The relationship between technological learning by hiring and innovation within the context of follower firms in the high-technology industry

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Abstract

Despite technological learning by hiring becoming more critical for follower firms within the technology-intensive industry, knowledge about the followers' technological learning by hiring is limited. Drawing upon interviews with managers and hired engineers from follower firms, this thesis provides several empirical studies which provide evidence on how technological learning by hiring affects followers' innovation.

This thesis first presents China's semiconductor industry as a research setting. Presenting the industry by looking into the transnational dimension of the sectoral system of innovation does not only provides a holistic understanding in terms of the industry but also helps to provide a clearer view for the following studies. The second study of this thesis investigates the effect of technological distance on the firm's innovation. This study classifies the knowledge of hired engineers into distant and familiar knowledge and investigates how this affects a hiring firm's innovation by dividing it into exploratory and exploitative innovation. The finding shows that when the knowledge of hired engineers is distant, it tends to be new or not available to the hiring firm and increases the combination of new knowledge, so is more likely to facilitate the firm's exploratory innovation rather than exploitative innovation. On the other hand, when the knowledge is familiar, the likelihood of facilitating exploitative innovation will be greater, as these engineers tend to work in accordance with the firm's existing technology.

The third study explored the status of hired engineers, which has not been a centre of the discussion in the previous studies. The finding also shows that the status distance between hired and incumbent engineers plays an important role in building the hiring firm's innovation. Status distance affects knowledge flows whereby the contribution of hired engineers with high status is greater, which spurs the knowledge flow from hired engineers to the hiring firm. In addition to this, the finding shows that status distance decreases the perceived psychological safety of high-status engineers, which negatively affects their willingness to share knowledge in the new firm. It is especially so when engineers are hired from other firms.

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Chapter 1 General Introduction

1.1 Research background

Follower firms, especially those in a technology-intensive and innovative industry, have become more visible in the global competitive landscape in the past decade. Followers who lag behind others are primarily aiming to "catch up" with global leaders (Kim, 1998). In order to reduce the technological gap between themselves and global leaders, they are heavily investing in the acquisition of technology or knowledge from global leaders as a strategy to build their innovative capability. Diverse strategies have been identified for technology or knowledge acquisition that focus on cross-border knowledge transfer mechanisms such as purchasing, collaborating, co-producing or co-developing by establishing a strategic partnership with global leaders from advanced economies (Hobday, 1995; Kim, 1997; Lall, 1992; Lee & Yoon, 2015; Xie, 2004). Although some followers have been able to build the capabilities through knowledge acquisition from global leaders (Chen & Qu, 2003; Hobday, 1995; Kim, 1997; Lall, 1992; Xie, 2004), we still do not fully understand the mechanisms that allow them to gain knowledge from global leaders thereby building innovative capability.

A particularly promising, but as yet under-researched mechanism, is 'technological learning by hiring' of engineers from global leaders (Almeida & Kogut, 1999; Peeters et al., 2019; Song et al., 2003). In recent years, the phenomenon of followers' technological learning by hiring from global leaders, especially those in technology-intensive and innovative industries, has become more observable in the field. Hiring has been considered a critical method of knowledge acquisition due to the accessibility of state-of-the-art knowledge from other firms without their approval (Teece, 1982). However, hiring has been an under-researched mechanism in international business studies and the effect of hiring has remained largely not understood, signalling that there are contributions to be made to international business studies. Hiring engineers from global leaders as a way of knowledge acquisition is, therefore, a topic worthy of research.

Before discussing the gap this research aim to fill in, it is important to discuss the research setting of this research. China's semiconductor industry is selected to set the scene from two aspects. Firstly, from an academic aspect, the previous literature has paid primary attention to the prior followers such as high-technology firms of Korea and Taiwan in their technological learning (Hobday, 1995; Kim, 1997; Lee & Lim, 2001) and later study shifted the attention to China's technological learning (Fan, 2006; Guo & Guo, 2011; Shan & Jolly, 2011; Xie, 2004). Particularly, among many ways that Chinese firms obtain for learning or knowledge acquisition, the method of hiring has not been the main focus in the previous studies. As a result, our knowledge about China's technological learning is not comprehensive, hence, China is worthwhile to study.

From an empirical aspect, China's semiconductor industry is relevant as a research setting. The Chinese semiconductor industry, putting effort in narrowing the technological gap with global leaders through knowledge acquisition or learning (Chen & Toyama, 2006; Grimes & Du, 2020; Rho et al., 2015). However, the high level of competitiveness within the semiconductor industry, Chinese semiconductor firms that are considered to be the greatest competitors for global leaders influences China's accessibility to foreign knowledge, which is also reflected in the extent of foreign partners' willingness to share knowledge (Rho et al., 2015; To, 2021). Chinese semiconductor firms, acquiring advanced knowledge from global leaders is relatively more difficult when compared to prior followers. Perhaps for that reason, China's hiring from global leaders has been an inflammatory issue in the industry. Even though this has not been intensively examined in academic studies, much attention has been paid to it within the industry. Hence, China's semiconductor industry makes it an ideal subject for investigating how a follower's technological learning by hiring can provide a contribution to its innovation, thereby supporting its catch up with global leaders.

In order to investigate the technological learning by hiring, this study adopts a qualitative research approach that facilitates obtaining an insider's view by interviewing managers from 14 semiconductor firms. These firms include: foundry model businesses (two foundries from 4 different locations) and fabless model businesses (from China's top 30 indigenous firms). This research approached from macro to micro-level, the first study is from sectoral approach, focuses on the Chinese semiconductor industry by examining its technological catching-up process whilst the focus of the second and third studies are from a firm and individual level particularly focus on the technological and sociological factor that is closely associated with technological learning by hiring. This will be discussed in detail in the next section along with its aims, objectives and research questions.

1.2 Research aims, objectives and research questions

This thesis arises from the need to increase insight into follower firms' technological learning by hiring and to resolve our understanding of its effect on innovation. A review of the technological learning literature reported in Chapter 2 of this thesis reveals that hiring as a method of knowledge acquisition or learning has received less attention and has barely been investigated within follower firms' technological learning context. It is mainly because the literature is built upon the idea of knowledge transfer through building partnerships with global leaders (Hobday, 1995; Kim, 1997; Lall, 1992; Xie, 2004; Guo a Guo, 2011). Hiring from global leaders is an important driver of knowledge acquisition and reflects learning from global leaders. However, hiring is complex input for innovation that does not only involve the technological factor (Braunerhjelm et al., 2020; Kaiser et al., 2015; Rosenkopf & Almeida, 2003; Slavova et al., 2016) but also the sociological factor as engineers have to interact with each other to transfer knowledge within a firm (Ebersberger et al., 2021). The purpose of this thesis is to investigate follower's technological learning by hiring by considering technological and sociological factors.

To structure this investigation, this thesis bundles three empirical studies from sectoral to firm and individual level. The first study approached from the sectoral level addresses China's semiconductor industry to set the scene for the following studies. Chapter 4 will present the catching-up process of the Chinese semiconductor industry, with an examination of the factors that affect the process of catching up. Specifically, the process of catching up is provided by including key actors within the industry and, knowledge acquisition mechanisms and policies. The factors that affect catching up have been examined using a sectoral system of innovation perspective, which not only allows us to have a broader understanding in terms of the industry throughout a historical time period but also helps us to have a clearer understanding from subsequent studies. This study mainly used secondary data from diverse sources, along with associated narratives. The reason to combine the secondary research method and narratives in this study is that the former enables us to have broad information, while the latter helps to fill the possible gaps where details are required from industrial narratives. In line with this study, the research questions are formulated as:

1. *What is the catching up process of China's semiconductor industry?*
2. *How do sectoral factors affect the catching up of the Chinese semiconductor industry?*

After presenting the industry, chapter 5 investigates the effect of hired engineers' knowledge on the hiring firm's innovation. Knowledge is transferable across firms and countries through hiring (Oettl & Agrawal, 2008; Slavova et al., 2016; Song et al., 2003), but the effect depends on the knowledge of hired engineers that is distant or not from that of the hiring firms' technology. This research examines how the technological distance between hired engineers and the hiring firms affect the hiring firms' innovation. *Technological distance*, defined as the difference in knowledge between the hired engineer's knowledge and the hiring firm's core technological domain (Song et al., 2003). It is previously noted that when firms access distant knowledge, it is often new to, or unavailable within the firm (Almeida & Kogut, 1999); such access, in turn, may increase the potential for firms to open to new technology (Wagner et al., 1984; Tzabbar, 2009). In line with this logic, this chapter steps forward from previous studies by borrowing the lenses of information processing and categorisation perspectives to investigate the 'how' question. More precisely, this study specifies the knowledge of hired engineers into distant or not distant (familiar) and investigates the differing effects on innovation that is classified into exploratory and exploitative innovation. Exploratory innovation is defined as the desire to pursue new technology and develop new technology (Benner & Tushman, 2003; Karamanos, 2012), while exploitative innovation is defined as pursuing building upon existing technology and reinforcing existing technology (Benner & Tushman, 2003; Karamanos, 2012). The study in this chapter adopted qualitative research with the deductive analysis that departs from the conceptual framework driven from the theory - information processing and categorisation theory. From the framework, the propositions are developed and applied to the collection and analysis of data (Hyde, 2000). Drawing upon interviews with 29 interviewees, including directors, managers and hired and incumbent engineers from 14 semiconductor firms in China provided us with the industrial insight to enable us to test the propositions of the research. This study formulates the research question:

3. *How does the technological distance between the hired engineer and the hiring firm affect the firm's exploratory versus exploitative innovation?*

Once engineers are hired, personal interaction with hired and incumbent engineers are required to transfer their knowledge to the firm (Ebersberger et al., 2021) or conduct the innovative activity within a firm. However, the status distance between engineers often plays a critical role in their interaction (Edmondson, 2003). *Status* is defined as the prestige accorded to actors "due to the hierarchical positions they occupy in a social structure" (Jensen & Roy, 2008; Podolny, 1993; Prato & Ferraro, 2018) and *Status distance* refers to the difference between individuals concerning the status they hold (Blau, 1970; Smith-Lovin & Mcpherson, 1987). Hired engineers from global leaders are often given expert power within the follower firms, which result in the emergence of the status distance (or power distance) between hired and incumbent engineers. The existing literature on knowledge spillover only had the assumption that status is already embedded in hired engineers (Jain, 2016; Song et al., 2003; Tzabbar et al., 2015), but does not bring status into the centre of the discussion. This study, to further increase insight into technological learning by hiring, leverages the status literature and explore the role of the status distance between hired and incumbent engineers.

This study leverages the status literature - suggesting that status distance plays an important role in the recipient firms' innovation as it may determine how knowledge flows within a firm (Bunderson & Reagans, 2011; Tzabbar, 2009). In addition, the status distance between engineers often influences the perceived psychological safety of engineers whose status is lower within a team that affect their involvement and participation in the innovative activity (Edmondson et al., 2004; Nembhard & Edmondson, 2006). This study contends that when status distance emerges between hired and incumbent engineers, even though hired engineers are with high status within a team, the perceived psychological safety of them may be influenced that may affect their innovative activity. In chapter 6, therefore, takes status into account, exploring the role of the status distance between hired and incumbent engineers, however, the focus is not on the direct effect between status distance and innovation, but rather on exploring linkage relationships by specifically focusing on knowledge flows amongst engineers and their perceived psychological safety. Thus, the following research question will guide the research:

4. *How does status distance between the hired and incumbent engineers affect knowledge flows and the perceived psychological safety of newly hired engineers?*

In summary, the main aim of this research is to provide an understanding of technological learning by hiring. The objectives of the research were threefold from sectoral to firm and individual level. First, this study examines China's semiconductor industry to set the scene for the study of technological distance and status distance. This, in turn, will increase our understanding of industry and technological learning by hiring along with its importance for follower firms' catching up. Secondly, this study investigates the effect of technological distance on the firm's innovation. Specifically, this inquiry focuses on the knowledge of hired engineers and its effect on the follower firms' exploratory versus exploitative innovation. Lastly, this study further explores technological learning by hiring by focusing on the role of the hired engineer's status (status distance) in building the firm's innovation by specifically exploring its linkage relationship – knowledge flows and perceived psychological safety. In so doing, this thesis does not only look at technological factors but also the sociological factor that is closely associated with technological learning by hiring.

1.3 Theoretical and empirical contribution

The literature indicates that technological learning by hiring plays an important role in building a firm's innovation (Kim, 1997; Schaefer, 2020). Previous research has stressed the importance of foreign knowledge in the technological learning process for follower firms to catch up with global leaders and illustrated how technological learning builds their innovation (e.g. Hobday, 1995; Kim, 1997, 1998; Mathews & Cho, 1999; Schaefer, 2020; Xie, 2004). That is, however, greatly underestimating the effects of hiring from global leaders. Generally speaking, most of the previous literature builds upon the idea of knowledge transfer through a partnership with global leaders, while to some extent ignoring the contribution of hiring from global leaders. One of the few exceptions is an empirical study by Schaefer (2020). Presented with the case of a Chinese multinational enterprise in the telecommunications sector, Schaefer found that hiring represents an important way to acquire state-of-the-art knowledge and build innovative capability. However, the context of this study is about the Chinese leading firm approached from an internationalisation perspective. Followers' cross-border hiring is an inevitable phenomenon in the globalised world economy, especially when accessing advanced technology through partnerships is limited. From a theoretical point of view, however, it is not clear about technological learning by hiring and the beneficial effect brought to follower firms. This research, therefore, aims to increase our understanding of followers' technological learning by hiring.

This research is mainly embedded in international business, and the main contribution thus is that the research advances the field of international business to consider technological learning by hiring and the firms' innovation. The international business study has identified that technological learning by cross-border hiring is an important channel for international knowledge spillover to the recipient countries or firms (Ejsing et al., 2013; Liu et al., 2010; Oettl & Agrawal, 2008). However, the extant international business study is shown to be insufficient for providing a full explanation of technological learning by hiring and its effect on the firms' innovation. To gain a clearer view, this study brings together technological learning by hiring and innovation by relying on intersectional fields, particularly those such as innovation and strategic management studies that have paid much attention to hiring engineers from other firms as the method for driving knowledge flows between firms and its effect on the firms' innovation (Braunerhjelm et al., 2020; Jain, 2016; Kaiser et al., 2015; Rosenkopf & Almeida, 2003; Slavova et al., 2016). This convergence of the literature stream also enhances the novelty of this research.

Specifically, this research, using innovation and strategic management fields that illustrate how international knowledge spillover through hiring affect the hiring firms' innovation (e.g. Braunerhjelm et al., 2020; Jain, 2016; Kaiser et al., 2018; Liu et al., 2010; Parrotta & Pozzoli, 2012; Slavova et al., 2016), studies both technological and sociological factors that are closely associated with technological learning by hiring. In terms of technological factors, this study steps forward from the existing literature that looks at knowledge spillover from one entity to another (Braunerhjelm et al., 2020; Rosenkopf & Almeida, 2003; Song et al., 2003), to investigate the knowledge of hired engineers by classifying it into distant or familiar knowledge and its effect on the firms' different dimensions of innovations: exploratory and exploitative innovation, and moreover by borrowing the lens of social psychological theories - namely information processing and categorisation theory.

Furthermore, technological learning by hiring is closely associated with a sociological factor that gives rise to the status distance between hired and incumbent engineers. However, related studies only had the assumption that status is embedded in hired engineers (e.g. Groysberg & Lee, 2009; Prato & Ferraro, 2018; Reschke et al., 2017; Zucker & Darby, 2014), and did not bring status to the forefront of the discussion. Taking status into account, this research, therefore, contributes to understanding unanswered questions regarding status distance by leveraging status literature that broadens our understanding in terms of the relationship between technological learning by hiring and innovation. At the same time, by studying the role of status distance in technological learning by hiring, this research also extends the study on the international knowledge spillover approached from an individual level.

This study contributes empirically to the related studies which illustrate hiring or worker mobility. Empirical research in this area is limited, mainly because most prior empirical research uses engineers' patent trajectories and patent citation data to indicate the hiring of engineers and to link them to inter-firm knowledge flows. Such studies valuably illustrate the role of hiring as a means for knowledge acquisition for the recipient firm (Rosenkopf & Almeida, 2003). However, these studies primarily adopted quantitative approaches to ascertain to what extent learning by hiring affects knowledge flows and innovation (e.g. Song et al., 2003; Irwin & Klenow, 1994; Parrotta & Pozzoli, 2012; Tzabbar et al., 2015; Slavova et al., 2016; Braunerhjelm et al., 2020; Kaiser et al., 2018; Storz et al., 2015). This thesis, in order to have a deeper investigation, conducted qualitative research, collecting data by using semi-structured interviews. This qualitative approach makes it possible to identify the knowledge of hired engineers, and its different effects on the firm's innovation, thereby investigating the 'how' question at the firm level. Moreover, it also enables us to explore the role of status distance from an individual level. Chapter 7 further elaborates on this study's contributions and implications.

1.4 Outline of the thesis

Having introduced the main aims, objectives and research questions in chapter 1, chapter 2 presents the current state of knowledge, starting from existing studies on followers' technological learning. The literature on technological learning has provided a general understanding regarding followers' technological learning and helped to articulate a research gap revealing a lack of understanding in terms of technological learning by hiring. After, a specific focus is presented by narrowing down to hiring and building upon the idea of knowledge spillover. A research gap revealing a lack of technological learning by hiring is presented and discussed.

Chapter 3 explains the study's methodology, an overview of the research approaches and methods adopted in this study, as well as data collection procedure is provided. As this study is a multilingual interview, how the researcher approached multilingual and cross-cultural interviewing in the fieldwork is also provided. The analysis and results of the data collected will be presented in each study in the following chapters.

The research setting of this thesis is the Chinese semiconductor industry. Chapter 4 presents the semiconductor industry including the discussion about the catching-up process of the Chinese semiconductor industry throughout the historical time period. This chapter provides a comprehensive understanding in terms of the catching up of the Chinese semiconductor industry by including actors, policies, the knowledge acquisition mechanisms and strategies that have been used, and presents why the mechanisms and strategies are adopted. After the process of catching up, the record of catching up is presented by using secondary data such as market value, patent counts filed in the United States Patent and Trademark Office (USPTO) and process technology, which presents to what extent China has achieved in catching up. In addition, the factors that affect catching up are examined by using the sectoral system of innovation perspective and followed with discussion and conclusion.

Chapter 5 addresses how hired engineers' distant knowledge affects the firm's innovation by categorising it into exploratory and exploitative innovation. As the chapter adopts qualitative research with a deductive approach, chapter 5 begins with the conceptual framework and propositions. The findings are discussed following the themes identified in the data analysis and tested propositions that have formed. This chapter closes with a summary of the findings of the study.

Chapter 6 is devoted to an exploratory study about status distance. At the start of the study, this chapter begins with literature. As little was understood about the status of hired engineers in learning by hiring literature, the study leveraged status literature. After the literature review, analysis and findings with discussion are provided. The findings are discussed following the themes identified through inductive data analysis. Two main themes are revealed, the knowledge flows among engineers and the perceived psychological safety of hired engineers. Chapter 6 closes with a summary of the findings of the study.

Chapter 7 provides the summary, main contribution and implications of the study. To consolidate the answer to the research question and objective, this chapter synthesises the overall findings. Detailed contributions to the empirical and managerial and policy implications of the study, limitations of the study are discussed, along with a suggestion for the future research agenda.

Chapter 2 Critical Literature Review

The previous chapter already illustrated that this study departs from the need to enhance insight into follower's technological learning by hiring. The literature review as presented in this chapter aims at positioning this study, establishing the importance of the study, and increasing our comprehensive understanding of its central constructs.

Section 2.1 gives a brief overview of the literature, based on studies of followers' technological learning, in which issues on the hiring can be found. The section illustrates how followers catch up with technological leaders through technological learning. Based on this same literature, the section provides a brief overview of learning by hiring, as a crucial way to access critical knowledge. Since the literature on follower's technological learning has mainly built on the idea of knowledge transfer, learning by hiring as a way of knowledge acquisition is rarely touched upon in this stream of literature. The following section, section 2.2, will focus on learning by hiring built upon the idea of knowledge spillover by specifically focusing on newly hired engineers' knowledge and status. Finally, the articulated gaps will be discussed, this serves to provide a rationale concerning the relations between the constructs.

2.1 Followers' technological learning

Followers are those who lag behind others and primarily aim to catch up with leaders (Kim, 1998). Followers are also distinct from latecomers, firms in developing countries will tend to be latecomers across a broad range of product and process technologies while followers usually refer to a firm's strategy in specific product technology, so a single firm could be a leader in some areas and a follower in others (Hobday, 1995). Many studies have looked at on successful catch up of follower firms in Newly Industrialised Economies (NIE). For instance, in the sectors of semiconductor industries in the 1990s and 2000s (Mathew & Cho, 2000; Hsu et al., 2008), Korean firm (Samsung) was a prior follower by the early 1990s, has caught up with the leader with its 4M DRAM, and other DRAM producers from East Asia came on stream in mid-1990s, from Taiwan, Singapore and Thailand (Mathews & Cho, 2001). In addition, in terms of process technology, Taiwan Semiconductor Manufacturing Company Limited (TSMC) became a leader caught up with the previous leader the U.S. firms such as Texas Instrument, and today Chinese semiconductor firms are considered as followers, closing the gap with technologically advanced firms.

Followers often face the situation to catch up with technological leaders by engaging in technological learning (Dodgson, 1991; Kim, 1993). Technological learning is the process by which firms engage acquisition and assimilation of existing technology and accumulate technological capability to enhance their competitive advantages (Hobday, 1995; Kim, 1997). It is often believed that, in general, followers, before being able to catch up with leaders mainly focus on acquiring technology or knowledge from technological leaders instead of developing their own advanced technology (Chang & Tsai, 2002). By acquiring technology, a follower may not only gain an advantage in terms of the cost of developing new technology but also reap the opportunity to modify the acquired technology into a more innovative one with rapid time. A large body of literature provided evidence about the prior followers who successfully caught up with leading firms through acquiring technology from them (Hobday, 1995; Kim, 1997; Mathews, 2004; Guo & Guo, 2011). Kim (1997, 1998) provided a comprehensive case study of the Korean semiconductor industry, showing that prior followers caught up with leaders by going through the process of learning by doing and progressing to learning by research.

The process of technological learning may differ depending upon the context of countries, industries, or firms (Kim, 1997, 1998; Teece et al., 1997), but as a common feature, technological learning is usually facilitated by knowledge acquisition strategies. Followers in the early development stage, in order to acquire knowledge, often build partnership or alliance relations with foreign partners (often global leaders) from advanced economies (e.g. Lall, 1993; Kim, 1997; Powell et al., 2005). Diverse strategies such as purchasing, collaborating, co-producing, co-developing are adopted by followers (Hobday, 1995; Kim, 1997; Lall, 1992; Xie, 2004). The prior followers such as Korean and Taiwanese semiconductor firms are typical cases that the previous studies have already provided the evidence that such strategies are used to acquire knowledge from global leaders thereby building technological and innovative capability (e.g. Hobday, 1995; Kim, 1993; Kim, 1997; Kim, 1998; Chuang, 2014).

