study of British hovercraft development', *Technovation*, vol. 3, no. 3, pp. 167-186.

Rüegg, W & Ridder-Symoens, Hd 2010, *A history of the university in Europe*, 2010 edn, Cambridge University Press, ProQuest Ebook Central, viewed 10 October 2017.

Saint-Antoine, P 2011, 'Antitrust law and intellectual property: Intersection or crossroad?', *COMPUTER AND INTERNET LAWYER*, vol. 28, no. 3, pp. 5-14.

Salter, A, D'Este, P, Pavitt, K, Scott, A, Martin, B, Geuna, A, Nightingale, P & Patel, P 2000, *Talent, not technology: The impact of publicly funded research on innovation in the UK*, Science Policy Research Unit, University of Sussex, UK.

Sampat, BN 2006, 'Patenting and US academic research in the 20th century: The world before and after *Bayh-Dole*', *RESEARCH POLICY*, vol. 35, no. 6, pp. 772-789.

Sanberg, PR & McDevitt, VL 2013, 'Patents: Universities profit from products', *Nature*, vol. 502, no. 7472, pp. 448-448.

Schoemaker, PJ, Heaton, S & Teece, D 2018, 'Innovation, dynamic capabilities, and leadership', *California Management Review*, vol. 61, no. 1, pp. 15-42.

Schroer, BJ, Farrington, PA, Messimer, SL & Thornton, JR 1995, 'Measuring technology transfer performance: A case study', *The Journal of Technology Transfer*, vol. 20, no. 2, pp. 39-47.

Scott, WR 1981, 'Developments in organization theory, 1960-1980', *The American Behavioral Scientist*, vol. 24, no. 3, p. 407.

Shapiro, C 2000, 'Navigating the patent thicket: Cross licenses, patent pools, and standard setting', *Innovation Policy and the Economy*, vol. 1, pp. 119-150.

Sharma, M, Kumar, U & Lalande, L 2006, 'Role of university technology transfer offices in university technology commercialization: case study of the Carleton University Foundry Program', *Journal of Services Research*, vol. 6, p. 109.

Siegel, DS, Waldman, DA, Atwater, LE & Link, AN 2004, 'Toward a model of the effective transfer of scientific knowledge from academicians to practitioners: Qualitative evidence from the commercialization of university technologies', *J. Eng. Technol. Manage*, vol. 21, pp. 115-142.

Sim, TS & O'Connor, A 2014, 'An exploratory study of polytechnic-small-medium-enterprise (Poly-SME) technology transfer (TT) processes', in *Australian Centre for Entrepreneurship Research Exchange Conference 2014,* Queensland University of Technology, Australia, pp. 1063-1079.

Singapore Academy of Law 2017, *Intellectual property law*, <http://www.singaporelaw.sg/sglaw/laws-of-singapore/commercial-law/chapter-12#section3>.

Singapore Chinese Chamber of Commerce & Industry 1992, *Tan Kah Kee Young Inventors' Award: Taking young minds to new frontiers*, Singapore Chinese Chamber of Commerce & Industry, Singapore.

Singapore Forum 2015, *Dialogue session with DPM Tharman Shanmugaratnam*, Video recording, *Youtube*, 27 Apr 2015, viewed 15 May 2017, <https://www.youtube.com/watch?v=o4kKsbPk3V8>.

Singapore Polytechnic 2012, *Future ready with SP, it's so possible,* viewed 20 July 2013, <http://www.sp.edu.sg/resources/docs/publications/annualreport/SP_AR_2012_2013.pdf>.

Singapore Polytechnic 2013a, *Lemonsi delight*, viewed 10 October 2013, <http://www.sp.edu.sg/wps/portal/vp-spws/schcls.abt.ourproducts.lemonsidelight>.

Singapore Polytechnic 2013b, *Purple gold*, viewed 3 December 2013, <http://www.sp.edu.sg/wps/portal/vp-spws/spws.i.techxfer.successfulprojects/?WCM_GLOBAL_CONTEXT=Lib-SPWS/site-spwebsite/industry/r+and+d/purple+gold+%28business+and+industry-consultancy-successful+projects-purple+gold%29?>.

Singapore Polytechnic 2013c, *Technology licensing opportunity,* viewed 10 October 2013, <http://www.sp.edu.sg/wps/portal/vp-spws/spws.i.techxfer.highlight/?WCM_GLOBAL_CONTEXT=lib-SPWS/Site-SPWebsite/Industry/Technology+Transfer/TTEC+licensing?>.