Such strategies, in general, entail a direct knowledge transfer associated with training engineers, technological suggestion or feedback, engineering support from foreign partners. For instance, Original equipment manufacturers (OEM) and Joint ventures often accompany with the process of training engineers of follower firms or sending out the engineers to foreign site to be trained as a part of the partnership agreement, and licensing usually involves a contract for foreign partners to provide technological suggestion and support or guideline to the licensee. Besides, an indirect knowledge transfer also occurs during the process of collaboration (e.g. Lall, 1993; Hobday, 1995; Kim, 1997; Kim & Lee, 2002; Mathew, 2004; Powell et al., 2005; Guo & Guo, 2011; Chuang, 2014).

However, followers encounter difficulty in acquiring state-of-the-art knowledge from their foreign partners. Foreign partners would not transfer their valuable or state-of-the-art knowledge to follower firms as transferring may deteriorate their competitiveness advantage (Kogut & Zander, 1996; Song et al., 2003; Javorcik, 2004 in Liu, et al., 2010). For instance, Fan (2006) suggested that foreign partners would not transfer their most advanced knowledge to their Chinese partners in the telecom-equipment industry because Chinese firms may become their potential competitors so there is no reason for them to transfer advanced knowledge to Chinese partners. Due to the limited accessibility to advanced knowledge, followers, often go abroad by setting up a research and development (R&D) outpost close to their competitors. The extant studies have mentioned that follower's setting up of outposts close to the competitors enabled them to collaborate with technological leaders. In a related study, the case of Huawei, a newly emerged firm from China, which became the technological leader in the telecommunication sector, in its early development stage, set up subsidiaries abroad to improve technological capability through collaboration with partners (Lee et al., 2016).

More importantly, it provides an opportunity to hire experts from their competitors, and these engineers generate an important human resource for the future knowledge building of the follower firms. Kim (1997) produced a case study on the technological learning of the semiconductor firm, Samsung and suggested that hiring engineers is a critical way to acquire advanced knowledge. In the early development stage, Samsung set up an R&D centre in Silicon Valley to acquire critical knowledge through the hiring of engineers with semiconductor design experience from U.S. semiconductor firms. Kim briefly mentioned that hiring high calibre scientists and engineers was the most effective way to leapfrog ahead in building technological knowledge in semiconductors and led Samsung to become a pioneer in Korea. He also suggested that by hiring experts, firms could acquire capabilities that permit further knowledge to be built, provided the host firm creates the environmental conditions necessary to diffuse knowledge from experts to other members of the firm (Kim, 1997). In a similar manner, Chinese followers such as Zhongxing Telecommunication Equipment Corporation (ZTE) were able to engage skilled engineers in their investment locations and was able to continuously learn from its technological advanced partners by building R&D outposts outside of China (Fan, 2006). Going abroad in the early time increased the opportunity to access state-of-the-art knowledge that is not shared by their foreign partners, this has been a crucial driver to accelerate generating innovative capability, thereby catching up with leaders in the future (Kim, 1998; Athreye & Godley, 2009; Schaefer, 2020).

While these studies have briefly stressed the significance of hiring for follower's technological learning, in the recent study, Schaefer (2020) has provided technological learning by focusing on hiring. He has provided the catching up of the Chinese telecommunications equipment manufacturer Huawei as a case study by specifically focusing on hiring offshore experts at foreign greenfield R&D subsidiaries. Huawei went abroad close to the location of competitors to access state-of-the-art knowledge through hiring R&D experts when they had little left to learn in their home country. He provided how their offshore experts using their skills in technological knowledge, experience, language, and embeddedness in a local and global industry network help Huawei build up the knowledge stock and maintain the innovative capability.

In brief, the reviewed studies provide support for the view that hiring plays an important role in a follower's technological learning. However, most of the existing literature on technological learning pays a great deal of attention to diverse strategies of knowledge acquisition through establishing partnership relations with foreign partners while to some extent ignoring the contribution of hiring strategy. It is mainly because most of the studies have focused on the followers' technological learning by mainly building upon the idea of knowledge transfer. Knowledge transfer often requires the transferor's willingness to transfer their knowledge to transferees. As illustrated above, transferors (foreign partners) would be reluctant to transfer advanced knowledge to their partners who may become potential competitors.

Related literature has touched upon hiring as a way of acquiring state-of-the-art knowledge but based on the view of the internationalisation in the location to gain a competitive advantage. That is, the existing literature of technological learning approached from a narrow perspective. Hiring from global leaders entails knowledge flows (Bell & Albu, 1999; Schmitz & Nadvi, 1999; Oettl & Agrawal, 2008), and provides a way for firms to obtain knowledge without the approval of knowledge holders (Teece, 1982; Winter, 1987). In other words, followers can use the strategy of hiring to access state-of-the-art knowledge that enables followers to build innovative capability, but not many studies have paid attention to it. In order to fill this gap, this study investigates technological learning by hiring from global leaders building upon the idea of international knowledge spillover. The next section of this literature will focus on examining hiring and its effect on the firms' innovation.

2.2 Effect of technological learning by hiring on innovation in the high-technology industry

A brief review of the relevant literature shows that no specific attempt so far has been made to investigate the effect of technological learning by hiring. This section, therefore, provides the effect of technological learning by hiring on a hiring firm by building upon the idea of knowledge spillover. Table 2-1 provides the existing literature on hiring and knowledge spillover and innovation this research has mainly looked at. Knowledge spillover arises from the fact that the tacit knowledge behind innovations becomes embedded within a person (Dose, 1988), and once this person is hired, the knowledge embedded in them also come along with them, regardless of geographical distance (Rosenkopf & Almeida, 2003; Song et al., 2003). Technological learning by hiring has initially received attention since Arrow's seminar paper. Arrow (1962) in his seminar paper had linked labour mobility and knowledge spillover as a critical way to access external knowledge. According to him (1962, p. 615) "mobility of personnel among firms provides a way of spreading information. Legally imposed property rights can provide only a partial barrier since there are obviously enormous difficulties in defining in any sharp way an item of information and differentiating it from other similar-sounding items." Two points can be illustrated here, one is that not all knowledge can be protected by legal means another point is that important knowledge can be acquired by hiring personnel from other firms.

Table 2-1 Selected studies on hiring and knowledge spillover, innovation

Authors	**Journal**	**Methodology/ approach**	**Industry**	**Finding**	
Zander & Kogut, 1995	Organisational Science	Case study and the questionnaire	Swedish manufacturing industry	Mobile personnel between firms enhance the knowledge spillovers in the form of imitation	Inter-firm hiring within a country
Zucker & Darby, 1997	Research Policy	Interview	Pharmaceutical firms	Large pharmaceutical firms have transformed their technological identity in drug discovery from a chemical/random screening to a biological/drug model primarily through hiring many new scientists embodying biotechnology.	Intra-firm and interfirm hiring
Almeida & Kogut, 1999	Management Science	Tracking patent inventor by using country-level establishment and employee data	Semiconductor	Inter-firm movement of patent engineers spurs knowledge transfer. Knowledge localization is specific to only a certain region and that the degree of localization varies across regions	Inter-firm hiring within a country
Song et al., 2001	Seminar paper	Case study	Semiconductor industry	The return of Koreans and Taiwan who were previously employed from U.S. firms brought similar patenting practices during the early stage of development.	Cross-border hiring
Song et al., 2003	Management Science	U.S. patent and patent citation data	Semiconductor industry	Learning by hiring is more likely to result in interfirm knowledge transfer when the hiring firm is less path-dependent, the hired engineers possess technological expertise distant from that of the hiring firm, and the hired engineers work in noncore technological areas in their new firm.	Cross-border hiring
Rosenkopf & Almeida, 2003	Management Science	Tracking patent citation	Semiconductor	Inter-firm mobility of engineers and patent citations in the U.S. semiconductor industry, the inter-firm movement of engineers carries knowledge from the prior employer.	Inter-firm hiring within a country
Palomeras, 2004		Patent	Semiconductor industry, IBM to competing firms	The patents are significantly different from patents by no-mover; moves to depend on the quality of the inventor's work, his experience in the industry and the firm and the number of co-inventors he has worked with.	Inter-firm hiring within a country
Cassiman & Veugelers, 2006	Management Science	Community Innovation Survey (CIS)	Belgian manufacturing industry	Found 42% of innovative firms use hiring to access external knowledge (internal R&D and external knowledge acquisition)	Inter-firm hiring within a country
Simonen &McCann, 2008	Small Business Economics	Community Innovation Survey (CIS)	Finland firms	Innovation outcomes of Finnish firm and the proportion of workforce hired	Inter-firm
Oettl & Agrawal, 2008	International Business Studies	Patent citation	The source firm/country to receiving country dyad year	The inventor's new country gains from her arrival above and beyond the knowledge flow benefits enjoyed by the firm that recruited her (National learning by immigration) The firm that lost the inventor also gains by receiving increased knowledge flows from that individual's new country and firm (firm learning from the diaspora)	Cross-border hiring
Tzabbar, 2009	Academy of Management	Patent data	Biotechnology industry	Firms tend to exploit new hire's prior inventions.	Inter-firm hiring within a country

				Hiring distant scientists enhance the likelihood of significant technological repositioning by a firm	
Singh & Agrawal, 2011	NBER Working paper	Pre-move versus post-move citation rates, (Patent citation rate)	All technology classes	Knowledge acquisition through hiring increases access to new hire's prior invention (exploit their own idea)	Inter-firm within a country
Filatotchev et al., 2011	Research Policy	The annual report. The dataset ‘ returnees are legal representatives’ and the numbers of patents	High-tech firms in Beijing Zhongguancun Science Park	Returnee entrepreneurs are a significant source of external knowledge spillovers affecting the firm's innovation, and that returnee also facilitates knowledge spillovers to non-returnee SMEs.	Cross-border hiring
Parrotta & Pozzoli 2012	RAND Journal of Economics	Danish employer-employee register	Danish firms	Learning by hiring enhances productivity at the firm level	Inter-firm within a country
Storz et al., 2012	Research Policy	Carrier histories. Internet website MobyGames by collecting reviews from leading industry magazines	The video games industry in the US and Japan	Mobility and innovation (reviews) in cross-country comparisons. Found that inter-firm mobility is beneficial for innovation in the US, negative effect in Japan. And individuals who have worked in multiple functions are more likely to contribute to the development of an innovative game in both countries.	Inter-firm within a country
Ejsing et al., 2013	IZA Discussion paper	Patent data and matched employer-employee data	Danish firms	New joiners contribute more than long-term employees to innovative activity. Newly hired former university researchers contribute more to innovative activity than newly hired recent graduates or joiners from firms.	Inter-firm hiring within a country
Tzabbar & Kehoe, 2014	Journal of Management	Patent	U.S. Biotechnology industry	Star scientist turnover decrease exploitation while increasing exploration	Inter-firm hiring within a country
Kaiser et al., 2015	Journal of Economic Behavior &Organization	Danish linked employer-employee data	Danish firms	Hiring R&D workers increased the number of patent applications of the hiring firms in Denmark	Inter-firm hiring within a country
Slavova et al., 2016	Organization Science	A longitudinal analysis	U.S. academic chemical engineering department	Hiring scientific personnel is likely to have positive effects on the performance of incumbent scientists with shorter organisational tenure; the positive effect of hiring on the performance of incumbent scientists is weaker for the department with more diversified research expertise.	Inter-firm hiring
Kaiser et al., 2018	Strategic Management	Patent and linked employer-employee data	Danish firms	Inward mobility of researchers has a positive effect on the level of innovation output in private business firms. The newly hired researcher with university experience has a greater effect on innovation than other types of inward mobility.	Inter-firm hiring within a country
Prato & Ferraro, 2018	Organization Science	The difference in differences regression (Institutional Broker Estimate System database)	Securities analysts in the U.S.	The higher the status of the newcomer, the greater the decline in the performance of incumbents, the performance of lower-status incumbents is declined more than high-status incumbents	Inter-firm
Peeter et al., (2019)	Global Strategy Journal	Elo rating (average of past game results) over 1980-2015	International men's football	The manager from high know-how countries enhances the performance of their arrived country's team. Cultural distance between a manager and the arrival country deteriorates the effectiveness of hiring, but this effect is diminished when the hired manager has high levels of international experience.	Cross-border hiring

Braunerhjelm, et al., (2020)	European Economic Review	Matched employer-employee dataset (patent application data) 2001-2008	Swedish firms	Mobility of R&D workers has a strong positive and considerable effect on firm innovativeness (patent applications)	Inter-firm hiring within a country
Van der Wouden & Rigby (2021)	Industry and Innovation	Tracking inventors by using patent data		Firm mobility and spatial mobility enhance the productivity of inventors. The influence of firm mobility on inventor productivity is larger than the influence of geographical mobility alone.	Inter-firm within a country

Building upon this idea, scholars (Almeida & Kogut, 1999; Rosenkopf & Almeida, 2003; Song et al., 2003) tracked engineers in a study of semiconductor firms and found that the engineers spur knowledge flow between firms. While these studies focused on intra-firm and inter-firm learning by hiring within a country, some studies have further given significance to cross-border learning by hiring as the potential to be an important driver of knowledge spillover and innovation. For instance, Song et al., (2001, 2003) found that knowledge flows from the U.S semiconductor firms to Korea and Taiwan, suggesting that the recipient firms gain knowledge from global leaders and that these engineers can play crucial roles in contributing to the technological development and catching-up of Korea and Taiwan in the semiconductor industry. In a similar vein, based on high-tech firms in Beijing Zhongguancun Science park, Filoecdatotchev et al., (2011) found that individuals returned from Organisation for Economic Co-operation and Development (OECD) countries to China are an important source of international knowledge spillover, and create significant spillover effect that facilitates innovation in high-tech firms in China, even to non-returnee firms when they possess sufficient level of skill intensity or absorptive capability.

The knowledge that is entailed by hired engineers is often the knowledge of hired engineers' previous employers. As shown in the table below, for instance, Zander and Kogut (1995) found that hiring engineers from other firms enhance the knowledge spillover in the form of imitation. In a related vein, Song et al., (2001) suggested that engineers who moved from the U.S. brought similar patenting practices to Korean and Taiwanese semiconductor firms. Similarly, Rosenkopf and Almeida (2003) noted that hiring from one semiconductor firm to another is positively associated with the recipient firm's likelihood of subsequently citing hired engineers' prior employer. Later, Tzabbar (2009) confirmed that firms tend to exploit new hires' prior invention, by using the patent citation, and found that hiring increases the citation rate of the hiring firms. In a related vein, Scholars like Singh & Agrawal (2011) concluded that new hires after moving to new firms tend to exploit their own prior idea, also using a patent citation, and found that firms considerably use the new hire's prior ideas.

The existing studies examined that such knowledge that is carried by hired engineers increases the recipient firm's knowledge stock, innovative performance and innovation, as shown in Table 2-1 (Braunerhjelm et al., 2017; Kaiser et al., 2015; Simonen & McCann, 2008; Tzabbar, 2009; van der Wouden & Rigby, 2021). For instance, using employer-employee datasets (firm-level patent) in Sweden, Braunerhjelm et al. (2017), also found that the hiring of R&D workers has a strong positive effect on firm innovativeness, measured as patent applications. However, the outcome of learning by hiring may differ contingent on the knowledge of hired engineers. It is highlighted in the study of Kaiser et al., (2008), who divided the firm workforce into R&D workers and non-R&D workers to find how hiring workers affects innovation in Danish firms and more in detail how the composition and past experience in patenting activity influence the firm-level patenting activity. The results show that newly hired R&D workers contribute more to the firms patenting activity than immobile R&D workers, and this effect is stronger when the R&D worker has been previously worked in a patenting firm, but they also find weak evidence that R&D workers carry a greater amount of knowledge than non-R&D workers. This finding implies that when the innovative activity is limited to patenting, their contribution is also limited to patents, and when the hired engineers do not engage in patenting activity, the contribution may likely lead to different consequences.

In the related literature, the existing studies have implicitly provided some clue that depending on the knowledge of hired engineers, the consequences that are resulted from learning by hiring may be different. For instance, Rosenkopf and Almeida (2003) suggested that the effectiveness of the movement of engineers regarding knowledge flows increases when technology between hired engineers' previous firm and the recipient firm is distant. It is because when two firms possess distant knowledge, the recipient firms would be more likely to gain knowledge that is new to them. In a similar vein, Song et al. (2003) have further confirmed that hiring engineers whose knowledge is distant is more likely to generate knowledge flow, since engineers may conduct exploratory activity within a firm, otherwise, newly hired engineers may tend to work within the firm's existing trajectory when their knowledge and firm's core technological domain is not distant. Hiring individuals with distant knowledge may enable technology firms to gain access to new knowledge (Almeida & Kogut, 1999), reinvigorate existing knowledge and creating new capabilities for the firm (Gavetti & Levinthal, 2000). In a similar vein, Zucker and Darby (1997) found a fresh injection of distant knowledge can seed transformation in technological identity, showing that a pharmaceutical firm in drug discovery has successfully transformed the technological identity from a chemical/random screening to a biological drug design model. This was achieved by hiring many new scientists specialising in biotechnology, which led to the acquisition of knowledge by the existing personnel. This has been supported by the finding of Tzabbar (2009), that firms hiring engineers whose knowledge is distant can allow firms to reposition them technologically (Tzabbar, 2009). Rahko (2017) further suggest that hiring engineers whose knowledge is distant and technologically related but not too similar bring complementary knowledge and skill that lead to a beneficial effect on the recipient firms' future innovation.

On the other hand, scholars also found that firms are more benefited by technological learning by hiring when hired engineers' knowledge that is not distant but familiar to the hiring firms. For instance, Simonen and McCann (2008) demonstrate the relationship between the innovation outcomes of Finnish firms and the proportion of their workforce hired from outside their region and found a positive impact of hiring workers who previously worked on innovation in the same industry. In a similar vein, Slavova et al., (2016) found that in the academic field, hiring individuals with less distant knowledge will likely reap greater benefits from technological learning by hiring. Hiring engineers with familiar knowledge may gain external knowledge and exploit procedures and routines previously acquired in other firms with similar technological profiles (Parrotta & Pozzoli, 2012). These results indicate that when knowledge is not distant, the relative absorptive capacity of the recipient firm is greater, so the firms will find it easy to assimilate and use this knowledge (Lane & Lubatkin, 1998). More importantly, hiring engineers with familiar knowledge enables the hiring firms to better support hired engineers, therefore, increasing their performance, it is because the work practices and processes are already in place for hired engineers to access, otherwise, firms have to create new organisational structures to support newly hired engineers (Groysberg & Lee, 2009). These findings are also interpreted as evidence that hiring engineers whose knowledge is not distant may increase the possibility that hired engineers may conduct innovative activity in accordance with firms' existing technology.

In the extant literature of technological learning by hiring based on knowledge spillover, scholars have focused primarily on the knowledge spillover that can emanate from hired engineers as the critical mechanism that positively affects the hiring firm's innovation. By considering technological learning by hiring, however, most scholars have not contemplated that the hired engineers, besides their knowledge, the status of engineers might also play an important role in building the firm's innovation. In the previous studies, scholars have provided the positive knowledge spillover that translates high-status hiring into a better individual and organisational performance (Azoulay et al., 2010; Oettl, 2012; Reschke et al., 2017; Tzabbar et al., 2015). The status of the hired engineer enables them to provide the authority to have control over others, conduct control roles in a firm's innovative activity. For instance, Clark and Fujimoto (1991) find that, within automobiles, a heavyweight product manager is a senior manager who possesses the substantial formal and informal influence to assign people, allocate resources, and direct the development team effort (Koufteros et al., 2002; Fujomoto et al., 1996; Clark & Fujimoto, 1991; Wheelwright & Clark, 1992; etc in Rauniar et al. 2008).

Kehoe and Tzabbar (2015) suggested that the presence of high status in organizations might be a mixed blessing for their colleagues: even though they increase their colleagues' productivity, but their colleagues become more dependent on them and contribute fewer innovative ideas. In a similar vein, Reschke et al., (2017) suggest that one's status can result in negative consequences on others as the existing distribution of power and resources induced by high status may negatively affect the performance of incumbents. Prato & Ferraro, (2018) further find that hiring engineers with high status are more likely to deter the performance of incumbents, especially incumbents with lower status suffer more than incumbents with higher status. Such studies have supported the so-called Matthew effect by standing on the position, rich get richer, and the poor get poorer (Prato & Ferraro, 2018). High-status engineers perceive the advantage over lower status (Podolny, 1993), have benefited more from resource advantages and opportunities than others (Merton, 1968). This eventually increases the dependency of low status on high status, cause lower status engineers may be less likely to take initiative or get involved in active participation in creating new knowledge. As such, the status distance between engineers may play an important role in building the firm's innovation. This study, therefore, takes status into account and explore the role of the status distance between hired and incumbent engineers on the hiring firm's innovation.

2.3 Summary

Several conclusions can be drawn from the literature review. First, follower firms' technological learning from the perspective that learning is facilitated by knowledge acquisition through relying on foreign partners is presented. This steam of literature helped us to understand that followers, in order to acquire advanced knowledge, resort to hiring strategies that provide a way to access to state-of-the-art-knowledge that is not easily transferred by their foreign partners. The literature on technological learning suggests that hiring engineers from global leaders can play a critical role in building the innovative capability of followers. However, our understanding of technological learning by hiring still remains unclear. It is mainly because the literature of followers' technological learning is mainly built upon the idea of knowledge transfer, pays a great deal of attention to the strategies to get access to foreign knowledge by establishing a partnership with foreign firms while to some extent ignoring the contribution of hiring method to get access to foreign knowledge. That is to say, technological learning by hiring has not been focused on in the previous literature. Although some studies have touched upon hiring as a way to gain access to state-of-the-art knowledge and its effect on the innovative capability of followers, the approach is from a narrow perspective. These studies primarily focused on the internationalisation of followers, that followers set the R&D facility in abroad close to their foreign competitors in order to gain access experts that can help them to build firm's innovation capability and the competitive advantage. Thus, the effect of technological learning by hiring from global leaders on follower's innovation is not clear. To fill this gap, this study focuses on the follower's technological learning by hiring.

Second, section 2.2 provides us with a more detailed view in terms of technological learning by hiring. By building upon the idea of knowledge spillover, the previous studies have investigated the knowledge spillover through cross-border hiring (Filatotchev et al., 2011; Song et al., 2003). These studies provide the view that hiring engineers from other firms typically involves the flow of knowledge that may foster the recipients' innovation. In addition, the knowledge that is entailed through learning by hiring is identified by many scholars. They found that knowledge is often from hired engineers' previous firms and such knowledge leads to a beneficial effect on the recipient firms' innovation. This empirical literature has often interpreted patent citations as the knowledge that reveals to what extent knowledge flows from one firm to another firm (e.g. Song et al., 2003; Irwin & Klenow, 1994; Parrotta & Pozzoli, 2012; Tzabbar et al., 2015; Slavova et al., 2016; Braunerhjelm et al., 2017; Kaiser et al., 2018).