Singapore Polytechnic 2014, *SP mission & vision*, 15 July 2015, <http://www.sp.edu.sg/wps/portal/vp-spws/spws.org.abtsp.corporateinfo.missionandvision>.

SIT 2013, *Vision and mission*, viewed 15 Aug 2015, <http://www.singaporetech.edu.sg/about/vision-and-mission>.

Smit, B 2002, 'Atlas. ti for qualitative data analysis: research paper', *Perspectives in Education*, vol. 20, no. 3, pp. 65-75.

SMU 2015, *Vision and mission*, 15 Aug 2015, <http://www.smu.edu.sg/smu/about/university-information/vision-and-mission>.

Somsuk, N 2010, 'A review of inter-firm technology transfer through the lens of the resource-based view', in *The Proceedings of the International Conference on Industrial Engineering and Engineering Management (IEEM),* IEEE, pp. 891-895.

Speser, PL 2006, *The art and science of technology transfer*, John Wiley & Sons.

Spivey, WA, Munson, JM, Flannery, WT & Tsai, F-S 2009, 'Improve tech transfer with this alliance scorecard', *Research-Technology Management*, vol. 52, no. 1, pp. 10-18.

SPRING Singapore 2012a, *Bridging the gap between research, commerce*, viewed 20 July 2013, <http://www.spring.gov.sg/NewsEvents/ITN/2011/Pages/Bridging-the-gap-between-research-commerce-20110419.aspx?skw=GET-up%20staff%20secondment#.Uq1loWQW1m0>.

SPRING Singapore 2012b, *Centres of innovation (COIs)*, viewed 20 July 2013, <http://www.spring.gov.sg/Enterprise/CDG/Pages/TI/centres-of-innovation.aspx?skw=coi#.Uq1d-2QW1m0>.

SPRING Singapore 2015, *Factsheet on new SME definition*, <http://www.spring.gov.sg/NewsEvents/PR/Documents/Fact_Sheet_on_New_SME_Definition.pdf>.

St Gallen Symposium 2015, *An investigative interview: Singapore 50 years after independence - 45th St. Gallen Symposium*, Video recording, *Youtube*, 7 May 2015, viewed 6 June 2017, <https://youtu.be/hpwPciW74b8>.

Stabell, CB & Fjeldstad, ØD 1998, 'Configuring value for competitive advantage: On chains, shops, and networks', *Strategic Management Journal*, pp. 413-437.

Stake, RE 1978, 'The case study method in social inquiry', *Educational Researcher*, vol. 7, no. 2, pp. 5-8.

Stanford Office of Technology 2009, *What is value?* The Stanford Office of Technology Licensing Annual Report 2008-2009, viewed 8 September 2017 <https://otl.stanford.edu/documents/otlar09.pdf>.

Stock, GN & Tatikonda, MV 2008, 'The joint influence of technology uncertainty and interorganizational interaction on external technology integration success', *Journal of Operations Management*, vol. 26, no. 1, pp. 65-80.

Susan, D & Serena, S 2014 'Uber seeks to patent pricing surges that critics call gouging', *Bloomberg*, vol. 2016, no. 1 June, viewed 20 December 2014, <https://www.bloomberg.com/news/articles/2014-12-18/uber-seeks-to-patent-pricing-surges-that-critics-call-gouging>.

SUTD 2015, *Mission & values*, viewed 16 Aug 2015, <http://www.sutd.edu.sg/mission_values.aspx>.

Tan, C 2018, 'Temasek Poly's fuel cell bet pays off', *The Straits Times*, 2 October 2018, viewed 2 October 2018, (electronic Dow Jones Factiva's global news).

Tan Kah Kee Foundation 2016, *Young Inventors' Award*, viewed 21 December 2016, <https://www.tkkfoundation.org.sg/young-inventors-awards>.

Tan, W 2017, ‘Meet the disruptors ‘, *AlumNUS Apr-Jun 2017, Alumni Magazine of the National University of Singapore*, no. 109, 23 Apr 2017, pp. 8-15.

Teddlie, C & Yu, F 2007, ‘Mixed methods sampling: A typology with examples’, *Journal of Mixed Methods Research*, vol. 1, no. 1, pp. 77-100.

Teece, DJ 1986, ‘Profiting from technological innovation: Implications for integration, collaboration, licensing and public policy’, *RESEARCH POLICY*, vol. 15, no. 6, pp. 285-305.

Teece, DJ, Pisano, G & Shuen, A 1997, ‘Dynamic capabilities and strategic management’, *Strategic Management Journal*, vol. 18, no. 7, pp. 509-533.