Third, although the previous studies on technological learning by hiring do not explicitly address the distant knowledge of hired engineers on the firm's innovation, references in these studies can be found suggesting that the knowledge of hired engineers can lead to a differing effect on the firm's innovation. Studies in the field indicate that hiring engineers whose knowledge is distant may increase new technological potential (Rahko, 2017; Tzabbar, 2009; Zucker & Darby, 1997) while hiring engineers whose knowledge is familiar can accelerate the beneficial effect from learning by hiring (Lane & Lubatkin, 1998; Simonen & McCann, 2008; Slavova et al., 2016). The hiring of engineers contributes to a firm's innovation and the different consequences may depend on the knowledge of hired engineers but it is not clear and somehow implicit. Consequently, there is a lack of understanding of how hired engineers' distant knowledge affect the hiring firm's innovation. Therefore, for a clear view, this study explicitly studies the knowledge of hired engineers (whether distant or not) and their effect on the firms' innovation as the outcome of technological learning by hiring. In this investigation, such innovation is characterised as lying along an exploratory and exploitative dimension. As a result, this research has identified knowledge of hired engineers and its contribution to a different dimension of innovation - exploratory innovation versus exploitative innovation.

Fourth, by focusing on technological learning by hiring, the status of hired engineers is also acknowledged to play an important role in building the firm's innovation, but it has received somewhat less attention. The previous studies suggest that hiring engineers whose status is high may lead to positive knowledge spillover by translating high-status engineers into better performance of individual and organisation (e.g. Oettl, 2012; Song et al., 2003; Tzabbar et al., 2015). Such studies have only assumed a status that embeds in hired engineers and did not bring status into the centre of the discussion. This study explicitly explores the status of hired engineers and adds value to the current literature on technological learning by hiring.

Chapter 3 Methodology

3.1 Introduction

The literature review presented in Chapter 2 demonstrated that technological learning by hiring as a method of knowledge acquisition is a critical way for followers to acquire or learn external knowledge, therefore, building their innovation which has been paid less attention in the literature until now. The aim of this thesis is to investigate the effect of technological learning by hiring on firms' innovation in the context of the follower firms in the semiconductor sector. This thesis adopted qualitative research as it provides insights that are challenging to produce with quantitative measures, by providing in-depth viewpoints (Rynes & Gephart, 2004) of technological learning by hiring. Besides, Mawdsley and Somaya (2015) noted that technological learning by hiring literature would benefit from research using a qualitative approach, such as interviews involved in hiring events, which would help identify and tease out significant information that is not observable in quantitative studies.

This chapter will illustrate in more detail how this research is designed and why; clarifying the research approach, the methods, the conducted research activities and the approach for data analysis.

3.2 Research approach

The research question would arise from a gap in the literature or based on observing empirical phenomena (Lawrence & Phillips, 2019). The former may not fit with the real-world phenomena while the latter may not fit with the existing literature. To bridge these gaps, the research questions of this study are based on a combination of a gap in the literature and a real-world phenomenon. This study, in order to give reliable and valid answers to the study's research question, adopted the qualitative approach. "Qualitative research is also known as an unfolding model that occurs in a natural setting that enables the researcher to develop a level of detail from high involvement in the actual experience" (Creswell, 1998), which is often the phenomenon that is investigated from the participant's viewpoint (Williams, 2007).

Qualitative research could be used to overcome the shortcoming of quantitative methodology as it helps to explore unclear or unexpected issues or phenomena that lack understanding and information (Corbin & Strauss, 1990). Technological learning by hiring may not be an unknown phenomenon, however, the knowledge of newly hired engineers on the hiring firm's different dimensions of innovation seems relatively unknown. In particular, this study focuses on the hired engineers' knowledge by categorising it into distant or not distant (familiar) in contributing to the hiring firm's innovation, an area in which the qualitative research method is more appropriate as this involves the individual's experience, meaning and perspective, and most often from the standpoint of the participant (Meyer, 2001). With qualitative methods, the research was able to probe for in-depth explanations about how the hiring firm's innovation is affected by the distant knowledge of hired engineers, from the perspective of managers, hired engineers, and incumbent engineers experiencing the phenomena.

Moreover, qualitative research has a literary and humanistic focus, which is both description and understanding of the actual human interactions, meanings and processes that comprise a real-life organisational setting; this is different from quantitative research that is grounded in mathematical and statistical knowledge (Rynes & Gephart, 2004). Qualitative research is well-suited for understanding phenomena within the context, uncovering links among concepts and behaviours, and generating and refining theory (Glaser & Strauss, 2017; Patton, 1990). It is useful to better understand relatively unknown phenomena in that it permits the researcher to delve into and uncover the underlying assumptions, beliefs and values (Yauch & Steudel, 2003). In this instance, a qualitative research approach is appropriate for this study in that it focuses on status distance between engineers, which in turn involves human interactions and interpersonal relations, and which is a relatively unknown phenomenon in technological learning by hiring study.

This relatively unknown phenomenon is investigated from the participant's viewpoint (Williams, 2007) rather than the concrete realities of objects (Erlingsson & Brysiewicz, 2013). Qualitative research is especially useful in exploring the meaning that people give to events based on their experience as it is less structured, more open-ended and flexible. It enables participants to have an opportunity to reveal their perspectives about the phenomenon under investigation without the research imposing any predetermined concepts and opinions on them (Azungah, 2018). The researcher employs constructs and meanings in use by participants to explain their experience in the organisation they have joined. Qualitative research is, therefore, more likely to provide meaningful data and clarity to the research question and concepts that relate to the status distance between engineers.

Qualitative methods typically focus on understanding relatively small samples in a more in-depth manner (Patton, 1990), and permits a unique understanding which is difficult to gain from the quantitative method. This study contends that qualitative research, in particular, is useful to investigate technological distance on a firm's exploratory and exploitative innovation and explore in greater detail how the status of hired engineers affects knowledge flows and the perceived psychological safety. However, it does not mean that qualitative research cannot be generalizable. According to Manson (2002), qualitative research should produce explanations or arguments rather than just descriptions. These explanations or arguments should also be generalizable in some way or have some demonstrable wider resonance.

In addition, it is noted that researchers that mainly deal with cross-cultural data which is emic in nature (Buckley et al., 2014), and emic perspective are affiliated with subjective/idiographic/qualitative/insider terms (Buckley et al., 2014). Emic applies in only a particular society that differs from ethics that perceive reality as objective, cultural-free or universal aspects of the world (Azungah, 2018). The emic viewpoint tends to avoid imposing the researcher's constructs on research participants and focuses on understanding the insider's contextualised experiences, viewpoints, perceptions, meanings and interpretations of social phenomena (Evered & Louis, 1981). The emic perspective favours the study of technological learning by hiring that focuses on technological distance and status distance from the point of view of hired engineers and managers, and incumbent engineers of the host country within their work context.

3.3 Data collection

This thesis has mainly relied on interviews and secondary materials. Although the interviews are the main data collection method adopted in this research, secondary data is heavily used for data collection in chapter 4 that presents the semiconductor industry. Before providing the main data collection method which is the interviews, this section will discuss how this research used the secondary material first.

3.3.1 Secondary materials

Before presenting the secondary data collection, it is important to understand the current situation of the Chinese semiconductor industry. During the last few decades, China's export of semiconductor chips has consistently increased. In 2019, the export of China's semiconductor chips accounted for 108 billion dollars, it is the second-largest exporter in the world, and the 3rd most exported product in China[1]. However, ironically, the production by Chinese indigenous semiconductor firms only accounted for a small portion, while the main production was from manufacturers headquartered outside of China. Since 2005, China has become the world's largest consumer of semiconductors, but around 90% of the semiconductors used by China are either imported or made by China-based foreign chipmakers[2]. China has remained highly reliant on foreign countries for semiconductor supply, and as a result, semiconductor chips have been the top imported product by China[3]. According to the China statistical yearbook (2020), China imported 350 billion dollars worth of chips in 2020, a 14.6% increase over 2019. It is noted that the data on export and import does not reveal the key differences between China's

[1] Source: China statistical yearbook, 2019
[2] Matthew Fulco, Betting All the Chips: China Seeks to Build a World-Class Semiconductor Industry, CKGSB Knowledge, November 29, 2018, Available at: https://knowledge.ckgsb.edu.cn/2018/11/29/technology/china-semiconductor- industry/.
[3] China statistical yearbook, 2019

imported and exported semiconductors, however, from the import side, electronic device makers in China rely on leading-edge semiconductors as inputs into the assembly of electronic devices such as smartphones, and telecommunications equipment, while from the export aspect, China produces lower-end semiconductors (Bown, 2020). Due to such a phenomenon, it is difficult for us to capture an accurate record of catching up by using export data. This study, therefore, instead of using export data as an indicator of catching-up, uses the data of market share by each segment, patents, and process technology (feature size) that is relevant to the research topic to form a record of catching-up. Table 3-1 provides the secondary data source used in this study.

Table 3-1 Data source

Type of data	**Collection period**	**Location and Data source**	**Major content and data coverage period**	
Market shares by segment	2021	Financial statements, WSTS, SIA, SEMI, IC Insight, Yole, VLSI Research, compiled by CSET	Semiconductor value add and market shares by segment and firm's HQ locations	Catching up records
Patent data	2020	OECD patent data (USPTO)	Patents grants referring semiconductor classes (1999-2018)	
Process technology node	2019	TrendForce; iSuppli; McKinsey analysis; SEMI China; IC Insights; firm's annual report	Semiconductor process technology (node by foundries) (2001-2019)	
Other secondary data	2018-2020	Previous works of literature; U.S. Chamber of Commerce; Made in China 2025	History of the Chinese semiconductor industry including the key actors, institutions and policies, innovative activity, and strategies for learning and knowledge acquisition	History and factors affect catching up

Specifically, the market shares by segment are used to see the overall picture of each segment and a record of China's catching up. It particularly provides an overview in terms of who is leading the global semiconductor market and how the semiconductor segments are integrated one to another. Additionally, based on the regions that are identified in the market share, this study also looked at the patent data. Many previous works in the literature used patents as a part of the innovative and technological activity of the specific country in specific industry and technology (Lin et al., 2006; Lee et al., 2008; Kwak & Yoon, 2020). Semiconductor-related patents possessed by a country show the country's technology quantity and quality, thus, patent possessed by the country is valuable in measuring China's record of catching up. In this study, patent grants at USPTO by referring to International Patent Classification (IPC) on semiconductor-related technology (H01L) were extracted from the OECD database. “H” is the sector in which semiconductor technology belongs within “Electricity”, “H01” is the class in which covers basic electric elements such as processes involving technical art such as drying or coating, “H01L” is a subclass, covers semiconductor devices; process; electric solid state devices not otherwise provided for. The categorisation of “H01L” covers varied semiconductor-related technology as a relevant measure of catching up records. In addition to it, the share of categorisation of “H01L” relative to the share of total patents in electricity, the categorisation of “H”, filed in USPTO by China and other regions and the growth rate of the patent by each country is also provided. The selected regions include China, the US, Korea, Japan, the EU and Taiwan that are identified from the market share by segment.

While patent counts enable us to look at the catching up record in semiconductor-related technology, the technology node by each region reveals the catching up record in a more specific segment. The technology node means the feature size[4], referred to as the semiconductor manufacturing process used to identify the technology generation of a chip (Platzer et al., 2020). A technological node can directly refer to the technological capability specifically in process technology as it is tightly linked to the performance of the products manufacturable by the production process (West, 2000). When the feature size is smaller, the chip is more powerful because more transistors can be placed on an area of the same size, so the products function more rapidly and the performance will be greater (Platzer et al., 2020). Over the past decades, leading-edge technology leadership has been required to shrink the feature size. In line with Moore’s Law[5], the industry’s innovation path for semiconductors is the number of transistors embedded in an integrated circuit (IC) would double around every 18 months to two years. Over the past decades, technological leadership in the semiconductor industry has followed Moore’s Law by shrinking the feature size every two years. This study, therefore, included and compiled the information regarding the semiconductor process technology from semiconductor specialised journals and the annual report of the firms.

One of the purposes of this study is to examine the history of the Chinese semiconductor industry and the factors that influence the catching-up of the semiconductor industry of China. The histories presented in this study represent a brief overview of the development of the semiconductor industry of China by including the key actors, mechanisms used for learning or knowledge acquisition, and policies of the semiconductor industry. The documents such as firms annual reports and industrial reports were rich in information which were useful to understand the semiconductor technology that enables us to

[4] Feature size is the size of the transistor gate length as measured in billionths of a metre, or nanometres(nm).
[5] Moore’s Law was first described by former CEO and co-founder of Intel Corporation, Gordon Moore in 1965. It is well known with theory of Moore’s Law (Platzer et al., 2020).

have a clear view in terms of the following studies. Moreover, the previous literature was consulted to construct a historical evolution of the industry and to identify key dates and developments throughout the time period.

3.3.2 Interview

Interviews are the main data collection method adopted in this research. Interviews are an established method of understanding the views, perceptions and opinions of research subjects through language (Easterby-Smith et al., 2008). They provide an opportunity to engage with interviewees who are involved in the issues under investigation. The interview provides a unique opportunity to uncover rich and complex information from an individual (Cavana et al., 2001, pp. 138) by engaging with interviewees who are involved in the issues under investigation. The type and range of interviews are diverse and provide much flexibility in collecting data, including structured, semi-structured, open-ended, face-to-face, telephonic, one-on-one, computer-assisted, group interview etc (Khan, 2014). This study adopted the semi-structured interview because semi-structured interviews correspond with the qualitative research design for answering the question “how” (Azungah, 2018), which enable the answering of the research question of this study.

Besides, the semi-structured interview allows and enables the researcher to have prepared a topic guide or relevant questions to be covered with each interviewee in one setting (Polit & Beck, 2008). The question of the semi-structured interview is not too specific as the intention is to allow the participants to talk on their own terms. Also, the interview questions are not given in any order, rather it is provided in a way that develops the conversation. The semi-structured interview allows the researcher to start with more general questions or topics, which the researcher has initially questioned with general questions in terms of the industry as a whole and later leading to the more specific and sensitive questions.

Semi-structured interviews are flexible and enabled the researcher to approach different interviewees in varied ways (Azungah, 2018). Due to the high sensitivity of industry, it is difficult to gain permission to access the firms, even with personal connections the researcher was not permitted to gain the access to the inner part of the firms. It is largely because the tension of the trading war peaked during the research, interviewing technology-intensive firms was not allowed within China. For this reason, the researcher did not recruit participants through their organisations, rather interviewees were contacted individually, and used snowballing techniques through the researcher’s personal contacts, social networks, previous work and the LinkedIn platform. The personal contacts and social networks enabled the researcher to approach interviewees directly by introduction. For the case of the LinkedIn platform, the researcher used the filtering function to select the potential interviewees by using the name of their current firms (Indigenous firms) and the interviewees' previous firms (global leaders) and, extracted the list of 500 potential interviewees. The researcher emailed all the potential interviewees, but less than 10 per cent of people contacted were able to participate in the interview. As a result, 29 people from 14 Chinese semiconductor firms were used in this study. The interviewees who agreed to participate in the project were again confirmed with a company card to examine whether they are qualified for data collection or not.

Among selected firms, foundry A is the pure-play foundry model, it is one of the biggest among China's semiconductor manufacturers, and is rapidly catching up with global industrial leaders while narrowing the technological gap. The researcher interviewed managers at three different plants of foundry A in different cities. Foundry B is one of China's largest manufacturers of electronic components, as well as one of the world's largest manufacturers in a specific technology. The rest of the firms are fabless firms that are selected from the list of China's top 30 leading fabless firms. Specifically, some fabless firms such as fabless A, B, C. ranked in the top 50 fabless IC suppliers worldwide (IC insight, 2017). In addition to this, managers from the foreign foundry and fabless firms are also interviewed to add insights to the study.

All involved interviewees for the interview are mentioned in the table below.

Table 3-2 List of participants

Interviewee	**Interviewee (s)'s Position(s)**	**Follower firms of Semiconductor**	**Knowledge domain**	**Nationality**	**Hired engineers**	**Incumbent engineers**
A1	Department Director	Foundry A (A location)	Yield Enhancement	Taiwan	Yes	
A2	Division Manager		Lithography process	Taiwan	Yes	
A3	Assistant Technical Director		Analog/RF CMOS development	Korea	Yes	
A4	Director		Failure Analysis	China		Yes
A5	Fab Director		Statistical Process Control	China		Yes
A6	Engineer		Process engineering	China		Yes
A7	Engineer		Process	China		Yes
A8	Engineer		R&D	China		Yes
B1	Department Manager	(B location)	Product engineering	Taiwan	Yes	
C1	Senior Manager	(C location)	Back-end	Taiwan	Yes	
C2	Manager		Process	China		Yes
D1	Former director	Foundry A	3D IC & bumping	Taiwan	Yes	
D2	Former director	Foundry A		Taiwan	Yes	
E1	Team Leader	Foundry B	LED process	Korea	Yes	
F1	Manager	Fabless A		China	Yes	
G1	Project leader/manager	Fabless B	IC design	China	Yes	
G2	Designer		Analog	China		Yes

H1	Project manager	Fabless C		China		Yes
H2	Designer			China		Yes
H3	Designer			China		Yes
I1	R&D director	Fabless D		China		Yes
J1	Chief Scientist	Fabless E	IP design	Taiwan	Yes	
K1	R&D director	Fabless F		China		Yes
L1	Manager	Fabless G	IC Package Principal engineering	Taiwan	Yes	
L2	Designer		Mobile embedded chip, 5G	China	Yes	
M1	Designer	Fabless H		China		Yes
N1	Director	Foundry C	Director of Chinese business development team/ venture investment	Korea		
O1	Director	Fabless I	Director in Foreign subsidiary	China		
P2	Manager	Fabless J	Manager in Foreign subsidiary	China		

Conducting interviews

The flexibility permits the researcher to collect data from diverse routes which also enabled conducting interviews at distance. During the data collection phase, this study has initially conducted the pilot interview from June 2018 via calling and the data collected in a pilot interview is transferred and extended into the data collection in the field. It is noted that the pilot interview is often conducted for the reason of collecting background information and adapting the approach (Hammersley, 1993). The researcher already had knowledge about the industrial background involved and the phenomenon that the researcher aimed to study was due to past working experience. However, the pilot interview was useful to ensure the background information and phenomenon, as well as identifying the likelihood of a flaw, limitations, or other weakness within the interview design and ensure whether the research can be successfully processed (Kvale, 2007 in Turner, 2010; Bell, 1999).

Furthermore, a pilot interview provides opportunities for the researcher to evaluate the usefulness of data that is collected in advance, which helps to save time and allows for the adjustment of interview questions before the main interview in the field. Findings drawn from the pilot interview are not abandoned, instead, they are re-categorised with field observation and data collected during the fieldwork and together contributed to the data analysis of this study. Also, the pilot interview can increase the validity of the research. More importantly, the pilot interview before the field interview via calling also allows the interviewees to be in a relatively more relaxed and trusting atmosphere enabling them to express their opinions, thoughts and experience through face to face interviews in the fieldwork.

After the pilot interview, the second round of data collection (fieldwork) was done from December 2018 to January 2019 in the cities in China mainly Shanghai and Beijing. Some of the interview questions used in the fieldwork are a more specified version of the pilot interview questions. The semi-structured interviews enable cross-checking and validate the information from previous interviews (Bryman & Bell, 2015). After the field interview, the researcher continuously reviewed the interview data with interviewees. Moreover, the researcher also matched the interview data collected from the pilot study and data collected from fieldwork in order to check whether the interview data from fieldwork has changed. The researcher found that the most data collected in the fieldwork was consistent with the data collected from the pilot interview and that the answer is more specific in the field interview, this applies to questions which overlapped and the researcher checked that the responses did not materially differ.

During the fieldwork, the interviewees who choose to have a face-to-face interview were able to determine the venue for their interviews. Consequently, each interviewee was interviewed at a venue chosen by him and at his convenience. Some interviews took place in the cafeteria of the interviewees' firm, some interviews took place around the firm, and some took place at a café or in restaurants when the interviewees were only available during the weekend. Most of the interviewees indicated a preference for the interview to take place away from their place of work. Although most interviews were conducted face-to-face, due to the geographic distance, some interviews particularly where the firms are located in other cities in China had to be conducted through telephonic and email means.

The telephonic and email interview enables the researcher to approach the individual who is geographically distant, but more importantly, such methods were useful to interview participants who perceived the interview as a sensitive issue. Three of the interviewees (one local director, and two hired engineers from Korea) that the researcher contacted preferred to have written interviews through email and social media such as messenger. Also, during the analysis processing after the fieldwork, one of the interviewees (a hired engineer from Taiwan) sent the researcher an email that further provided important information for the extension of the interview.

Interestingly, the researcher found that some interviewees who participate in the interview through telephonic means tended to talk in a more direct and explicit way than interviewees who participated in a face-to-face interview, so even if the interview is not face-to-face, it still helped the researcher gain rich data. Besides, there are also interviewees who perceive the interview as an especially sensitive issue and tend to prefer the written interview through email. Moreover, while interviewees that are in the top management positions tend to be more open and comfortable with interview questions, interviewees that are not in a top management position but in engineers' positions tend to be more reserved in answering questions, so they (engineer position) often avoided answering specific questions.

The interview questions were structured beginning with background, position and, past experience leading to the firm's experience and focussing on hiring practices. Interviewees are all those who worked in Chinese semiconductor firms, including local directors, managers and engineers. The researcher also interviewed hired engineers who had previously worked for global leading firms in the respective industry. It is important to note that since hired engineers are positioned in the top management, their roles are often both hired engineers as well as directors or managers within the firm. Therefore, hired engineers are provided with further questions, that enabled the researcher to articulate and find high-quality information. Also, directors of firms in the same sector within China participated in interviews to reduce potential interview bias and allow a more robust understanding of the phenomenon. These interviewees are directors in the subsidiaries of foreign semiconductor firms based in China.

Interviewees might not remember accurately past events owing to memory failures leading to distortions (De Massis & Kotlar, 2014; Golden, 1992), using multiple interviewees with different perspectives and "well-informed interviewees" with diverse views can reduce these problems (De Massis & Kotlar, 2014) and allows the researcher to cross-validate the information provided that increase the confidence and reliability of the findings (Graebner, 2009; Patton, 2015). In this study, the application of multiple sources of data including interviewing local managers, hired engineers, incumbent engineers, directors of foreign firms based in China increases the validity of this study.

Each interview lasted approximately 120 minutes or a litter longer, some were in written form as a requisite of interviewees. Besides, the follow-up interviews (researcher's interpretation) were conducted over the phone to clarify some of the points made by the interviewees during the interviews. Under a guarantee of anonymity, some allowed digital recording, but others allowed only note-taking. In the case of the written version, the transcription was carried out right after the interview to minimise information loss.

Multilingual and Cross-cultural interviewing

This research context involved a multilingual environment. According to Wright (1996, pp.73), 'cross-cultural studies should not be carried out in a unilingual English language fashion'. It is because a multilingual approach enables the researcher to collect valid and trustworthy data from non-English contexts (Marschan-Piekkari & Reis, 2004). In this study, interviews are in either Mandarin or Korean as interviewees are mostly Taiwanese and Mainland Chinese, and few are Korean. More specifically, most interviewees in fabless firms are Chinese nationals while most interviewees in the manufacturing sector are Taiwanese and Korean nationals. In particular, the Taiwanese are the largest cohort amongst the interviewees.

The mother tongue of the potential informants was used when approaching them by sending an email. During the interview, the researcher used the interviewees' mother tongue rather than English to ensure each interviewee can participate in the conversation more comfortably in their own words. Expressing comfortably in their mother tongue language benefited the richness of the interviews. The researcher's mother tongue language is Korean, with her skills in Chinese allowing her to conduct interviews with people who were not comfortable using English. This allows the researchers to carry out multilingual interviews without many restrictions, otherwise, the cross-cultural interview may end up only accessing a group of informants who are proficient at English this may result in different attitudes and behaviour from non-English respondents (Wright, 1996).

Language is known to play an important role in building up a rapport and gaining trust (Marschan-Piekkari & Reis, 2004). On a note of personal reflection, this trust may depend on the background of the researcher. Similar to Marschan-Piekkari and Reis's suggestion that nationality is likely to intervene in the act of communication (2004), interviewing participants whose mother tongue is Korean was expected to be more opened and relaxed. However, the researcher notes that even though there was a shared mother tongue and shared cultural background, Korean interviewees felt reserved about the interview and cautious about their responses. On the other hand, interviewees whose mother tongue is Chinese tend to be more open to the researcher and they often perceive the researcher as a guest and are more active in participating in face to face interviews. Therefore, the researcher found it easier to conduct an interview with Chinese speakers than Korean speakers.

The wording of the interview questions in a linguistically correct and consistent manner is another important consideration when conducting multilingual interviews. This thesis has involved three languages. When interview questions were initially designed, they were in English and then translated into the interviewee's mother tongue (which was, in turn, checked by the supervisor, who was a native speaker of Chinese). In addition, conducting pilot interviews can help the researcher with the correct wording of interview questions (Marschan-Piekkari & Reis, 2004). Employees of firms in the semiconductor industry tend to master the common technological terms. For instance, 'solving problem' for manufacturing indicates dealing with abnormal products, and 'enhancing efficiency' often indicates reducing cycle time and cost. The researcher has asked in a pilot interview to give an explanation about the meaning of the specific terms that often appear, ensuring the researcher's understanding and the wording of interview questions in the field.

Despite the richness of the data, a careful translation process was required to merge it into the overall data collection. After collecting interview data, the interview data was transcribed and then translated into English. Therefore, in terms of the Korean interview, the researcher translated the transcribed interview responses from Korean, her mother tongue, into English in collaboration with native English speakers. In a similar vein, in the Chinese interviews, the researcher transcribed the Chinese responses into English. The researcher's mother tongue of Korean and fluency gained in both Chinese in Taiwan and English after having studied in England for many years, allowed the researcher to go through the multi-lingual interviewing. Moreover, for the data verification, the researcher remained in contact with interviewees and checked the researcher's understanding of the interview data with interviewees during the process of the analysis and writing-up phases.

3.4 Data analysis approach

As discussed in chapter 1, this thesis has approached from macro to micro-level, sectoral to firm and individual level. The first study approached from the sectoral level mainly relied on secondary materials in order to gather a broad amount of data throughout different time periods along with narratives. In addition to said data, analysis of the narratives was conducted to fill the possible gaps where details are required from the interviewed actors' industrial insights. Furthermore, the study of technological distance which is approached from the firm level and status distance which is individual level has mainly used the interview as the main data collection. However, the findings and results do not emerge from the interview transcripts by themselves but require the researcher's deliberate work to identify the important elements and write them up into a "story" that answer the research questions and delivers insights that are loyal to the data (Miles et al., 2013).

In qualitative research, data analysis can be processed either from the deductive or the inductive approach. A deductive approach is usually related to a positivist paradigm of scientific research and with quantitative research methods through theory testing in social sciences (Guba & Lincoln, 1994). However, in research contexts where the phenomena are unique and adequate quantitative measures are lacking it makes the application of quantitative methods insufficient (Bitektine, 2008), in such a case, a qualitative method for deductive approach can be more effective. The deductive approach is "basing analysis on pre-existing theory", while the inductive approach is based on unexpected or unpredicted responses (Gale et al., 2013). As deductive data analysis is often used when some views, previous research findings, theories or conceptual framework about the phenomenon exist (Armat et al., 2018; Mayring, 2014). This research employed deductive approaches in analysing the data because the basing analysis of this study is in the light of a pre-existing theory, that is information processing and categorisation theory. In this stance, with the research question as 'how does technological distance affect exploratory versus exploitative innovation'. The presentation of findings with the analysis process in regard to technological distance is provided in chapter 5.

To further increase insight into technological learning by hiring, and to benefit from data that does not fit the categorisation frame from the previous study an inductive approach is taken to explore how the research goes beyond what is already known. The inductive approach for data analysis is especially used in the study of status distance because the inductive approach is useful when there is a lack of or limited previous theories or research findings to help explain the phenomenon being studied (Armat et al., 2018; Linneberg & Korsgaard, 2019; Mayring, 2014), and the relationships among various constructs and related boundary conditions cannot be easily deduced from the existing literature. The researcher found that the previous literature on technological learning by hiring does not provide a clear explanation about status in technological learning by hiring as it has not been brought into the centre of the discussion, instead assumed that status is already embedded in hired engineers (see Song et al., 2003; Rosenkopf & Almeida, 2003; Simonen & McCann, 2008; Tzabbar, 2009; Singh & Agrawal, 2011; Agrawal et al., 2015; Rahko, 2017; Kaiser et al., 2018). Therefore, it is difficult to formulate precise hypotheses for testing purposes (Edmondson & Mcmanus, 2007).

In addition to this, the inductive approach is used when the research is evolving subjective perceptions of the groups (thinking and emotion) and how these influence behaviour (Huy, 2012). The status is directly evolved with one's perception and emotion that may affect their behaviours, therefore, adopting the inductive data analysis is appropriate for the study of status distance. While deductive data analysis is to test whether data are consistent with prior theories or propositions formed by the researcher, an inductive approach is employed when the researcher cannot predict responses in advance (Gale et al., 2013). Therefore, the inductive approach for data analysis is to derive concepts or themes from the raw data from open coding (Thomas, 2006) and the key concepts and themes were identified using the research questions as the lenses (Azungah, 2018). The presentation of findings including the process of the analysis and data structure is provided in Chapter 6.

3.5 Ethical Issues

'It is the moral and professional obligation of the individual researcher to be ethical even when research participants are unaware of or unconcerned about ethics'. (Neuma, 2011, p .143). Ethical issues arise at various stages of business research. Conducting business research, researchers must be professional and responsible in the use of relevant means of data collection. This study followed the ethical principles, first of all, the participants are voluntary, and participants are informed regarding all aspects of the research study. Confidentiality of information in a more general sense was also an important ethical issue. I, therefore, explained in detail the objective of this study and undertook to ensure that interviewees were guaranteed both organisational and individual anonymity during the analysis and presentation of findings to protect any sensitive information. In the final thesis, the identity of the participants was removed, and alphabets were used for identifying the interviewees. The participants were told that should they wish to withdraw at any point during the interview they could do so. Permission to record the interview was obtained from the participants and some of the participants had difficulties recording. All the participants were informed that except for the researcher and the supervisor team, no one will able to access the interview data. The consent form that was used as a guideline for the research and consent process is attached in Appendix (B). When the interview is involved via calling, the consent form was explained by verbal, and gain the verbal agreement.

3.6 Summary

This chapter discussed the methodology and methods adopted in this research and made justification why and how the researcher employed qualitative research with a diverse approach. It drew upon interviews with 29 interviewees from 13 semiconductor firms including hired engineers, local managers and incumbent engineers.

As the thesis firstly present the industry to have a holistic understanding of the industry, heavily relied on secondary data with narratives in order to gather a broad amount of data throughout different time periods. In addition, this thesis in order to investigate technological distance on the firm's different dimensions of innovation, namely exploratory and exploitative innovation employed qualitative research of deductive data analysis. Qualitative research of deductive data analysis approach is often used when phenomena are unique and adequate quantitative measures are lacking. As the deductive approach is theory-driven, the deductive approach in qualitative research makes it possible for the researcher to form the propositions and test them when some views, previous research findings, theories and conceptual framework about the phenomenon exist (Armat et al., 2018; Mayring, 2014). Therefore, the study of technological distance is approached from the firms' level employed a deductive approach to analyse the data. On the other hand, to further enhance insight into technological learning by hiring, and to benefit from data that does not fit the categorisation frame from the previous study an inductive approach is taken. The inductive data analysis approach is particularly useful when the previous research regarding the phenomenon is not clear and sufficient. Hence, the study on status distance is employed qualitative research of inductive data analysis.

Chapter 4 Catch-up in China's semiconductor industry: A sectoral system of innovation perspective

4.1 Introduction

Having introduced the research methods that have been adopted to conduct this research. This chapter outlines the research setting for chapters 5 and 6 by presenting a comprehensive understanding of the semiconductor industry from a transnational dimension of the sectoral system of innovation perspective. In section 4.2, the background of the semiconductor industry is introduced, and the problem is articulated. The next section (4.3) presents the theoretical framework of the analysis based on the literature regarding the sectoral system perspective in order to provide an understanding of the semiconductor industry. The following section (section 4.4) then presents the historical background of the Chinese semiconductor industry in order to increase a comprehensive understanding in terms of industry, and section 4.5 examine factors that affect catching up from a sectorial system perspective. Section 4.6 provides a summary of the study. China's semiconductor industry as a research setting, understanding the industry using a sectoral system of innovation perspective serves as preparation work for better view in Chapters 5 and 6 that have approached from the firm and individual level.

4.2 Background

With the rapid catching up of Chinese technology-intensive industries, inter alia, the Chinese semiconductor industry has increasingly gained significant attention and importance in the world. The semiconductor industry manufactures semiconductors (that is chips, integrated circuits) that are embedded in most electronic devices, and are essential for most electronic devices and as such are core building blocks of other technologies such as artificial intelligence, autonomous systems and, 5G communication. Semiconductor manufacturing is at the centre of the industry's persistent pace of advancement that plays a key role in the catch up of the semiconductor industry as a whole (Rho et al., 2015; Varas et al., 2020). Due to its significance, during the last few decades, China has been putting great effort into expanding its domestic semiconductor manufacturing and capability in order to move toward global leadership (Fuller, 2005; Li et al., 2019). China has grown to be the second-largest exporter in the world and the semiconductor became the 3rd most exported product in China in 2019[6].

Nevertheless, China's indigenous semiconductor firms encounter difficulty in producing specialised and advanced chips that are globally competitive in performance. For instance, while the global leaders

[6] Source: China statistical yearbook, 2019

have run high-volume manufacturing at the 7nm node[7] since 2018 and shortly expect to have production for the 5 nm node, China's most advanced technology in semiconductor manufacturing is 14nm[8]. This node is gate density, the performance of the product is strongly dependent on the component density[9] manufacturable by the production process (West, 2000). China's semiconductor manufacturing technology lags at least two generations in chip development behind the global leaders. Surprisingly, however, prior studies have rarely paid attention to China's catching up and the factors that affect their catching up. This represents an important research gap.

Though China's indigenous semiconductor technology remain a few generations behind international competitors in their ability to produce advanced semiconductor, the semiconductor industry has long had a presence in the country and has pursued to catching up with global leaders. The term "catching up" primarily refers to closing the gap between leading firms and indigenous Chinese firms regarding their technological capabilities (Lee & Lim, 2001). Reviewing the experiences of the catching up of the Chinese semiconductor industry, it is noticeable that China's semiconductor industry reveals a different story from the catching up of other high-tech industries of China such as telecommunications, mobile and automobile industries that have achieved remarkable catching up (Lee et al., 2008; Xie, 2004; Yu et al., 2017), as well as a previous follower who are managed to take the position of leadership in the semiconductor industry (Kim, 1997). As a result, the different catching up story is eventually resulted depending on the different sectoral environments surrounding the industry.

According to the sectoral system of innovation perspective, different sectors are involved with different actors and networks within their surrounding sectoral environment, this includes the regime of knowledge and technologies, the demand conditions, and the institution (Malerba & Nelson, 2011; Lee & Malerba, 2017), which eventually determines the catching-up process. The sectoral environment may provide the window of opportunity for followers to achieve rapid catch up (Lee et al., 2016; Lee & Lim, 2001; Park & Lee, 2006; Perez & Soete, 1988) but this may also increase the difficulty of catching up (Rho et al., 2015; Yu et al., 2017). For instance, scholars like Perez and Soete (1988) suggest that a sectoral environment where the technology of the industry has a shorter cycle time plays the role of opportunity for a rapid catch up with rapid adoption of new technologies. However, Lee (2013) argues that a short cycle time could be an opportunity to catch up when firms have accumulated a certain level

[7] The technology node or process technology node is gate density, specifically refers to semiconductor manufacturing process. The number such as 7nm refer to a specific generation of chips made in a particular process technology.
[8] Source: TrendForce; iSuppli; McKinsey analysis; SEMI China; IC Insights; firm's annual reports; SEMI China.org, SMIC official web
[9] Number of transistors per unit of chip area, the device components are closer together, the circuit can perform the functions faster

of technological and catching up capability, otherwise, a short cycle time or frequent change in technologies may serve an additional difficulty for catching up (Park & Lee, 2006; Rho et al., 2015) by truncating their learning process (Lall, 2000). In addition to this, various perspectives of the sectoral environment have been analysed, some studies approached from a demand perspective (Lee et al., 2009; Li et al., 2019; Mu & Lee, 2005), and some approached from the institutional perspective (VerWey, 2019).

Since the different sector is involved with different actors and different form of a network between them in the surrounding environment of the sector, it also offers a different story of catching up. In particular, for the case of China's semiconductor industry which is greatly globalised and integrated, the role of the global factors should not be ignored. For instance, the global production network has played an important role in promoting China's industrial upgrading and technological advancement since the early catching up period. It has long been emphasised as a role of a driver for upgrading China's semiconductor industry and industrial technology through integrating with foreign firms (Grimes & Du, 2020; Kong et al., 2016; Rasiah et al., 2010). However, it has not been seriously investigated that how the global production network within a sectoral environment affects catching up. Furthermore, institutions within the sectoral environment have been considered as a critical role for catching up, however, the institutional factors are limited to sectoral and national aspects. This study contends that external institutions can also play a vital role to restrict technology transfer to China, and such external institutions can affect catching up.

Surprisingly, however, prior studies on catching up have not paid much attention to China's semiconductor industry by taking global factors into account in the catching up study. It is partly because that the previous studies mainly focused on the system factors that lead to rapid catching up, they rarely have paid attention to these factors that are considered as windows of opportunity that may also cause barriers in catching up with but few exceptions in the context of the Chinese semiconductor industry (Rho et al., 2015; Yu et al., 2017). To address this research gap, this study looked at the technological catching-up process of China's semiconductor industry by examining the factors that affect catching up from a comprehensive approach. Specifically, this study presented the Chinese semiconductor industry to describe its history of catching up over time, including the key actors, policy, mechanisms of learning and knowledge acquisition, and then provide the record of catching up. By doing so, it allows us to expand the understanding of how the Chinese semiconductor industry evolved over time and to what extent China has achieved catching up with global leaders. Besides, this study, using the sectoral system perspective, identifies the factors that are engaged in the Chinese semiconductor industry and examines how these factors affect the catching up of the Chinese semiconductor industry. This study, along with the factors identified by the sectoral system of innovation perspective, also includes the global production network and external institutional factors as additional factors in the sectoral environment.

This study makes several important contributions to the literature on catching up. Firstly, it enhances our understanding of the catching up of the Chinese semiconductor industry. Until now, in regard to existing research on catch up, there is a lack of a holistic understanding of China's semiconductor industry (Grimes & Du, 2020; Kong et al., 2016; Rho et al., 2015). Secondly, even though the previous literature has provided data on a variety of the factors that lead to the rapid catching up (Chen & Toyama, 2006; Chou et al., 2014; Garrison et al., 2006; Lall, 1992; Liu & Gu, 2010; Xie, 2004; Zhang et al., 2013), yet they have not paid sufficient attention to the factors that affect catching up in the context of China's semiconductor industry by including global factors (Kong et al., 2016; Rho et al., 2015; Grimes & Du, 2020). This study attempted to provide a more comprehensive understanding by looking into a transnational dimension of sectoral systems of innovation that allows us to look at the industry from a broader context.

This study, using the sectoral system of innovation perspective, identify the factors and examine how the sectoral factors affect catching up. In addition to it, by considering the sectoral environment, this study also takes the role of the global production network and external institutional factors into account. As a result, the factors that have been identified by this research complement the other key factors that have traditionally been regarded as the basis of catching up (Lee et al., 2008; Lee & Ki, 2017; Mu & Lee, 2005; Xie, 2004). Moreover, this study further extends the existing framework of the sectoral system of innovation in accordance with the catching up of the semiconductor industry. Initially, this study adopts Malerba's sectoral system of innovation framework (2004), linking between each factor and extend the framework concerning China's semiconductor industry by adding a global production network and external institutions, as shown in Figure 4-1.

4.3 Theoretical framework

The notion of "innovation system" was originally developed by Freeman (1987) based on the observation of the Japanese national innovation system, and later it was developed into a series of related concepts such as national innovation system and regional innovation system. Among the different types of innovation systems that exist, the "sectoral systems of innovation" perspective is particularly relevant for this study that approaches studying specific industries (Li et al., 2021). The concept of a sectoral system perspective was further developed by Malerba (2002, 2004) based on several empirical studies of industry practice. Sectoral system perspective provides a holistic view in terms of sector, considers sectors as a system and the sectorial environment as a collection of elements that interact with one another rather than as single elements working independently (Malerba, 2002, 2004). The sectoral system of innovation building blocks mainly including both firms and non-firm actors (government, university, research institutes) and their network and sectoral environment, which include the regime of technology and knowledge, the demand condition (market regime), and institutions surrounding these actors (Lee & Malerba, 2017).

4.3.1 Actors and networks

Internal network. From a sectoral system perspective, actors can be classified into firms and non-firm actors (Malerba, 2002; Li et al., 2021). Different types of networks existing among various actors within the sectoral system, not only in terms of network structures but also in terms of the roles played by actors within the networks. The interaction between actors can be competition as well as collaboration as firms in a sectoral system do not only include producers but also suppliers and users that often play different roles in the sectoral system (Li et al., 2021). Global production network from value chain typically represents this type of networking in which participation involves specialisation in a specific stage of production at the international level (Malerba & Nelson, 2011). The global production network will be discussed later.

In addition to firms, non-firm actors also play an important role in the sectoral system. Non-firm actors include governments, universities and public research institutes and so on (Mu & Lee, 2005). The role of the government is especially crucial for followers to catch up with global leaders. For instance, by making sectoral-specific policies, governments can shape the direction and development of specific sectors. The literature has found many cases that the governments provide a substantial portion of initial R&D expenditure or protection of the indigenous products to accelerate the catching up of domestic firms (Lee et al., 2008). Rasiah et al., (2010) examined drives of technological catch-up in the integrated circuits (ICs) industry in Taiwan and China and found the role of government played in stimulating technological catch-up through funding, research and development laboratories and development of human capital. Along with the role of government, universities and research institute also play a critical role in the catching-up process of followers by providing knowledge and qualified human capital to the industry (Kim, 1997; Lee & Lim, 2001; Mu & Lee, 2005).

Global production network. The semiconductor industry is one of the world's most globalised industries and holds great strategic importance (Grimes & Du, 2020). The semiconductor industry's global value chain spans a wide variety of segments with a variety of actors that are closely engaged with the global production network. The global production network enables followers to strive to obtain a dominant position through technological cooperation with global leaders and it provides the possibility to move out from low value-added to the value-added chain. For instance, Japan and Korea are good examples that have achieved their industrial upgrading and technological advancement by producing low-end products and progressing to high-end products with the participation of a global production network (Chen & Xue, 2010; Kim, 1997, 1998). The role China plays in the global production network has accelerated since the early 2000s when global leaders transferred their manufacturing, packaging and testing capacities to China for cost reduction purposes and to gain a larger market (Grimes & Du, 2020). Over time, China has also become an increasingly important supplier of semiconductors and like South Korea and Taiwan, entered through assembly and packaging (Bown, 2020). In addition to this, the global manufacturers including TSMC, Intel, SK Hynix and, Samsung operating their manufacturing in China, creating a stronger network between Chinese indigenous fabless firms. As a fact, China benefited significantly from its integration of the semiconductor value chain through developing a global production network (Grimes & Du, 2020; Kong et al., 2016). However, on the other hand, the semiconductor industry is vertically integrated that the key inputs and manufacturing segments are controlled and dominated by few advanced economies (Grimes & Du, 2020; Rho et al., 2015), this structure within the global production network gives a rise to heavy dependency on upstream suppliers that in turn affect the catching up.

4.3.2 Sectoral environments

The regime of technology and knowledge. The technological regime is a particular knowledge and technological environment where a firm's innovative activities take place (Winter, 1983). The technologies and knowledge play a critical role in a sectoral system (Malerba & Nelson, 2011) because it determines the extent to which followers can learn from leading firms and eventually catch-up with them (Breschi et al., 2000; Lee & Lim, 2001; Park & Lee, 2006). Different works view different factors that constitute the regime of technology and knowledge depending on a certain sector.

The previous studies have provided that technological cycle time has been a factor that can lead to rapid catch up and also slow down catch up. For instance, Perez and Soete (1988) pointed out "technological cycle time" can be the window of opportunities for firms to catch up with leaders by the rapid adoption of new technologies. Shin (2017) suggests that in the memory chip sector, the successful catch-up from the US to Japan and then from Japan to Korea was possible because the technological regime in the memory chip sector was characterised by rapid technological progress with generational changes of products being developed every three to four years. These created a critical opportunity for followers to catch up and forge ahead forerunners. However, Lee (2013) argued the short cycle time can be a window of opportunity only when followers have already accumulated a certain level of technological capability, otherwise, frequent transformation in technologies may cause an additional barrier against catch-up (Park & Lee, 2006; Rho et al., 2015).

In addition to the frequent and rapid change of technology, the degree of tacitness of industrial knowledge is pointed to as a critical factor in catching up. When sectors greatly engage with high tacitness of knowledge can result in more difficulty in catching up. Lee et al., (2008) suggest that quick catching up is more likely to be achieved in the sector with high explicitness than in the sector with high tacitness. High tacitness of knowledge means codifiability and transferability of such knowledge are low and complexity is high (Lee et al., 2008). That is, its transfer between firms or countries can be difficult (Grant, 1996). In fact, catching up is more likely to occur in sectors where technologies are more explicit, because knowledge acquisition may be easy. For instance, Jung and Lee (2010) found that the catch-up of followers is positively associated with the condition of non-tacitness of knowledge and technology and the degree of embodied knowledge acquisition. It implies that when technology is explicit, knowledge can be codified and such knowledge can be acquired by followers easily through diverse ways, otherwise, the way of knowledge acquisition may be limited. As a consequence, when the sector is largely engaged with explicit knowledge, external knowledge is easier to obtain while the sector is greatly involved with the tacit nature, knowledge acquisition can be more difficult.