Temasek Polytechnic 2012, *Applied nutrition competency – Promoting healthier living through nutrition research and education*, viewed 6 October 2013, <http://www-as.tp.edu.sg/ps2012_applied_nutrition_intro_ready2print.pdf>.

Temasek Polytechnic 2013, *New Singapore plastic film is the future of 3D on-the-go*, viewed 5 October 2013, <http://www.tp.edu.sg/abouttp/mediacentre/pressrelease/p_20130328.asp>.

Temasek Polytechnic 2014, *Mission, vision & values*, 15 July 2015, <http://www.tp.edu.sg/about-tp/mission-vision-values>.

Teng, A 2016, ‘Polys push students to develop for the market’, *The Straits Times* 25 January 2016, viewed 10 Mar 2016, (electronic Dow Jones Factiva’s global news).

THE 2015, ‘World university rankings 2014-15’, 21 July 2015 edn, *Times Higher Education*, <https://www.timeshighereducation.co.uk/world-university-rankings/2015/world-ranking>.

The Economist 2002, ‘Innovation’s golden goose’, *The Economist*, vol. 365 no. 8303, 14 Dec, 2002, pp. 3-T3.

The Economist Intelligence Unit Ltd & Asian Development Bank 2014, *Creative productivity index: Analysing creativity and innovation in Asia*, viewed 25 Jan 2015, <http://www.adb.org/sites/default/files/publication/59586/creative-productivity-index_0.pdf>.

The Unilever Foundry 2017, *The state of innovation a deep dive into corporate - Startup partnerships from The Unilever Foundry*, The Unilever Foundry, Singapore.

The University of Adelaide 2013, *Library search,* 15 November 2013 edn, <http://www.adelaide.edu.au/library/>.

Thompson, JD 1967, *Organizations in action: Social science bases of administrative theory*, Transaction Publishers, USA.

Thomson Reuters 2014, *Highly cited researchers 2014*, viewed 18 July 2014, <http://highlycited.com/>.

Thursby, JG & Thursby, MC 2004, ‘Are faculty critical? Their role in university–industry licensing’, *Contemporary Economic Policy*, vol. 22, no. 2, pp. 162-178.

Todeva, E & Knoke, D 2005, ‘Strategic alliances and models of collaboration’, *Management Decision*, vol. 43, no. 1, pp. 123-148.

Tufford, L & Newman, P 2012, ‘Bracketing in qualitative research’, *Qualitative Social Work*, vol. 11, no. 1, pp. 80-96.

University of Bradford 2017, *Heritage*, viewed 12 June 2017, <http://www.brad.ac.uk/50/#event-university-of-bradford-is-born>.

University of Westminster 2017, *Heritage*, viewed 10 June 2017, <https://www.westminster.ac.uk/about-us/our-university/our-heritage>.

Upstill, G & Symington, D 2002, ‘Technology transfer and the creation of companies: The CSIRO experience’, *R&D Management*, vol. 32, no. 3, pp. 233-239.

Van Wulfen, G 2016, *The innovation maze: 4 routes to a successful new business case*, BisPublisher.

Varaprasad, N 2016, *50 years of technical education in Singapore: How to build a world class TVET System*, World Scientific Publishing Co. Pte. Ltd.

Verganti, R 2009, *Design driven innovation: changing the rules of competition by radically innovating what things mean,* Harvard Business Press.

Vohora, A, Wright, M & Lockett, A 2004, 'Critical junctures in the development of university high-tech spinout companies', *RESEARCH POLICY*, vol. 33, no. 1, pp. 147-175.

von Wartburg, I, Teichert, T & Rost, K 2005, 'Inventive progress measured by multi-stage patent citation analysis', *RESEARCH POLICY*, vol. 34, no. 10, pp. 1591-1607.

Wagner, S 2015, *Are 'patent thickets' smothering innovation*, viewed 09 May 2019, <https://insights.som.yale.edu/insights/are-patent-thickets-smothering-innovation>.

Wang, J 2018, 'Innovation and government intervention: A comparison of Singapore and Hong Kong', *RESEARCH POLICY*, vol. 47, no. 2, pp. 399-412.

Ward, V, House, A & Hamer, S 2009, 'Knowledge brokering: The missing link in the evidence to action chain?', *Evidence & Policy: A Journal of Research, Debate and Practice*, vol. 5, no. 3, pp. 267-279.

Wayne, KT 2003, 'Commercial determinants of successful university technology transfer: A resource dependence perspective', Doctor of Business Administration thesis, Nova Southeastern University.

Wee, J 2016, 'An electronic encyclopedia on Singapore's history, culture, people and events', *National Library Board Singapore*, <http://eresources.nlb.gov.sg/infopedia/articles/SIP_350_2005-01-13.html>.

Wengenroth, U 2000, *Science, technology, and industry in the 19th century*, Munich Center for the History of Science and Technology Working Paper. http://www. mzwtg. mwn. tum. de/fileadmin/w00bmt/www/Arbeitspapiere/Wengenroth_scitech-ind-19c. pdf.

Wernerfelt, B 1984, 'A resource-based view of the firm', *Strategic Management Journal*, vol. 5, no. 2, pp. 171-180.

Winner SG PTE LTD 2018, *Awards*, viewed 22 Mar 2018, <http://winner-sg.com/awards/index.php>.

WIPO 2007, 'Technology transfer, intellectual property rights and university-industry partnerships: The experience of China, India, Japan, Philippines, the Republic of Korea, Singapore and Thailand', pp. 1-51.

WIPO n.d., 'How to commercialise inventions', *Part 1 General overview of items (A) – (F) Country: Singapore*, pp. 273- 325, viewed 18 Jan 2017, <www.wipo.int/ip-development/en/pdf/asean/singapore.pdf>.

WIPO Lex 2017, *Singapore Patent Act (Chapter 221, Revised Edition 2005)*, 15 July 2017, <http://www.wipo.int/wipolex/en/text.jsp?file_id=188319#LinkTarget_3350>.

Wong, PK 1999, 'University-industry technological collaboration in Singapore: Emerging patterns and industry concerns', *International Journal of Technology Management*, vol. 18, no. 3, pp. 270-284.

Wong, PK 2001, 'Leveraging multinational corporations, fostering technopreneurship: The changing role of S&T policy in Singapore', *International Journal of Technology Management*, vol. 22, no. 5-6, pp. 539-567.

Wong, PK, Ho, Y-P & Singh, A 2011, 'Contribution of universities to national innovation systems in Asia: Technology commercialization and academic entrepreneurship', in S Shane (ed.), *Academic entrepreneurship in Asia: The role and impact of universities in national innovation systems*, Edward Elgar, pp. 1-27.

Wong, PK, Ho, YP & Singh, A 2006, *Survey of innovation, intellectual property creation & usage among Singapore firms*, IP Academy, Singapore.

Wong, PK, Ho, YP & Singh, A 2007, 'Towards an "entrepreneurial university" model to support knowledge-based economic development: The case of the National University of Singapore', *World Development*, vol. 35, no. 6, pp. 941-958.

Wong, PK & Singh, A 2008, 'From technology adopter to innovator: Singapore', *Small country innovation systems: Globalization, change and policy in Asia and Europe*, pp. 71-112.

Wy-Cin, L 2009, '$25m for polys to grow fruits of research', *Straits Times*, 12 May 2009, viewed 8 Jan 2016 (electronic Down Jones Factiva's global news).

Wyatt, E 2011, 'Banks turn to Schumer on patents', *The New York Times Company*, viewed 15 May 2016, <http://www.nytimes.com/2011/06/15/business/15schumer.html?_r=0>.

Yahya, Y 2017, 'Economic affairs; intellectual property: The next big thing in business', *The Straits Times,* viewed 10 May 2017, (electronic Dow Jones Factiva's global news).

Yeo, P 2011, 'Attracting whales, nurturing guppies', in *Heart Work: EDB & partners, new frontiers for the Singapore economy*, vol. 2, Straits Times Press, Singapore, pp. 178-185.

Yiannouka, SN 2015, 'The secret of Singapore's success', *The Straits Times*, 11 April 2015, viewed 21 July 2015 (electronic Dow Jones Factiva's global news).

Yin, RK 1981, 'The case study crisis: Some answers', *Administrative Science Quarterly*, vol. 26, no. 1, pp. 58-65.

Yin, RK 2003, *Case study research: Design and methods.* Volume 5, Thousand Oaks, CA: Sage Publications.

Yong, YW & Keng, KA 1992, 'Government and technology transfer: The case of Singapore', *International Small Business Journal*, vol. 10, no. 2, pp. 54-65.

Yuen, B 2007, 'Squatters no more: Singapore social housing', *Global Urban Development Magazine*, vol. 3, no. 1, November 2007, viewed 23 July 2015, <http://www.globalurban.org/GUDMag07Vol3Iss1/Yuen.htm>.