Accessibility to foreign knowledge is often an important factor in catching up. It is particularly to do so for followers who have to build technological capability by relying on foreign technology or knowledge. The importance of access to foreign knowledge has been confirmed by many cases including six industries in Korea by Lee and Lim (2001), Chinese industries by Lim et al., (2005), and Mu and Lee (2006). They suggested that the technology and knowledge gained from foreign firms often played an important role in the development of the indigenous industry and caught up with leaders. Lee (2005) explained the access is conducted in diverse ways including informal learning, licencing, strategic alliance, co-development and so on. For instance, in the early stage of Samsung, Samsung was able to co-develop CDMA[10] wireless technologies with Qualcomm who was the first mover in CDMA technologies because Samsung was transferred knowledge from Qualcomm (Lee & Malerba, 2017). Furthermore, in the case of digital switches in China, foreign joint ventures were critical to access foreign knowledge bases (Mu & Lee, 2005). As a result, the sector that can easily access foreign knowledge can accelerate the catch-up while low accessibility of foreign knowledge may cause difficulty for the catch-up.

Demand. Similarly, as a key part of a sectoral system, the role of demand has been pointed out as an important factor in catching up. The demand conditions determine whether the technologies or products developed by firms can succeed in markets (Lee et al., 2008). The demand regimes can be characterised by their different size and distribution of different market segments. For instance, Mu and Lee (2005)

[10] Code-division multiple access

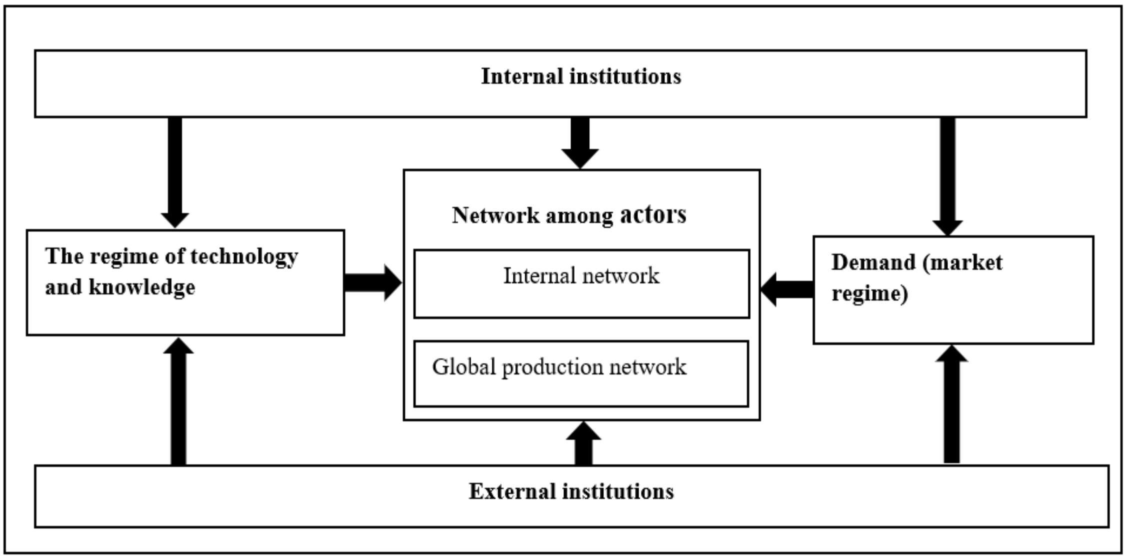
found that China's telecommunication industry could successfully enter the market, therefore, gain competitiveness because China's domestic firms could dominate the rural market due to the high demand for lower-end markets in a rural area. In a similar vein, Li et al (2019) also showed that market segmentation affects Chinese domestic firm's catching-up in the mobile communication sector by targeting the low-end market and gradually expand to the high-end market. As a result, segmentation of the market can provide a window of opportunities for followers to catch up when firms could seize the opportunity and expand to the high-end market.

Internal institutions. Institutions include intellectual property rights (IPRs), rule, law, policies and so on, and the interaction of actions in a sectoral system are shaped by institutions (Lee et al., 2016; Malerba, 2002; Malerba & Nelson, 2011). Institutions can be national that may have different effects on a different sector (patent and IPR system) and specific to sectors that provide an environment more suitable for certain types of sectors (Malerba & Nelson, 2011). Institutions and public policies have a considerable impact on the innovation of the sectoral system (Li et al., 2021) that enables learning, capability-building, technological change, innovative activity and performance (Malerba & Nelson, 2011) and catching up. The institution is often implemented through government intervention in industry or through systematic changes in institutional conditions (Lee & Malerba, 2017). The government has often targeted specific sectors using various tools and instruments (Malerba & Nelson, 2011). For instance, semiconductor and computer hardware have been targeted in Japan, Korea and Taiwan and aircraft in Brazil. Besides, Japanese shift in leadership, the VLSI (Very Large Scale Integration) project, which was coordinated by the government, reinforce the development of the knowledge base and associated investment by Japanese firms (Lee & Malerba, 2017). The governments also implement policies that advocate the firm's learning and acquisition of foreign technology through diverse ways (Malerba & Nelson, 2011). As a result, IPRs, rules, laws, the policies stipulated by the domestic government is regarded as the internal institution.

External institutions. While in the sectoral system of innovation, a lot of institutions are national or sectoral to a specific industry (Malerba & Nelson, 2011) by the implementation of domestic government, this study also highlight the external institutions surrounding innovation system with respect to accessibility of external knowledge. Within a certain industry, such as the semiconductor industry that is closely associated with a variety of actors within the global production network, not only the national or sectoral institutions by the domestic government's intervention but also the external institutions that restricting accessing foreign technology, play a critical role in their catching up. The external institution can target specific industries of a specific country in a way that can easily put the specific country into a disadvantaged position. In regard to the external institutional environment surrounding the Chinese semiconductor industry, the most notable fact is the restriction of advanced foreign technology. For instance, the Wassenaar Arrangement is an example where advanced technology transfer to countries such as China is restricted (Chen & Toyama, 2006; Grimes & Du, 2020). Such controls result in the restriction of foreign firm's introduction of cutting-edge processes to China, as well as limiting China's access to advanced technology from the upstream suppliers based in foreign countries. In many cases, the internal institutions including national and sectoral institutions are established to respond to the external institutions that are designed to limit access to advanced technology. Hence, an institution that is stipulated by a non-domestic government is identified as an external institution. This study, therefore, contends that external institution plays a critical role in catching up in the semiconductor industry.

By considering the context of this study, this study extends the existing framework of the sectoral system of innovation by taking the global production network and external institutions into account. Figure 4-1 illustrates the extended framework of the sectoral system of innovation by considering the global production network and external institutions.

Figure 4-1 Extended framework of the sectoral system of innovation



Source: author, adopted from Maleba (2004 and Malerba and Nelson (2012). Global production network and external institution were added for the purpose of this study

4.4 The historical background of the Chinese semiconductor industry

The analysis consists of two periods (see Table 4-1): (1) catching up through inward internationalisation (the 1980s-1990s), and (2) catching up through indigenous capability (2000s-till now). This section will discuss the evolution of the Chinese semiconductor industry by taking different actors in the sector, institutions and policies, strategies and mechanisms of knowledge acquisition into account. Table 4-1 provides details on the catching-up process in the Chinese semiconductor industry. After presenting the evolution, the record of catching up by China's semiconductor industry in comparison with technological leaders in the industry will be discussed.

4.4.1 Catching up through inward internationalisation: From the 1980s to the 1990s

The catching up of China's semiconductor industry began in the late 1970s when China opened its door to the world, as shown in Appendix A. Before the open up, semiconductor was elected as one of the four national emergency technologies, the Chinese government has controlled over semiconductor production for national security benefits (VerWey, 2019). China carried out the autonomous development of semiconductor technology mainly for military purposes rather than for commercial objectives (Naughton & Segal, 2003). Foreign technology was acquired from the Soviet Union (Rho et al, 2015) but the relations between the two counties split in the 1960s, resulted in technological isolation that China had no linkage with foreign firms and no access to external semiconductor technology. Since the economic reform in 1978, China has accelerated to build an indigenous semiconductor capability by providing financial incentives, cultivating talents and investing in technology, and constructing a cooperative relationship with global partners. Since then, the Chinese semiconductor industry began to access foreign technology. State-owned factories had imported 24 lines of semiconductor manufacturing facilities in 33 units by 1985 (Rho et al., 2015). However, not all of these facilities met production targets with the exception of the Wuxi Factory No. 742 (later became the state-owned Huajing Group) by successfully launching the 3-inch wafer line imported from Toshiba in 1984 (Li, 2016). This was due to the lack of technology or human capital for facility management and capital to purchase manufacturing equipment was in shortage (Rho et al., 2015) while the Wuxi factory was able to manufacture over 10,000 wafers a month due to Toshiba's technological transfer for facilitating management.

During this period, the research and development activities were mainly led by the Chinese government. The Chinese Academy of Science Institute of Semiconductors and regional semiconductor labs conducted the R&D activity, while the manufacturing was undertaken by No. 878 Factory (Beijing) and No. 19 Shanghai Wireless Electronics factory (Shanghai), two major state-owned factories (Li, 2015). However, in the mid-1980s, the factory was producing chips that were 10-15 years out of date on wafers with yields as low as 20 to 40 per cent, this meant that 60-80 per cent of the semiconductors produced were defects (Simon & Rehn, 1987). They also observed that the Chinese Academy of Science Institute developed 64K RAM in its lab, while more advanced 256K RAM was already in the international mass market in 1985 (Simon & Rehn, 1987).

Since the late 1980s, China, in order to promote industrial development, urged integration with global leading firms through JVs (Joint Ventures). In 1989, Chinese state-owned enterprises established JV with Belgium's ITT and the Netherland's Philips, established Shanghai Bell. In the 1990s, China has established an additional Sino-foreign JV including Shanghai Philips Semiconductor, Wuxi Huajing and NEC (Shougang NEC, and later known as Huahong NEC). Beginning with the eighth (1991-95) Five-year plans (FYP), China set up the Project 908 plan, attempted to develop Wuxi Huajing into a leading IDM (integrated device manufacturer)[11] with a joint venture with Lucent Technologies from the United States with the agreement for transferring the process technologies, training engineers and provide an IP design library. However, a joint venture was established after 8 years since the plan was set with old manufacturing equipment and process technology that lagged behind the industry's leaders (Li, 2016). Project 908 was failed to close the technology gap with leaders due to the long delay to enter the production on time.

By taking a lesson from the failure of project 908, China Nith FYP (1996-2000) initiated project 909 called for the development of domestic chips made by an internationally competitive firm using Chinese IP and engineers (Fuller, 2005). Under the project, the Chinese firm Huahong, successfully leveraged a partnership with NEC (Japan) to enter production on time and bring dynamic random-access memory (DRAM) chips to market. JV However, the knowledge spillover was limited due to in part the engineers in the Chinese facility were primarily Japanese (VerWey, 2019). Under such a process, Huahong engineers could not learn the knowledge of the whole production process beyond their specific tasks (Li, 2015). Thus, by end of 2002, Huahong decided to restructure itself completely by bringing in new returnee management, taking on Jazz Semi (U.S) as a new foreign partner, adopting the pure-play foundry business model (Li, 2015). Huahong sends engineers to be trained at IMEC, the European semiconductor research centre in Leuven, Belgium, and these engineers returned in 2002 with the skills to deploy 0.18-micron process technology[12].

By 2000, the Chinese semiconductor industry was dominated by state-owned enterprises and was lagging far behind other countries in terms of both volume and technological level. In 1999, the combined output of Chinese semiconductor manufacturers accounted for less than 2% of world production (Fuller, 2005b). The vast majority of this output came from packaging and testing facilities which were mainly operated by multinationals, that had located in China in order to take advantage of low-cost labour (Yu et al., 2017).

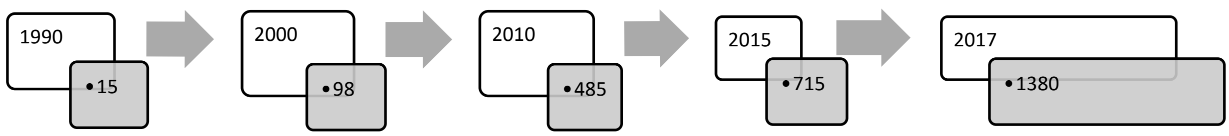
[11] IDM conducts chip design, fabrication and assembly, test, package in house. For instance, Intel, Samsung are IDMs
[12] Huahong website: www.huahong.com.cn

4.4.2 Catching up through indigenous capability: From the 2000s and the present

Since the 2000s, China shifted into new industrial ecosystems, entering the stage of experiencing the largest wave of entry into semiconductor manufacturing (Bown, 2020). The Chinese government designed a big shift in strategy by issuing a new policy to accelerate the development of the semiconductor industry. China initiated the first comprehensive plan to create an indigenous industry and therefore represented an important shift away from the traditional IDM model towards vertical specialisation and integration (Yu et al., 2017). The Chinese government has supported Chinese semiconductor producers to access tax holidays and enterprise income tax rate reductions and the location subsidies from areas in which they site operation. In addition, the National Semiconductor Talent Training Project was also established in 2003 to provide human resource support for industrial development (Zhang et al., 2013).

At this point, a big number of semiconductor fabless firms initiated to emerge, shown in Figure 4-2, there were 485 in 2010 and reached 1380 in 2017 dramatically shown for the last two decades, 1380 in 2017 increased dramatically from 15 in 1990. For example, Spreadtrum, Vimicro and Galaxycore were founded between 2000 and 2003 and grew to become major players.

Figure 4-2 The number of Chinese fabless firms



Source: The China Centre of Information Industry Development, Statista

In 2000, Semiconductor Manufacturing International Corporation (SMIC), a partially state-owned foundry, emerged within China and becomes the largest Chinese semiconductor foundry firm. The establishment of SMIC was slightly different from other Chinese manufactures because there was a certain degree of accumulated tacit knowledge with their establishment. SMIC was formed by a Taiwanese expatriate, a Taiwanese American who had previously worked at Texas Instruments (U.S.) and Taiwan Semiconductor Manufacturing Corporate (TSMC) with the Chinese government’s support (VerWey, 2019). When the firm was founded, among 1,043 engineers, around 400 engineers were from outside of China or non-Chinese foreign citizens (Li, 2011). They were mostly Taiwanese engineers from Taiwanese foundries such as TSMC or United Microelectronics Corporation (UMC). Those engineers have tacit knowledge that is not easily codified, and which was and is used to build up the firm’s knowledge stock. China’s semiconductor manufacturers actively promoted technology advancement by licensing from global partners. By 2009, SMIC also licenced process technology from various sources from major semiconductor firms. For instance, the licence of 45nm bulk CMOS technology from IBM in 2007 (Lapedus, 2008), 0.10-micron logic from Chartered of Singapore, 0.13-micron back-end logic from Toshiba of Japan (Li, 2011).

Over the 2000s, SMIC had continued to expand its capacity by building fabs in Beijing, Shenzhen, Wuhan and Chengdu. SMIC obtains a 12-inch Fab for the first time in China and completed building a 12-inch factory in Beijing in 2005, and operated a 12-inch production line in Shanghai in 2007 (Rho et al., 2015). Since initiating volume production in 2002, SMIC has emerged as the largest and so far, the most advanced chipmaker among Chinese semiconductor firms, grown as a fast-follower. SMIC appear to be advancing their capability by collaborating with foreign partners under the financial support by the government. In the late 2000s, global chip producers such as Intel, Samsung (memory fabs), TSMC, UMC (foundry fabs) began building fabrication manufacturers in China (Bown, 2020), provide advanced semiconductor chips to fabless firms in China. These manufacturers have become the largest producers of semiconductors and major competitors of Chinese semiconductor manufacturers such as SMIC, Huahong.

Since 2006, China's goal for the semiconductor industry is to reduce the dependency on foreign technology and become self-sufficient. China's 13th Five-year plan (2016-2020) and 14th Five-Year Plan (2021-2025) is to strengthen China's autonomy in semiconductor production by strengthening the domestic supply chain and lessen the dependency on foreign technology in each process from design and manufacturing to packaging and testing and the production of related materials and equipment (To, 2021; VerWey, 2019). China created a government fund - the China Integrated Circuit Investment Industry Fund in supporting domestic industry and the purchase of foreign semiconductor equipment. As one example, in 2020, SMIC received financial support worth 2.2. billion dollars from Chinese state investors[13]. Table 4-1 below provides the summary of China's semiconductor industry that have been discussed above. Next, the record of catching up is provided to view to what extent China has achieved in catching up.

[13] Reuters, China semiconductor fab SMIC gets $2.2 bln investment from gov't funds amid global chip spat, May, 2020, at http://www.reuters.com/article/china-semiconductor-smic-idUSL4N2D019Y

Table 4-1 Summary of the Chinese semiconductor industry

The Chinese semiconductor industry		Features	The main mechanism for knowledge acquisition
1980s - 1990s	Catching up through inward internationalisation	• State agents withhold the ultimate decision-making power in state-owned enterprises and their joint ventures with foreign firms • Technology transfer from foreign partners/competitors (but limited technology transfer) • Major output came from packaging and testing • Global chip producers build the fabrication manufacturers to China • Foreign leaders penetrate China's semiconductor market	Learning by importing and joint ventures
2000s - present	Catching up through indigenous capability	• IDM towards vertical specialisation and integration • Newly established foundries are established by engineers or managers from foreign leading firms • Numbers of fabless firms established by oversea's returnees • Technology transfer from foundry customers; licensing from IP suppliers • Government's funding to support domestic industry	Learning by licensing and hiring
Compiled by the author based on the previous literature			

4.4.3 Catching up records of the Chinese semiconductor industry

In spite of the long history and government support in advancing semiconductor technology, China's semiconductor industry has limited achievement in catching up in market share and ability in the technological aspect. For the record of catching up, this study has looked at the three aspects including market share by segment, patents and technological node in process technology. First of all, in terms of market shares by each segment, Chinese indigenous firms do not have a big market share in each segment. As can be seen in Table 4-2, the US is the world leader overall and, leads most segments. Especially the segment in electronic design automation (EDA): that is in the software used to design chips where it is monopolised by accounting for 92% of all. This may imply that most countries have to rely on the US's supply for design chips. It is the same in core intellectual property (IP) and Fabrication tools, that the US is dominant in the segments that are initially required as input of producing semiconductor chips. The fabrication segment by US-headquartered firms holds a relatively lower market share compared with other segments. It is because advanced U.S. semiconductors are manufactured by Taiwanese firms such as TSMC where possess the most advanced fabrication technology.

Table 4-2 Semiconductor value-added and market share by segment and firm headquarters

Segment Value added		**Market shares**						
		US	**Korea**	**Japan**	**Taiwan**	**EU**	**China**	**Other**
EDA	**1.5%**	96%	<1%	3%	0%	0%	<1%	0%
Core IP	**0.9%**	52%	0%	0%	1%	43%	2%	2%
Wafers	**2.5%**	0%	10%	56%	16%	14%	4%	0%
Fab tools	**14.9%**	44%	2%	29%	<1%	23%	1%	1%
ATP tools	**2.4%**	23%	9%	44%	3%	6%	9%	7%
Design	**29.8%**	47%	19%	10%	6%	10%	5%	3%
Fab	**38.4%**	33%	22%	10%	19%	8%	7%	1%
ATP	**9.6%**	28%	13%	7%	29%	5%	14%	4%
Total value added		39%	16%	14%	12%	11%	6%	2%

Note: each of the values is a weighted average of a region's market shares across all supply chain segments. The weighting is each segment's weighted by sectoral value-added. The table excludes fab materials besides wafers and packaging materials due to a lack of data. The value of non-wafer fab materials and packaging materials are incorporated into "fab" and "ATP".

Source: financial statements, WSTS, SIA, SEMI, IC Insight, Yole, VLSI Research, compiled by CSET

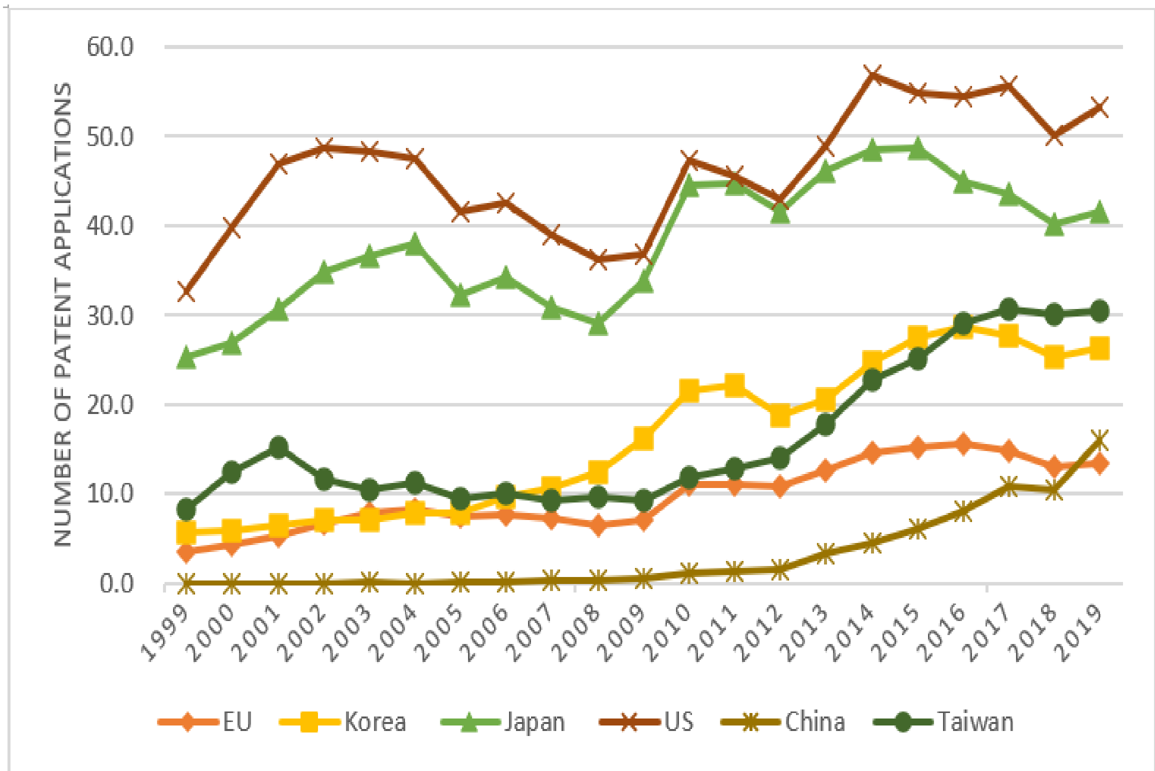
Korea and Taiwan contain world-leading firms leading in the fab segment, Korea especially leads in Dynamic Random Access Memory (DRAM) chips and Taiwan has strengths in foundry fabrication, concentrating on contract manufacturing for other semiconductor firms that design semiconductors for application-specific purposes such as artificial intelligence (AI) and, wireless communications. For instance, Huawei's advanced chips are mostly produced by relying on Taiwan's fabrication technology. As a result, the share of Korea's fab is 22% of the market and Taiwan holds 19%, leading the fab market. Similar to the US, Japan is leading in equipment and materials, holding 56% market share in Wafers and 44% in assembly, packaging and testing (APT) tools and 29% in Fab tools, it plays an important role in supplying these segments to other regions such as Korea, Taiwan and China for their semiconductor manufacturing.

China lags behind overall but is progressing in some segments. It excels in ATP accounting for 14% of market share, ranked after Taiwan (29%) and the U.S (28%). A number of Chinese firms such as Power-Tech, Jiangsu Changjiang Electronics Tech Co, grew as the leading global integration packaging assembly and test providers. Along with ATP, the share of ATP tool accounts for 9%, much higher than Korea and Japan. As seen in Table 4-2, the design and fabrication segment accounts for very little in market share compared to ATP value chains. The design segment which involves the specification, logic design and, physical design, held 5% of the market share showing a similar market share as Taiwan's design segment. In the fab segment, China accounted for 7%, China's foundries such as SMIC, grew to become a new player in the global market, but most of the market share in fab segments remains dominated by the firms of Taiwan and Korea. Additionally, as seen in Table 4-2, the segment of EDA, core IP and fab equipment of China count for very little in the world market share. EDA is software used in designing chips, and the designed chipset will be made as chips by the fab foundry that equipment and materials are required. However, China encounters a challenge in value-added segments in EDA, fab materials and tools that are considered as the crucial inputs for design and fabrication manufacturing.

The market share shows several important inferences. Firstly, it shows the value-added segments are controlled by technological leaders. US, EU and Japan dominate in essential inputs for chip design and chip manufacturing, this can also be inferred from China's degree of dependence on imports and foreign technology from the U.S, Japan, EU in the segment of EDA, core IP, and materials. Furthermore, Korea and Taiwan control front-end manufacturing that is capital intensive and requires advanced technological expertise. Given that fabrication requires the most advanced technology and corresponds to higher added value, the developed economies resist transferring fab manufacturing into China (Rho et al., 2015). Although technological leaders such as Intel, Samsung, TSMC built their fab facilities in China in the late 2000s, the fabrication technology operating within China is a few generations behind the international standard. On the other hand, China is leading the market in back-end manufacturing that is labour intensive and requires relatively less technical skill across all segments.

Apart from the market share, patents are used to access China's catching up record. The patent is closely associated with technological and innovative activity and enables us to view the technological leadership in a specific industry. Patent data were extracted using a search algorithm based on the selection of IPC classes that target semiconductor-related technology. The number of semiconductor-related patent grants by five main regions in USPTO is displayed in Figure 4-3: China, US, Japan, Taiwan, Korea, EU (27 countries). Figure 4-3 indicates that China's patents filed in the US has remained a small number from 1999 until 2010. As can be seen in the figure, the gap between the US, Japan and China is especially wide, and the EU, Korea and Taiwan remained in the mid-range. However, since 2010, the number of China's patents showed a graduate increase and outnumbered the EU's patent number in 2019. The figure clearly shows that China's catching up has accelerated since 2010.

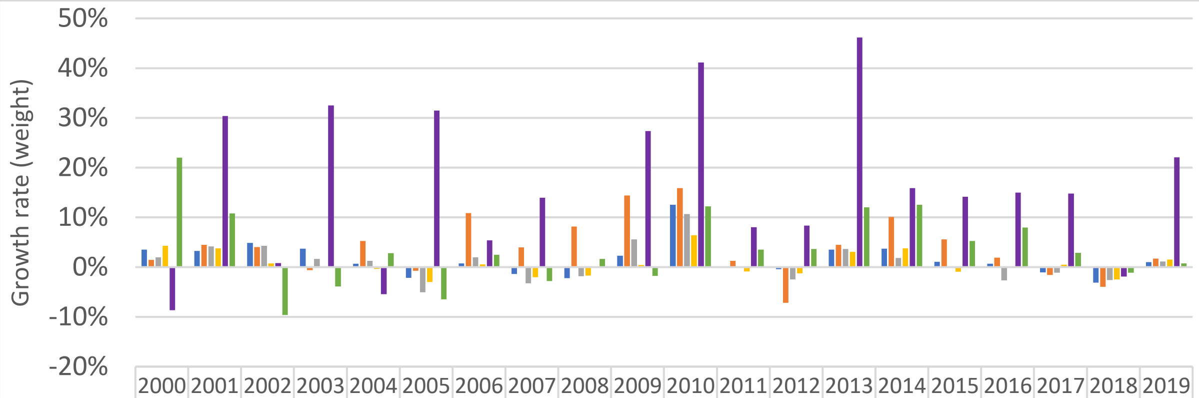
Figure 4-3 Patent counts in semiconductor



Source: OECD Patent database

Additionally, this study also examined the growth rate of the patent. As seen in Figure 4-4, China's patent growth rate grew at a rate of 30.3% in 2001 while other regions except for Taiwan whose growth rate is more than 10 % remained less than 5%. China had a consistent growth rate from 2009 to 2017, and in 2019 the number of patents grew 22 % from the previous year. Overall, in comparison with other regions, the average annual growth rate is 15.57% throughout the period, while Japan and the US is less than 1 %, Korea and Taiwan are 3.74%, 3.98% respectively, and EU is 1.55%.

Figure 4-4 Annual growth rate



	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019
EU	3.50	3.23	4.89	3.69	0.67	-2.1	0.74	-1.3	-2.2	2.30	12.5	-0.1	-0.3	3.53	3.71	1.04	0.65	-1.0	-3.1	1.01
Korea	1.47	4.49	4.04	-0.5	5.26	-0.7	10.8	3.96	8.18	14.3	15.9	1.23	-7.2	4.51	10.1	5.60	1.88	-1.5	-3.9	1.71
Japan	1.98	4.19	4.31	1.65	1.23	-5.0	1.95	-3.2	-1.8	5.55	10.6	0.09	-2.4	3.66	1.84	0.05	-2.6	-1.1	-2.6	1.15
US	4.26	3.80	0.75	-0.1	-0.3	-3.0	0.57	-2.0	-1.7	0.40	6.41	-0.8	-1.2	3.09	3.77	-0.9	-0.1	0.49	-2.4	1.49
China	-8.6	30.3	0.83	32.5	-5.4	31.4	5.38	13.9	-0.0	27.3	41.1	8.03	8.33	46.1	15.8	14.1	14.9	14.8	-1.8	22.0
Taiwan	22.0	10.7	-9.6	-3.9	2.79	-6.4	2.48	-2.7	1.67	-1.7	12.2	3.54	3.66	12.0	12.5	5.23	7.96	2.90	-1.1	0.73

Source: OECD Patent database

The previous study suggested the main reason behind the limited achievement in catching up is due to the fabrication technology that is a few generations behind the global leaders (Rho et al., 2015). The fabrication technology that is required to produce the advanced and high-performance chip, is often considered as a crucial technology in catch up with the semiconductor industry as a whole (Rho et al., 2015) but China's most advanced technology generation is still a few generations behind those of the leaders. While global leaders produce the chips by following Moore's Law, upgrading the manufacturing process every two years, China, in general, takes 4 to 5 years to advance the process technology. As seen in Table 4-5, in 2001, when China's most advanced manufacture was built, the process technology operated here was 250nm, while leaders already produced chips using 130nm manufacturing technology in the same year. China under the intensive support of the government is putting in the effort to advance the manufacturing technology but continuously remained few generations behind.

Figure 4-5 Semiconductor manufacturing process (Node)

	2001	2004	2006	2008	2010	2012	2014	2016	2018	2020
Intel (IDM) (U.S. HQ)	130nm	90nm	65nm	45nm	32nm	22nm	14nmFinFET	10nmFinFET		7nmFinFET
Samsung (IDM) (Korea HQ)		90nm	65nm	45nm				14nmFinFET	10nmFinFET	7nmFinFET
TSMC (Pure foundry) (Taiwan HQ)	130nm	90nm	65nm						10nmFinFET	7nmFinFET
Global foundries (Pure foundry) (U.S. HQ)		90nm	65nm				22nm	14nmFinFET	10nmFinFET	7nmFinFET
SMIC (Pure foundry) (China HQ)	250nm		90nm		65nm		40nm			14nmFinFET

Source: TrendForce; iSuppli; McKinsey analysis; SEMI China; IC Insights; firm's annual reports; SEMI China.org, SMIC official web. Compiled by the author

In 2014, the process technology reached 40nm and after 5 years initiated 14nm technology. It is the most advanced manufacturing technology possessed by China's indigenous firms today. In 2019, the Chinese indigenous firm SMIC commenced volume production of chips using 14nm FinFET manufacturing technology, however, 90% of SMIC's revenue is based on technology nodes of 40-250nm (Shilov, 2020). This implies that their customers, which are fabless firms, mainly rely on Chinese foundry for producing low or medium-range chips rather than advanced chips. On the other hand, firms headquartered in Taiwan, Korea and the US manufactured chips with 7nm process technology in their own headquartered locations, and look to the production of 5nm soon. For the case of TSMC, 70% of TSMC's revenue in 2020 came from 28nm and 7nm nodes (TSMC Report, 2020).

This section has mainly looked at the brief history of the semiconductor industry throughout the different time periods and the record of catching up. Under the leadership of the Chinese government, the Chinese semiconductor industry has been upgrading its technological capability to narrow the gap with technological leaders, however, the gap remains visible by examining the record of catching up in comparison with other regions. Given the limited achievement in catch-up in China's semiconductor industry, one of the main goals of this study is to examine the factors that affect catching up. In the next section, this study will use the sectoral system perspective to examine the factors.

4.5 The factors that affect catching up: from a sectoral system perspective

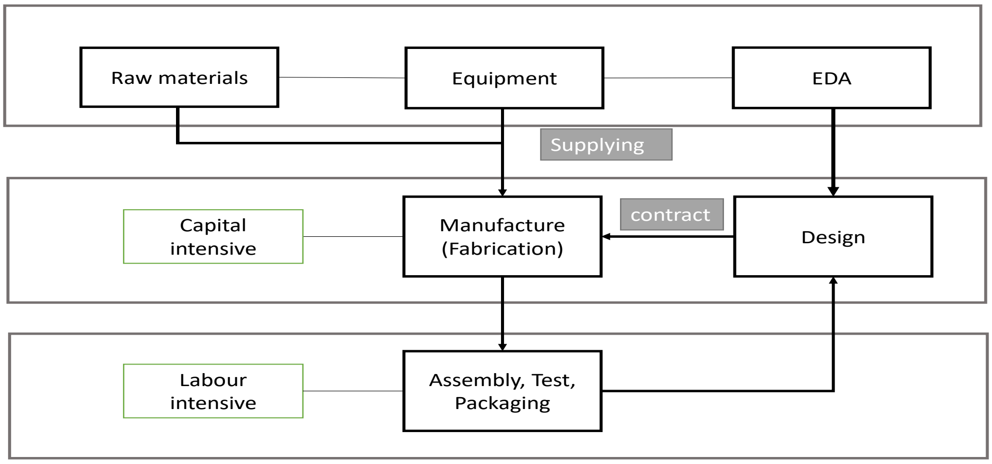
Drawing on these brief histories and catching up records, this section examines the factors that affect catching up from the sectoral system of innovation perspective. The factors are categorised as a network including internal network and global production network, the regime of technology and knowledge, demand (market regime) and institution including internal and external institution. Even though the section is divided into the network, technological regime, demand, and institutions, it is important to note that these factors are interactive rather than working independently.

4.5.1 Global production network and internal network

The semiconductor industry is characterised by a variety of actors. Regarding the actors in the Chinese semiconductor industry, the domestic and foreign firms and the government can be identified as the central actors. The government played the main role in developing the semiconductor industry, guiding industrial development and technological advancement. However, when China opened its doors to the outside world in the late 1970s, its semiconductor industry was significantly behind the world frontier (Lee et al., 2016). The Chinese government began to redevelop the semiconductor industry by inducing foreign firms to China. Since then, foreign firms have played a critical role in China's semiconductor industry not only as competitors but also as co-operators, enabled China to be a part of the global production network that provided considerable benefit to the Chinese semiconductor industry.

Participation in the global production network enabled China to upgrade its industrial development and its technological capability, however, it seems to trap China within the low-value position. The semiconductor industry's global value chain spans a wide variety of segments such as equipment, materials, design, manufacturing and assembly and testing. Figure 4-6 shows how the global production network of the semiconductor industry is structured and how it has been complicatedly integrated. In fact, China's participation within the global production network has upgraded the industry and its technological development through learning and cooperation with foreign firms (Kong et al., 2016). However, China's role in the global production network is relatively limited to low-added activities; much of the production is in the labour-intensive final stage, ATP while the most critical components headquartered outside of China such as the US, South Korea, Taiwan, Japan and various European locations (Grimes & Du, 2020). It is also a part of the strategy of advanced economies not to transfer the value-added function to China, especially the front-end manufacturing part to China (Rho et al., 2015). Therefore, even though semiconductor production has increasingly moved to China, the value-added production is captured by non-Chinese firms (Grimes & Du, 2020).

Figure 4-6 Global production network



Source: Bown, 2020, Grimes & Du, 2020, Platzer et al., 2020. Compiled by author

In addition to it, the global production network has resulted in an asymmetric and interdependent relationship between China and other regions, in which other regions control the key inputs into the value chain (Grimes & Du, 2020). For instance, the essential inputs such as the design tool, equipment, chemical materials and wafers that are required for designing and manufacturing semiconductor chips are controlled by the US, the EU and Japan. That is, Chinese semiconductor manufacturers have to rely on the U.S. and other non-Chinese suppliers for equipment and materials for manufacturing semiconductors (Platzer et al., 2020). This asymmetric and interdependent relationship in the global production network between China and other regions often result in barriers for China in accessing advanced technology. Chinese semiconductor firms have often faced hardship in accessing advanced equipment for the advanced process from advanced economies since the early catching up period.

The global production network may result in a weak network between large indigenous firms. Internally, the Chinese semiconductor industry had a big shift in strategy, transforming the traditional IDM (integrated device manufacturer)[14] model to a vertical integration model. The IDM model is known as intensive in terms of capital investment and technology innovation (Lee et al., 2016). It is in large due to the IDM model enables technological transfer between design and manufacturing parts. For instance, global leaders such as Intel and Samsung are typical cases of the IDM model operating from in house design to manufacturing. In fact, China had attempted to adopt the IDM model in the early catching up

[14] IDM conducts chip design, fabrication and assembly, test, package in house. For instance, Intel, Samsung are IDMs.

period, but this was not successful, hence, China has followed the vertical integration model focused either on fabless firms or on foundries since 2000 (Yu et al., 2017). The diversion of IDM to the vertical integration model results in the establishment of pure-foundry such as SMIC in 2000, and the emergence of a large number of fabless firms[15] built by overseas returnees within China. The vertical integration model enabled foundry to obtain transferred technology by building partnerships with foreign firms and licensing intellectual property cores from their international customers (Yu et al., 2017) while increasing the participation of Chinese fabless firms within the global production network thereby taking advantage of the advanced manufacturing process.

However, it also causes the Chinese semiconductor manufacture difficulty in technological upgrading through technology transfer from large indigenous fabless firms to Chinese semiconductor manufacturers. Chinese-headquartered foundries are in general less technologically advanced than those of firms headquartered in other regions, whereas the most advanced fabrication production in China is the performance by non-Chinese manufacturers such as Intel, TSMC and, Samsung who are major global semiconductor firms that operate fabrication manufacturing in China (VerWey, 2019). Large indigenous fabless firms often contract their chip production to foreign manufactures in producing advanced chips while contract indigenous manufacturers for low-end chips due to their inability to offer large amounts of IC production using leading-edge technology. As a consequence, it does not only cause a weak network between indigenous firms, limit technology transfer between large indigenous design and manufacturing firms but also lock Chinese indigenous manufactures into low-end technology.

Moreover, the industry itself limited the technology transfer due to the separation of activity between R&D and manufacturing in the early stage. R&D is conducted in state-run labs, whereas manufacturing was conducted in state-owned factories, and the activities were rarely co-located. This made technology transfer difficult from state labs to the factories (VerWey, 2019). In addition, universities and research institutes normally play an important role in contributing to technological advancement, yet this is lacking in the Chinese semiconductor industry. There is no centre for public research, no tool to take the lead in advancing technology in the Chinese semiconductor industry. Unlike Korea and Taiwan, where universities and research institutions were pioneers in the development of the semiconductor industry, Chinese universities and research institutes do not show greater R&D capability (Rho et al., 2015). In this manner, the lack of a programme in terms of the combination of university education and

[15] Fabless firms are also known as design firms, design its own high-end chipsets but cannot produce them in-house so rely on manufacture to produce the chips they designed.

technical experience in advanced technologies in association with semiconductors and direct cooperation with foreign research centres results in a slow catch up (Yu et al., 2017).

4.5.2 The regime of technology and knowledge

The technological regime of the semiconductor industry has been characterised as the frequent changes in the generations of technologies or short cycle time of technologies. The effects of Moore’s Law are evidence of frequent changes in the generation of technologies or short cycle time that firms are in a constant race to develop new products and processes. The short cycle time in technology is regarded as the window of opportunities to catch up with the rapid adoption of new technology (Park & Lee, 2006; Perez & Soete, 1988; Shin, 2017). That is, firms should be able to rapidly produce new and next-generation products by replacing old technology. Followers, in so doing, must invest continuously and heavily in both R&D associated with the development of next-generation chips and replacement of the equipment with new generation products (Shin, 2017). However, semiconductor foundries, are capital intensive operations, and as new technology develops and becomes more complex, the cost for the equipment for the next generation also rises (Rho et al., 2015). Accordingly, building a new semiconductor factory cost at least 7 billion dollars, with some asserting that an advanced chip fab can cost more than 20 billion dollars (Lewis, 2019), and some pieces of equipment cost more than 100 million each (Platzer et al., 2020). The short cycle time in technology with its continuous requirement for investment in R&D, facilities and equipment became a barrier for the Chinese semiconductor industry in its efforts to rapidly catch up.

More importantly, investing in next-generation technology often requires experienced engineers to be able to drive and bring on this new generation of technology. Even if China can gain access to advanced manufacturing equipment, making high-quality chips with consistent performance still requires the know-how and accumulated experience. However, China is lacking experienced engineers and talent in the semiconductor industry (To, 2021) and engineers specialising in process technology are still relatively inexperienced in China (Rho et al., 2015). Experienced engineers are especially necessary for the semiconductor industry because technological knowledge in the semiconductor industry is highly cumulative. Rho et al (2015) analysed China’s semiconductor industry from the sectorial system perspective where they explained the reason for limited achievement in catching up by emphasising the characteristics of the technology/knowledge regime of the semiconductor industry, technologies are highly cumulative, which puts followers in a disadvantageous position. This implies that in such a sectoral environment, lacking experienced engineers is especially vital for catching up. It is well explained by the interviewees:

"The process gets smaller and smaller, in the semiconductor industry there is Moore's Law, we manufacture chips, every 18 month we have to upgrade once. For instance, like 28, 14, 10, 7 nanometres, shrinking the size. This is how technological leaders follow the theory, if you do not follow this theory then you cannot be considered a leader. But realistically, the advanced process requires high cost and experienced talents. Firms when entering new generation technology, they have to have accumulated technology, engineers must have the experience, and able to redo the new generation technology from the beginning, leading firms they have the experience to develop 14 nm so they can develop 10 nm in around two years, but Foundry A may need 5 years to develop same technology." (A4)

"Advanced or cutting-edge manufacturing relies on advanced equipment, they are closely related and none is dispensable, at present, the advanced equipment is in abroad, the capability of China's manufacturing rate is very low, so has to rely on imports. More importantly, even if the advanced equipment can be obtained, it requires sufficient technical experience to know how to use it to complete manufacturing" (A5).

China has been putting much effort into cultivating engineers specialising in the semiconductor industry, but nurturing talents in semiconductor production takes a long time that cannot be achieved in a short period. In fact, university graduates who specialised in semiconductor technology were still relatively young in China unable to apply their knowledge within the manufacturing process technology (Yu et al., 2017). The gap between university and industry, between theory and practice, means that graduates are not able to fully apply their knowledge in the manufacturing process. Accordingly, *"Technological demand is high in this industry, there is a gap between what school and industry doing, including a newly recruited doctoral student in our company, I feel that he cannot understand what we do in the industry at all, so difficult to adapt this thing."* *(L1)* In addition, *"the technological requirement is relatively high in this field, there is a gap between what university and industry do, including a newly hired doctoral student in the firm, he cannot understand what we do in the industry at all, students graduated from university are not able to apply their knowledge into manufacturing process technology directly before they are trained for a long period." (D2)*

Also, talented engineers who do not show the preference to work for the semiconductor manufacturing sector frequently causing a shortage of talents in the sector. Chinese electrical engineers who wanted to engage in the most advanced work in the field went abroad or work for foreign firms in China (VerWey, 2019) or design firms. One of the interviewees stated that: *"there are relatively more talented engineers in fabless sectors (design firms), so they have no such problem, and they are doing very well. However, it is short-handed for the semiconductor manufacturing industry, especially when it goes to more advanced technology, fewer talents in the semiconductor manufacturing."* (A2) This has further explained by another interviewee *"based on what I observed these years, the talents are not in this* *industry (semiconductor manufacturing), a lot of them prefer working in design firms (such as telecommunication industry), …, in other words, for China's local semiconductor manufacturers, the top engineers are not in this industry, so within China, they cannot hire engineers because engineers all go to firms like Huawei, so Chinese semiconductor manufacturers invest the money to dig from Taiwan and South Korea."* (B1).

This phenomenon differs from other regions such as Taiwan, where, in their early development stage, many talented engineers were keen to work in semiconductor manufacturers. One of the interviewees wrote in the letter as *" there are many talented students from a top university in China, but they would not prefer to work for the semiconductor manufacturing sector, they would prefer firms like Huawei that provide a much higher salary,… the semiconductor manufacturing sector is considered as a difficult job with less pay than design sectors, there are not many graduate students would prefer to work in the sector, hence, lack of the number of engineers… it is different from Taiwan, where top talented students preferred working in semiconductor manufactures such as TSMC, UMC because the salary was high and higher than IC design firms… so most of them went to work for semiconductor manufactures."* (A1) As a matter of fact, China's semiconductor firms have to actively hire engineers from Korea and Taiwan was and is a sign that China suffered a shortage of talented and experienced engineers (Grimes & Du, 2020). For instance, two of the three new memory chip producers have sought to hire talent from existing non-Chinese memory industry leaders (VerWey, 2019).

In addition to that, the difficulty in catching up is also caused by the nature of the technological regime of the semiconductor manufacturing sector, which feature a higher degree of tacit knowledge. Indeed, high tacitness of knowledge in the sector caused low codifiability and transferability of such knowledge, this increased the difficulty for Chinese semiconductor firms to acquire external knowledge. During the period of catching up by inward internationalisation, JV was the main strategy to acquire foreign knowledge for Chinese semiconductor firms, however, the knowledge acquisition was limited that Chinese engineers could not learn the know-how or skills from their foreign partners. Notably, JV between Chinese Huahong and Japanese NEC was a representative case, as they failed to result in knowledge spillover, it is largely because the manufacturing was operated by Japanese engineers and Japanese firms' control over the top management (Fuller, 2016). Huahong, after realising they could not learn much from their Japanese partner, changed strategy by sending their engineers to be trained at a European semiconductor research centre. These engineers returned with the skills to deploy 0.18-micron process technology to China (Li, 2011). In addition, the case of SMIC's strategy was also successful. When SMIC was initially established in 2001, a large number of engineers were hired from Taiwan, not only did this enable SMIC access to the tacit knowledge base, it also helped to build further technological capability. As a result, much of semiconductor knowledge resides in engineers, knowledge acquisition can be challenging unless learning by hiring is conducted. Hence, a high degree of tacit nature of the semiconductor technology may cause additional hardship for followers to catch up.

Lastly, accessing foreign semiconductor technology is relatively difficult for Chinese semiconductor firms. In fact, foreign knowledge particularly plays a critical role for followers to catch up with leaders. However, the barrier for China to acquire advanced foreign knowledge is relatively high, especially when comparing with previous followers such as Japan, Korea and Taiwan. These three economies benefited from the US's technology transfer due to their allied relationship. For instance, Taiwanese engineers were sent to the US for training in the 1970s, and they later returned to Taiwan to build Taiwan's semiconductor foundry (To, 2021). In addition to that, the strategy of leading firms that dominate patent portfolios often limits followers from acquiring the most recent technology, it has relatively low accessibility as followers go for more sophisticated or advanced technology (Rho et al., 2015). For example, it was not long after China began manufacturing semiconductors that SMIC quickly encountered several problems with TSMC which filed a lawsuit in US courts in 2003 alleging that SMIC had infringed its patents from TSMC (Bown, 2020). SMIC fell on hard times after losing in the patent lawsuit that began in 2003 with TSMC and there was another suit in 2006 (Rho et al., 2015). Compare with the previous followers in the respective industry, the Chinese semiconductor firms encounter a relatively higher barrier in accessing foreign knowledge since the early catching up period.

4.5.3 Demand (Market regime)

The large and growing demand for semiconductors is a feature of the Chinese market. The large and growing demand for semiconductors came from a wide variety of user industries as semiconductors are embedded in most technological devices. Since 2010, with the emergence of technologies such as artificial intelligence, virtual reality and IoT, the market demand for advanced semiconductors is constantly expanding. However, many of the design and user firms that purchase semiconductors need to become internationally competitive, so they look for foreign suppliers at the global leaders, rather than Chinese semiconductor manufacture that is behind, that is to say not leading edge, to source their component parts (Yu et al., 2017). Semiconductor fabrication requires high precision, the most advanced chips pack as many transistors as possible into increasing smaller and more efficient chips. For instance, China's largest chipmakers such as SMIC who only possess limited process technology (e.g. 14nm) has no capability to produce chips that meet Huawei's need, so their advanced chipsets are produced by foreign foundry (To, 2021). It is also reflected by one of the interviewees as, *"in some design firms, their orders are sent directly to abroad, foreign manufacture because we do not meet their requirement and the fabrication becomes more and more advanced, better fabrication better performance of products, so many design firms would not give all the order to you."* (C1).

The rapid changes in market demand also result in product life cycles being much shorter (Brown & Linden, 2005). As mentioned in the regime of technology and knowledge, rapid changes in demand require great investment in terms of diverse resources such as equipment and facilities. Although advanced equipment or facilities for new technology may be purchased, more importantly, engineers who can efficiently manage and operate this equipment cannot be easily fulfilled in a short time. Interestingly, the interview data finds that lacking talented and experienced engineers in the sector is partly due to the fact that talents are concentrated in a specific industry in accordance with the market demand. In China, the large demand and a wide variety of user industries result in the concentrations of talented engineers in particular sectors, this causes the lacking of talented engineers in the semiconductor manufacturing sector. This is reflected by the industrial expert as *"Chinese semiconductor industry in this stage, there are a lot of talents in the design sector ..., Different levels of industrial development have led many people to invest in the design sector. From the U.S to Japan, South Korea and Taiwan, and China, this leads to a different development environment. For instance, the era of the Internet, 4G, mobile phones, etc. this result in bringing all talents to the Internet Capital market, only the fourth class will choose to do manufacturing, so there is no talent in the semiconductor manufacturing sector."* (D2)

4.5.4 Internal and external institutions

The institutional environment surrounded the Chinese semiconductor industry may be divided into two dimensions. One is an internal institution, it is the sectoral or sometimes national institution to strengthen and advance China's semiconductor industry. Another one is an external institution that aims to restrict China's semiconductor industry from gaining advanced technology. The internal institution of China is comprehensive, is designed to lift up the semiconductor industry and its technological advancement to the global leadership. The State Council of the Software and Integrated Circuit Industries in 2000 provided support through financial incentives, preferential investment policies, R&D incentives, import and export subsidies[16]. The State Council further strengthened it in 2011 by issuing human resources initiatives and intellectual property rights protection. Human resources are to promote the semiconductor-related talents attraction and cultivation through industry and academic collaboration, the establishment of the institute in microelectronics, the reformation of the education and formulation of talent stimulations (Kong et al., 2016). IPR is to encourage copyright registration and strictly implement the integrated circuit intellectual property protection system (Rho et al., 2015) in response to the concern over IPRs protection that has been noted as a major deterrent for foreign firms to transfer their advanced manufacturing technology to China (Yinug, 2009). It also explains the

[16] Zhang (2020), China Briefing

reason why many large fabless firms such as Qualcomm and Broadcom have been really slowly brought leading-edge design into China to be manufactured by indigenous manufactures (Grimes & Du, 2020). Recently, the Chinese government emphasised expanding the role of China in developing international rules for the protection of intellectual property and advancing Chinese standards in 2020 (Platzer et al., 2020).

In order to bring semiconductor manufacturing into a worldwide industry leader, China has implemented the "National Long-term Scientific and Technological Development Plan (2006-2020)" includes 16 major national science and technology projects, one of which is to enhance the technological level of China's semiconductor industry. A special fund has been established of almost US $100 billion to support innovation and development in the semiconductor industry (Li et al., 2019). A government fund (the China Integrated Circuit Investment Industry Fund) was also created for the purchase of foreign semiconductor equipment. Accordingly, Chinese semiconductor manufacturers received subsidies amounting to 50 billion dollars over the last 20 years, which helped to increase the volume of chip production (To, 2021). China set the goal of becoming a global leader in all segments of the semiconductor industry by 2030, implemented in 2014 by China's State Council "National Integrated Circuit Industry Development Guidelines". The document included measures to support an aggressive growth strategy, which the goal of achieving 70% of China's semiconductor demand from domestic production by 2025[17] . This is to promote high-quality manufacturing sectors capable of producing advanced products at modern facilities operated by well-known brands, increasing the market share of Chinese firms to meet domestic and international demand. In 2019, China revised to set the target of domestic production of semiconductors (including from foreign firms in China) to reach 80% of domestic demand by 2030, as part of its *Made in China 2025* industrial strategy. By 2030 the roadmap specifies that "that main segments of the IC industry … reach advanced international levels"[18].

On the other hand, the external institutional factors surrounding the sectoral innovation with respect to the restriction of accessing foreign knowledge cause a considerable barrier. In fact, external institutions are often designed to restrict technology transfer to China since the early stage. For instance, the Coordinating Committee for Multilateral Export Control (COCOM) was formed to forbid materials and technology exports to China since 1950. China was limited to import wafers bigger than 5 inches and production facilities smaller than 2mm, this was one of the reasons why China could only import old facilities during the initial stage of Reform, and this significantly slowed the pace of learning (Rho et al., 2015). Later in 1996, COCOM was succeeded by the Wassenaar arrangement with the leadership of the US, China is banned to obtain advanced technology from advanced economies (Chen & Toyama,

[17] McKinsey, A new world under construction: China and semiconductors
[18] U.S. Chamber of Commerce, Made in China 2025, March 15, 2017,65.

2006; Yu et al., 2017). Until today, under the control of the Wassenaar arrangement, China cannot access the advanced processes such as photomasks and lithography process equipment from the semiconductor equipment firms from advanced economies, cause the Chinese fabrications to operate quite outdated processes equipment (Zhang et al., 2013).

China's situation obviously differs from that in prior followers such as Korea and Taiwan, allied to the U.S., to license production technologies during their earlier stage of development. China is unable to access leading-edge technologies from the U.S. (Yu et al., 2017; Grimes & Du, 2020). The U.S. government strictly limits China's access to advanced materials, equipment and technology from the US's upstream suppliers, which can be highly disruptive for Chinese semiconductor indigenous manufactures. For instance, China's semiconductor firms Fujian Jinhua Integrated Circuit Co. (JHICC) was banned to be supplied with a major facility with components or materials from US firms (Grimes & Du, 2020). Moreover, in 2020, SMIC is added to the Entity List that limits SMIC to acquire certain U.S. technology both via exporting or licensing [19]. Along with the US's restrictions on technology transfer, other institutions such as Taiwan also ban semiconductor investment in China. For instance, Hejian is the representative case, a firm established by a retiree from UMC from Taiwan in 2002. Engineers from UMC enabled the high technology capacity of Hejian. However, later, when UMC implemented initial technology support via the form of strategic alliance and filed for M&A, this led to restrictions by the Taiwanese government thus, stalled Hejian's development (Rho et al., 2015). Today, Taiwan where possess the most advanced process technology in the world banned the transfer of advanced facilities to China, but only permit facilities that are at least 2 generations behind (Rho et al., 2015).

In response to the externally institutional factors that restrict the development of the Chinese semiconductor industry, it seems to motivate China to seek to fill technological gaps by using new pathways. Indeed, China has been reinforcing indigenous capability by reducing the dependency on foreign technology. A priority of the 14th Five-year Plan (2021-25) is to strengthen China's autonomy in semiconductor production. This is in response to US sanctions restricting the supply of chips containing US technology to China. This trade war is further motivating China to develop in house core technology pursue technological leapfrogging than relying on importing semiconductors (Platzer et al., 2020; To, 2021). The Chinese government, in order to increase the self-sufficiency in semiconductor production and bring up the industry to the top foundries, spend massively not only on acquisition but also the hiring of specialised foreign industry talent to China, advocating cross-border exchanges of

[19] Addition of Entities to the Entity List, Revision of Entry on the Entity List, and Removal of Entities From the Entity List. By the Industry and Security Bureau, 2020.

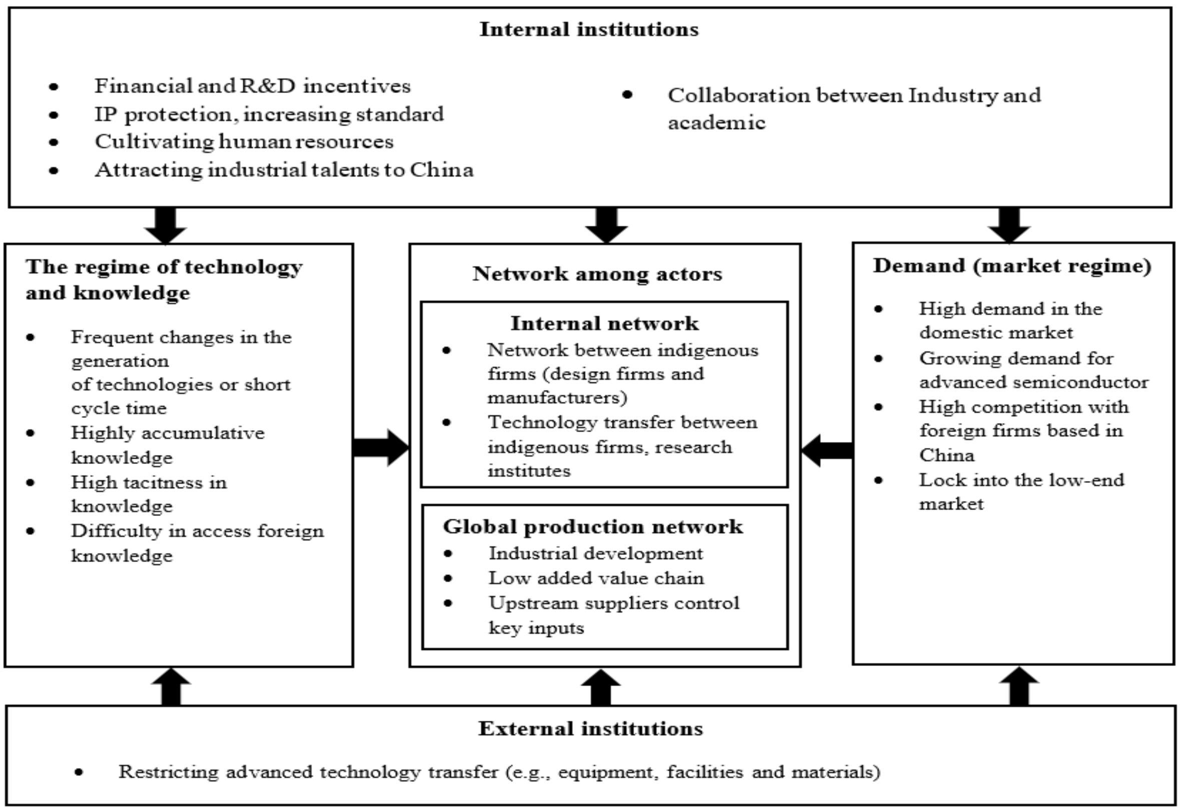
personnel and the collaboration between foreign academic and industry in both domestic and overseas R&D centres (Platzer et al., 2020). Table 4-3 summarised key factors of a sectoral system that have been discussed above and based on it, Figure 4-7 provided extended frameworks of the sectoral system of innovation and catch-up of China's semiconductor industry.

Table 4-3 Summary of key factors in sectoral system

Chinese semiconductor industry		
Actors and network	Global production network	• Upgrade industrial development by expanding the role in a global production network • Asymmetric and interdependent relationship within the global production network traps China within the low value-added position • The foreign suppliers control key inputs and restrict value-added segments and technology transfer to China
	Internal network	• Limited technology transfer between indigenous firms (the design firms rely on foreign foundry to produce advanced chips while looking for Chinese semiconductor manufacture for low-end chips) • Technology transfer between state-led R&D and manufacturing is limited • Lack of collaboration between university and research institutes and industry • Lack of cooperation with foreign research centre for advanced semiconductor technology
The regime of technology and knowledge	Short cycle in technology	• High investment in the replacement of equipment, facility and human capital causes the barriers • Lacking experienced engineers for the new technology
	High accumulativeness	• Graduates specialised in the semiconductor are still young and lacking experience • The wide knowledge gap between the university (graduate students) and industry, unable to apply knowledge into practice • Lack of a talent pool as working for the semiconductor sector is less preferable
	High nature of tacitness	• Difficulty in knowledge acquisition due to its tacit nature
	Accessibility of foreign technology and knowledge	• A high barrier in access foreign technology and knowledge • Advanced technology transfer is restricted by foreign partners (e.g. filing lawsuits in patent, IPR)

Demand	Wide variety and rapidly changing market demand	• Demanding for advanced technology from user industries, but also locked Chinese semiconductor manufacturers into low-end products markets • A wide variety of markets caused the concentration of talents in a specific industry
Institutions	Internal institution	• Financial supports in R&D and importing advanced equipment • Cultivating human resource • Inducing talents from overseas to China • Invest in collaboration between industry and academic (domestic R&D centres)
	External institution	• The international mechanism is often designed to limit the technology transfer to China • China's access to advanced equipment and materials is limited

Figure 4-7 Extended frameworks of the sectoral system of innovation and catch-up of China's semiconductor industry



Summary of finding

This study examined the factors that affect catching up from a sectorial system of innovation perspective. Along with the sectoral factors that have traditionally been regarded as the basis of catching up (K. Lee et al., 2008; K. Lee & Ki, 2017; Mu & Lee, 2005; Xie, 2004), this study has further identified the factors that affect catching up. As a result, the global production network and internal network, short cycle of technology, highly accumulative knowledge, tacit nature of knowledge and accessibility of foreign technology and knowledge, market demand and internal and external institutions were mainly identified as factors in the sectoral environment. As discussed above, it is important to note that these factors do not work independently but interact with one another.

In the semiconductor industry, especially the manufacturing segment, technology cycle time is short, highly cumulative, large tacit and difficult in accessing foreign knowledge which may cause barriers for rapid catching up. Followed by Moore's Law, the manufacturing process is required to shrink its size every 18 to 2 years to be in the technological leadership as well as seizing the market opportunities. Short cycle time in technology may be a double-edged sword. The previous studies have pointed out that the short cycle time enables followers to have a better opportunity to catch up (Perez & Soete, 1988) when they have already accumulated certain absorption and catching-up capabilities, otherwise, it may serve as an additional hardship against catch-up (Park & Lee, 2006; Rho et al., 2015). This study found that a short cycle time in technology may give the Chinese semiconductor industry hardship in their effort to catching up. It is because the short cycle time in technology requires continuous investment in R&D, new material and equipment, but this is getting more hardship with a difficulty in accessing foreign technology. Chinese semiconductor firms have encountered difficulty in accessing foreign technology since the beginning of the catching up. As discussed in the previous sections, the advanced economies' restriction transfer critical technology to China has been a chief difficulty for China that affect its catching up.

More importantly, the finding shows that the lack of a sizeable talent pool in the sector especially causes difficulty for catching up. Lacking the talent pool has directly related to the lack of accumulated knowledge that is highly critical in the semiconductor industry. Moreover, the finding of this study shows that because the graduate students specialising in Chinese semiconductor technology are still young and lacking experience, they are not able to apply their knowledge in the industry, a result of the wide knowledge gap between university and industry. This situation may cause additional difficulty when the technological cycle time is short, as nurturing talents takes a longer period. Interestingly, this study found that this phenomenon is closely associated with market demand. The large and wide variety of market result in numbers of talents to concentrate on specific areas of industry, mostly design sectors rather than the semiconductor manufacturing sector, therefore, the hiring event is often observed in the manufacturing sector. As a consequence, the lack of talents and experienced engineers serves hardship for catching up.

This study also looked at the global factors as the semiconductor industry is highly globalised and integrated. China's participation in the global production network has contributed to upgrading industrial development and technological advancement. However, the researcher has approached from a different perspective in that the global production network may also restrict further achievement in catching up by trapping China within the low-value position. The important segments of the production value chain are controlled by advanced economies and they resist its transfer to China as a part of the strategy. Therefore, even though the production of semiconductors shifted to China, the value-added production is mainly by foreign headquartered firms. Besides, the global production network is asymmetric and interdependent between China and other regions such as the US, Japan and European countries which controls the key inputs in the value chain, often result in the restriction of key inputs such as advanced equipment and material to China. In addition to it, as mentioned above, accessing foreign technology is extremely challenging for Chinese firms. External institutional factors often restrict transferring advanced technology to China, so China could only access the out of dated technology.

The finding of this study also shows that the global production network may weaken the internal network between indigenous firms. The internal production network between indigenous firms especially between large fabless and foundry firms may become weak and limit technology transfer between them. The finding shows that Chinese design (or fabless) firms depend on foreign fabrication manufacturers to produce leading-edge semiconductors as inputs into their assembly of devices while relying on Chinese indigenous manufactures that are a few generations behind the leaders to produce low-end semiconductors. Relying on foreign manufacturers for producing leading-edge chips provide competitiveness to fabless firms in the market but this may lock Chinese semiconductor manufacturers into a low-end technology, as well as the low-end market. Moreover, in regard to the internal network, the industry shows limited technology transfer between R&D and manufacturer (VerWey, 2019), university and research institutes and collaboration with foreign research centres, also cause the slow learning by indigenous firms (Rho et al., 2015; Yu et al., 2017).

In response to the current situations and external institution that restricts technology transfer to China, the Chinese government is strongly motivated to reduce its reliance on foreign technology and increase the internal supply value chain. The government has implemented a series of supportive policies and funding in the investment of purchasing advanced equipment, inducing foreign talents from abroad and establishing collaboration with foreign R&D centres.

4.6 Summary

This study looks at China's catching-up process in the semiconductor industry. As discussed above, the semiconductor industry has long had a presence in China, which this study has classified into two distinct periods: (1) catching up through inward internationalisation (the 1980s-1990s), and (2) catching up through indigenous capability (2000s-till now). This study by looking at a brief history of China's semiconductor industry advanced our understanding of China's technological catch up over time by considering the main actors, strategies in knowledge acquisition and, policy. Despite the long history in the semiconductor industry, China has had limited achievement in catching up by looking at diverse records of catching up.

This study mainly looked at three indicators of the record of catching up, these include market share by segments, patent data and process technology by regions for China, the U.S., EU, South Korea, Japan, Taiwan. China has been gradually narrowing the technological gap with global leaders, however, the record of catching up shows that the industry still remains limited. This study, in order to determine the reasons, examined the factors that affect catching up by using a sectoral system perspective. With sectoral factors such as the regime of technology and knowledge, market regime and institution that have been identified to affect the catching up. This study finds that the sectoral factors play the role of windows of opportunities for followers to catch up (Lee et al., 2008; Lee & Ki, 2017; Mu & Lee, 2005; Xie, 2004), but also cause the barriers for catching up. In the semiconductor industry, technological cycle time is short, technology is highly accumulative, which put followers in a difficult position. This study found that the characteristics of the technology and knowledge regime of the industry can be more vital in the causation of hardship in catching up when there is a lacking pool of experienced engineers and talents in the sector. Although new facilities or equipment can be replaced, having engineers who are able to operate the new facility and equipment takes time. Furthermore, difficulty in accessing foreign knowledge may cause more hardship, and it is especially to do so when external institutions restricting the transfer of core technologies to China, which slows the learning path of Chinese indigenous firms.

This study, by considering the features of the semiconductor industry, takes the global production network into account and attempted the extension of the sectoral system of innovation framework. While the previous studies have intensively investigated the benefits brought by the global production network to China's industrial development, this study also suggests that a global production network may trap followers into low-value activities because global leaders could easily control the supply of essential input for manufacturing semiconductors. In addition to this, the global production network also weakened the internal network between indigenous fabless and manufacturing firms. The finding shows that large indigenous fabless firms often rely on foreign manufacturers for producing semiconductors that require advanced process technology while depending on indigenous manufacturers for making low-end semiconductors. This may provide the opportunity for fabless firms to be able to produce high-performance products using advanced process technology of global foundries but limits technology transfer between indigenous firms that may trap Chinese indigenous foundry into low-end technology or market.

The barriers arise since the global leaders' resist transferring the advanced technology or knowledge to followers who thus are able to design and produce by themselves. But this barrier is also a window of opportunity for catching up when follower succeeds in designing and producing their own advanced chips. As a matter of fact, the Chinese government shifted the direction of the policy that prioritises indigenous innovation. The government heavily invest in the semiconductor industry and technology to produce its high-performance chips that are globally competitive, by providing financial support, supporting collaboration with foreign research institutes, nurturing talents and inducing experienced engineers from abroad.

In this chapter, a brief review of the history of China's semiconductor industry enabled us to have an understanding of the role of hiring that has been played in their catching-up process. Furthermore, looking into the transnational dimension of the sectoral system of innovation, provided an idea of why hiring engineers from global leaders is important and necessary in China's semiconductor industry. This chapter serves as preparation work for studying technological and sociological factors in Chapter 5 and Chapter 6.

Chapter 5 How does the technological distance between the hired engineer and the hiring firm affect the firm's exploratory versus exploitative innovation?

5.1 Introduction

The hiring of engineers is closely connected to the beneficial effect the hiring firms gain, reflecting the knowledge that newly hired engineers carry over from their previous firms and their contribution to facilitating the firm's innovation (see Rosenkopf & Almeida, 2003; Simonen & McCann, 2008; Parrotta & Pozzoli, 2012; Storz et al., 2015; Kaiser et al., 2018). Therefore, learning by hiring provides insight into how hiring typically occurs. However, although previous studies have long presented hiring as a mean to explain building the hiring firm's innovation (see Kaiser et al., 2018; Marino et al., 2012; Storz et al., 2015), they have devoted less attention to the knowledge of hired engineers which results in different consequences for the firm's innovation. Up until now, only a few studies looked at a technological distance (defined as the difference knowledge between the hired engineer's knowledge and the hiring firm's core technological domain (Song et al., 2003)) that result in different dimensions of innovation: exploratory or exploitative innovation (Zucker & Darby, 1997; Rosenkopf & Almeida, 2003; Song et al., 2003). Exploratory innovation is defined as the desire to pursue new technology and develop new technology (Benner & Tushman, 2003; Karamanos, 2012), while exploitative innovation is defined as pursuing building upon existing technology and reinforcing existing technology (Benner & Tushman, 2003; Karamanos, 2012).

When firms hire engineers, they may gain access to knowledge that may either be distant from the firm's technology or knowledge that may be not distant but familiar to it. According to Phene et al (2012), when firms gain access to distant knowledge they open up directions for technological exploration; otherwise, firms may also gain new knowledge in contributing to better ways of reinforcing existing technology. This implies firms can gain access to new knowledge through hiring but distant knowledge increases the firm's acquisition of new knowledge and opens new opportunities for novel knowledge integration (Nelson & Winter, 1982; Audia & Goncalo, 2007; Fleming, 2001) that contribute to a firm's exploratory innovation. Conversely, when acquired knowledge is not distant, this means the knowledge may be already available within a firm and increases a firm's understanding and familiarity in terms of the knowledge; hence, firms can maximise the effective use of acquired knowledge (Bierly et al., 2009). Firms often hire engineers whose knowledge is familiar to them, aware of how to place their knowledge into use. Therefore, there is great potential that hired engineers will tend to conduct innovative activity based on a firm's existing technology (Levinthal & March, 1993) by building on the firm's established knowledge (Tzabbar et al., 2013).

Concerning the hiring of engineers from other firms, the important role of technological distance on the hiring firm’s innovation is underscored, yet such studies tend to provide an implicit aspect and do not provide a clear view (Song et al., 2003; Tzabbar, 2009; Tzabbar et al., 2013). In the existing literature, there is very little systematic investigation addressing the underlying role of technological distance on the hiring firm’s innovation by classifying it into exploratory and exploitative innovation. This has resulted from the fact that previous studies mainly focused on to what extent that knowledge (patent-related knowledge) has flowed to the recipient firms (Almeida & Kogut, 1999; Parrotta & Pozzoli, 2012; Rosenkopf & Almeida, 2003; Tzabbar et al., 2015). The patent-related knowledge has been a proxy of knowledge spillover and outcome of hiring, and so has limited our view regarding technological distance on a firm’s innovation (Rosenkopf & Almeida, 2003; Song et al., 2003; Tzabbar, 2009). Consequently, how does technological distance affect a firm’s innovation from the dimension of exploratory versus exploitative innovation remains a relatively open question. Moreover, the theoretical clarity concerning the effect of technological distance on the hiring firm’s innovation seems to be unclear.

To fill these voids in the literature, this study draws from both information processing (Van Knippenberg & Schippers, 2007) and categorisation perspectives (Tajfel, 1982) to investigate the effect of distant knowledge on a hiring firm’s innovation. Two main traditions have been used in the research in order to study workers within a firm: different demographic factors (such as race or age), and non-demographic factors (such as education, functional background, work experience in specific areas) (Tajfel, 1982; Williams & O’Reilly, 1998). Williams and O’Reilly (1998) stressed that different types of demographic factors have different effects, some resulting primarily from changes in information processing and others from categorisation. This study expected the effects of technological distance to be explained by information processing and categorisation theory, the knowledge that newly hired engineers bring to a firm, which may determine their different contributions to a firm’s different innovation. Thus, this study contends that the information processing and categorisation perspective can help us to answer the research question on *How does the technological distance between the hired engineer and the hiring firm affect the firm’s exploratory versus exploitative innovation?*

Our study intends to contribute to the literature in two important aspects. Firstly, while the conventional studies of learning by hiring build on knowledge spillover focused on knowledge flow (Rosenkopf & Almeida, 2003; Song et al., 2003; Singh & Agrawal, 2011; Tzabbar et al., 2013) and innovation building (Simonen & McCann, 2008; Agrawal et al., 2015; Kaiser et al., 2018; Rahko, 2017), this study moves beyond this sequence by focusing on the knowledge of hired engineers. Specifically, this study identified hired engineers’ knowledge into distant or non-distant knowledge from that of the hiring firm’s technology and investigates how hiring such knowledge lead to different consequences on the hiring firm’s innovation. Although the previous studies have provided information that hiring engineers whose knowledge is distant leads to greater learning (Song et al., 2003), and the firm's technological repositioning (Tzabbar, 2009), these studies are somewhat implicit and did not provide a comprehensive understanding in terms of 'how' question. This study explicitly investigates the role of technological distance in affecting a firm's exploratory versus exploitative innovation. For this purpose, this study borrows the insights of information processing and categorisation to explain technological distance and innovation. Overall, this study advances the literature on learning by hiring (Rosenkopf & Almeida, 2003; Song et al., 2003; Tzabbar, 2009) by investigating novel challenges that show how newly hired engineers with distant knowledge facilitate a firm's exploratory and exploitative innovation by using information processing and categorisation perspectives.

Finally, this study contributes empirically to the literature on learning by hiring. Empirical research in this area is limited to patents as an outcome of knowledge spillover and proxy of innovation (Rosenkopf & Almeida, 2003; Song et al., 2003; Singh & Agrawal, 2011; Tzabbar et al., 2013; Simonen & McCann, 2008; Agrawal et al., 2015; Kaiser et al., 2018; Rahko, 2017). Although patent provides a valuable view in terms of hiring study, this may also limit the view in identifying their contribution within a new firm. In so doing, this study moves away from patent-related knowledge as an outcome, which is the main feature of existing studies based on quantitative studies (Rosenkopf & Almeida, 2003; Simonen & McCann, 2008; Singh & Agrawal, 2011; Song et al., 2003; Tzabbar et al., 2013), to a qualitative approach. This study uses interview data to investigate the outcome of innovation specifically with regards to exploratory and exploitative innovation. In so doing, the findings help provide new insights into learning by hiring and broaden our understanding of the significance associated with hiring engineers as a way of knowledge acquisition on the firm's innovation.

5.2 Theory and conceptual framework

Hiring engineers from other firms enables the hiring firm to access external knowledge (Arrow, 1962) thereby facilitating innovation; however, depending on the knowledge that hired engineers possess, this can provide the catalyst for learning that leads to a different consequence on the firm's innovation. The primary interest of this study is in how hiring engineers with distant knowledge affects the firm's different dimensions of innovation, as distinct from whether hiring affects innovation. This study focuses on hired engineer's distant knowledge (or not distant) to what hiring firms possess and its effect on a firm's innovation. Technological distance (or distant knowledge) is defined as the difference in knowledge between the hired engineer's knowledge and the hiring firm's core technological domain (Song et al., 2003). For instance, when the engineer's knowledge does not exist in the hiring firm or it is not in the firm's core technological domain then this is considered as distant knowledge. On the other hand, if the engineers' knowledge is already available in the firm or matched with the firm's core technological domain, this is considered as familiar knowledge as opposed to distance.

Innovation as an outcome is categorised into a dimension of exploration and exploitation. Exploratory innovation is defined as the innovation to pursue new technology and develop new technology, brings in new methods or material novel to a given firm (Quintana-García & Benavides-Velasco, 2008; Benner & Tushman, 2003; Karamanos, 2012). This study will focus on the creation of technological knowledge that is new to the firm that falls outside of a firm's existing technology. This differs from exploratory innovation which yields knowledge that is new to the industry or the world. Exploitative innovation is defined to pursue building upon existing technology and reinforce existing technology, improves the existing methods or materials used by firms to achieve their goal (Quintana-García & Benavides-Velasco, 2008; Benner & Tushman, 2003; Karamanos, 2012).

Engineers at the technical level are carriers of knowledge, hiring them can be conceived as a strategy by which firms can build their exploratory and exploitative innovation. According to information processing theory, a firm perceives itself as an information processing system that learns (Egelhoff, 1991). For firms to accelerate information processing, knowledge that is from different resources is required (West, 2000). However, the human brain has limited capacity (Grant, 1996; Simon, 1991), knowledge from different individuals is required. Different knowledge, skills, the perspective that leads to information processing can result in a beneficial effect on the new creation (Van Knippenberg et al., 2007). The information processing perspective suggests that bringing different knowledge together allows firms to 'think outside the box' (Martin et al., 2009) and this process eventually increases the potential for creativity and avoids the typical way of doing things. Information processing theorists may perceive hiring engineers with distant knowledge as critical for a firm's exploratory innovation because they can bring different knowledge that can enhance new creation (West, 2000). In addition, information processing theorists also stress that different knowledge stimulates intensive experimentation with a new combination through which, within a firm exchange, process and interpret the different knowledge (Olson et al., 2007), and create better synergy in developing new technology (Van Knippenberg & Schippers, 2007).

However, categorisation views a human being based on the differentiation between species; ingroup-outgroup categorisation is based on the differentiation between groups of people by identifying occupation, class and other diverse variables that can be categorised (Oakes & Turner, 1990). People tend to categorise others and themselves in accordance with perceived similarity and difference (Tajfel, 1982; Van Knippenberg & Schippers, 2007). They tend to treat members of their group (similarity) with favouritism and may judge "others" (difference) according to group traits (stereotyping) (Stahl et al., 2010). People in the similar "in-group" will have easier communication, show more affection, trust (Van Knippenberg & Schippers, 2007), cohesion (O' Reilly et al., 1998), and commitment (Tsui et al., 1992) because the similarity between individuals stimulates mutual liking and interpersonal attraction (Byrne, 1971). In addition, when engineers work with similar each other, the categorisation decreases, it is less likely that individuals depend on the opinions and viewpoints of members that are perceived as ingroup only, such is expected to promote knowledge integration of its members (Van Knippenberg & Schippers, 2007). Therefore, engineers with familiar knowledge who engage with each other will lead to an easy collaboration that may stimulate knowledge integration.

This study will use the lens of information processing and categorisation perspective to discuss both engineers with distant and familiar knowledge of the firm's different dimensions of innovation. This study expects distant knowledge can be better explained with an information processing perspective while hiring engineers with not distant knowledge can be better explained with a categorisation perspective.

Distant knowledge and exploratory and exploitative knowledge

This study posits that firms that hire engineers whose knowledge is distant from that of the hiring firm's technology may assist their generation of innovation that in turn leads to exploration. According to the information processing perspective, creativity often increases the requirement of different knowledge (West, 2000). Firms exposed to distant knowledge benefit from exposure to different knowledge that allows for "think outside the box" from the typical way of thinking (Martin et al., 2009). It is often noted that ideas and a multiplicity of points of view in problem-solving are created by people who have different knowledge working together and this is often deliberately established by the most innovative firms (Cox & Blake, 1991). Firms in a technology-intensive industry that involves multidisciplinary expertise must assemble a wide array of engineers with highly specialised skills and experiences in many fields, (West, 2000), and require their knowledge that can breakthrough in the technology and continuous problem-solving through different ways of doing things, idea, and methods. Firms that hire engineers with distant knowledge will lead to a direct increase in the different knowledge and perspectives brought to a problem and this process eventually results in more innovative ideas and solutions for problem-solving (Ancona & Caldwell, 1992). Newly hired engineers with distant knowledge in the new firm increase the search potential or discover a wider set of applications for an existing problem by bringing in different ways of doing things or the ideas that are not previously attempted by the firm. They will likely conduct more varied experimentation within a firm, leading firm to generate breakthroughs from the existing limitations.

In addition to hiring engineers with distant knowledge, the potential for generating exploratory innovation driven by the integration of different knowledge is increased. Information processing theorists stress that different knowledge stimulates intensive experimentation with a new combination (Van Knippenberg & Schippers, 2007). Firms that hire engineers whose knowledge is distant can increase the opportunities for knowledge integration that may contribute to the firm's new technology.

Newly hired engineers with distant knowledge can bring in their new knowledge into the existing one, and their different ideas and approaches may be combined to provide strong inputs for increasing the exploratory content of novel combinations of knowledge (Fleming, 2001; Audia & Goncalo, 2007). Engineers working with others whose knowledge is distant can be superior concerning the prerequisites to innovation, as this different knowledge-gathering together enhance the new knowledge potential while reducing the same way of thinking (Amabile, 1994). Their distant knowledge can be combined and improved upon the discrete viewpoints to produce results that are more informed, more innovative than that which could be produced by engineers with similar knowledge. Therefore, engineers with distant knowledge working with each other can come out with a better idea and encourages the potential of more advanced perspectives of a problem, and this is likely to provide strong inputs for creativity that reasonably yield a significant contribution of exploratory innovation.

However, the combination of knowledge requires making connections across different knowledge, this needs active knowledge sharing between engineers. Knowledge sharing can enhance mutual understanding and comprehension to integrate and employ technological distance (Kogut & Zander, 1992; Tzabbar, 2009), and this increases the great potential for a new, and innovative combination of knowledge (Zhou & Li, 2012). The disparate perspectives, task conflict where group members argue over which viewpoint is better, may result during the collaboration for knowledge combination. However, such disparate perspectives and conflicts are thought to foster the creation of innovative solutions and creativity in general (Bantel & Jackson, 1989; Ancona & Caldwell, 1992).

Furthermore, knowledge sharing may be less impeded as engineers would not feel threatened by each other with different knowledge. It is reflected in the social comparison perspective, that people are more willing to share their unique knowledge with different others than those who are similar to them, as people, in general, feel less competitive when different from each other (Phillips et al., 2003). In the case of engineers with distant knowledge, knowledge sharing will be more likely to happen because they will feel less competitive with each other and less threatened by each other. They may instead recognise how their peer’s knowledge bears on their work and how to synthesize it to serve the common goal of creating new technology through frequent interaction and knowledge exchange (Schulz, 2001). Thus, hiring engineers with distant knowledge assumes importance in building the firm’s exploratory innovation as which opens a great opportunity in gaining different knowledge that the hiring firm does not previously possess and which also enhances the possible combination of different knowledge that lead to exploratory innovation. Taken together, these lines of arguments, provide insights and suggest the following proposition.

P1a) Hiring engineers whose knowledge is distant from that of the hiring firm's core technological domain is more likely to facilitate the firm's exploratory innovation rather than their exploitative innovation.

Conversely, when firms hire engineers whose knowledge is not distant but familiar, they increase the potential for facilitating the firm's existing technology. Where firms access the knowledge that is not distant, the learning is greatest (Cohen & Levinthal, 1990) due to the familiarity in terms of knowledge increases the firms' absorptive capability and innovative activity (Knoben & Oerlemans, 2006; Benner & Waldfogel, 2007; Cantner & Meder, 2007). The prior studies suggested that absorbing and using external knowledge requires the recipient firm to possess certain technological overlap (Cantner & Meder, 2007), in so doing, the learning can take place. Hiring engineers with familiar knowledge indicates a better understanding of specific technology, so firms can reap the greater benefit from learning by hiring (Slavova et al., 2016). Hiring firms may be better aware of how to place the hired engineers in their operation based on their prior experience (Jain, 2016), this also provides an easy way for firms to use the acquired knowledge and building blocks depending on the firm's need (Rosenkopf & Almeida, 2003; Makri et al., 2010).

Hiring engineers with familiar knowledge indicates that the resource is relating to the facility that firms already in place for hired engineers to access. Having supportive facilities in place for hired engineers to access can maximise the engineers' performance. Groysbery and Lee, (2009) provided a study about professional service firms, suggest that firms hire engineers with familiar knowledge have some specific advantage in assisting support the performance of new hire because of the systems and structures that firms already have in place. This infers that when firms hire engineers whose knowledge is not distant, a great possibility that hired engineers can access the facilities offered by their new firm. That is, more likely hired engineers would be offered to pursue innovative activity along with the recipient firm's existing technology by accessing the facility resources in place. They will be likely to conduct the innovative activity inside a frame constituted by a particular way or established practices and procedures the hiring firm use within which it operates (Levinthal & March, 1993; Song et al., 2003) by filling the gap or overcome the limitation of existing technology and investigate solutions in search to their existing areas of knowledge.

More importantly, by hiring engineers with familiar knowledge, collaboration may be easy between engineers with familiar knowledge. The previous studies have shown that for the knowledge of hired engineers to be learnt and integrated into the firm, incumbent engineers must be willing and able to integrate the knowledge provided by the newly hired engineers (Argote et al., 2000; Tzabbar, 2009). When engineers are hired by a firm where incumbent engineers feel familiar with the knowledge, incumbent engineers can gain a deep understanding from hired engineers' guidance without unnecessary risks of confusion and misunderstanding (Broekel & Boschma, 2012). It is because engineers working with familiar knowledge share a common language for understanding (Inkpen & Wang, 2006) and technological mindset (Phene et al., 2012) which may eliminate the great difficulty in collaboration. Incumbent engineers in the firm enable to support hired engineers who possess familiar knowledge and enable hired engineers to get into technological tasks immediately. This can result in a higher level of performance of hired engineers as they can quickly take advantage of the firm's existing human capital which can maximise their knowledge use and the performance in their area of specialisation in the new firm (Groysberg & Lee, 2009).

The problems encountered in the collaboration between these engineers with familiar knowledge may be easy for knowledge integration. According to the categorisation perspective, which is complemented with a similar-attraction paradigm (Williams & O'Reilly, 1998), engineers will likely be more attracted to, and more accepting of, those with whom they are connected. Newly hired engineers with familiar knowledge will be more accepted and included by incumbent engineers who are likely to perceive newly hired engineers as an ingroup. Although newly hired engineers once hired by the firm, will build a working relationship with their colleagues, it may require a long time to build good relations. Newly hired engineers who possess knowledge that is familiar to incumbent engineers will likely breed greater trust (Van Knippenberg & Schippers, 2007), cohesion (O' Reilly et al., 1998), and commitment (Tsui et al., 1992) while reducing possible conflict (Jehn et al., 1999). Therefore, hired engineers with familiar knowledge will be easily integrated within a firm or team without consuming much time in building a working relationship and this eventually increases collaboration between engineers.

However, knowledge integration that leads to exploratory innovation may be limited while the possibility of contributing to exploitative innovation may be increased. Acquiring familiar knowledge increases the redundancy of knowledge, which diminishes the learning of new knowledge (Mowery et al., 1998) and limits the opportunities for creating novel knowledge (Makri et al., 2010). According to this line of reasoning, if hired engineers generating innovation know exactly what others also know, they will have a similar understanding of how technologies work, and similar methods to approach problems. Thus, engineers working with others who possess similar knowledge tend to come out with the most accessible ideas that are likely similar. This will likely give rise to a reinforcement of the firm's existing technology (Knoben & Oerlemans, 2006; Makri et al., 2010). Hence, and in line with this logic, this study proposes:

> P1b) Hiring engineers whose knowledge is not distant (but familiar) to the hiring firm's core technological domain is more likely to facilitate the firm's exploitative innovation rather than exploratory innovation.

This section illustrates the conceptual research framework which results in propositions in the discussion. As above, the propositions are developed on the effect of technological distance on the recipient firm's exploratory and exploitative innovation as an outcome of learning by hiring. By using information processing and categorisation theory, the first proposition was formed as when firms hire engineers whose knowledge is distant, which enable firms to get access to knowledge that is new to the firm, as well as increase the knowledge integration of different knowledge, this is more likely to facilitate exploratory innovation than exploitative innovation. The second proposition was formed that when firms hire engineers whose knowledge is not distant but familiar to the hiring firm's core technology, this will result in easy collaboration between engineers for knowledge integration but engineers may mostly come out with similar knowledge, hence, this is more likely to facilitate exploitative innovation than exploratory innovation.

5.3 Analysis and results

In this section, this study presented the analysis and the key finding emerging from the data. As mentioned in the methodology chapter, this study employed deductive data analysis. The deductive analysis is often used when some views, previous research findings, theories or conceptual framework about the phenomenon exist (Armat et al., 2018; Mayring, 2014). This research employed deductive approaches in analysing the data as the basing analysis of this study is in the light of information processing and categorisation theory.

The deductive approach is theory-driven by the researcher's theoretical interest in the topic, deductive analysis is, therefore, a process of coding the data to fit it into a pre-existing coding frame, rather than from data to theory that is often the case of the inductive data analysis (Gale et al., 2013). The deductive approach helps the researcher focused on the coding on the issue that is known to be important in the existing literature, and it is often linked to test the theory (Linneberg & Korsgaard, 2019). As initial codes are deduced from the existing literature on the topic of inquiry of what is known about the phenomenon of inquiry (Azungah, 2018). It allows the researcher to approach the analysis with a focused lens and rapidly identify relevant data.

This study adopted qualitative research of deductive data analysis based on the following steps.

1. *Forming a conceptual framework and proposition.* A conceptual framework can be theory-driven, explains, the main things to be studied- the key variables or constructs and the presumed interrelationships among them (Miles *et al*., 2014). And from the framework, the propositions that will be studied are identified.

- P1a) Hiring engineers whose knowledge is distant from that of the hiring firm's core technological domain is more likely to facilitate the firm's exploratory innovation rather than their exploitative innovation.

- P1b) Hiring engineers whose knowledge is not distant (but familiar) to the hiring firm's core technological domain is more likely to facilitate the firm's exploitative innovation rather than exploratory innovation.

2. *Becoming familiar with the data.* The researcher should read and digest the data to make sense of the whole set of data. The recorded interviews were transcribed verbatim by the researcher and written in text. Due to the interviewees' mother tongue language being both Mandarin and Korean, the researcher interviewed by using the interviewees' original languages. This is to capture the authentic meaning of the words and to understand the precise meaning of the interviewees' intention. So the interview transcription was written in their original language. Secondly, the researcher attempted to become familiar with the whole interview, re-read the original text before translating it into English. After familiarisation with the interview, the original text of the interview was translated into English. The researcher has re-read the whole data set in the original version to capture the original meaning and detailed information that may be lost after translation. In this stage of the analysis, the researcher gains the whole picture of the studies phenomena and writes down the insights and understanding, as well as identifying certain key aspects of the data that are directly related to the research question.

3. *Labelling or tagging the data.* After familiarisation, as the concepts have been pre-defined by an existing theory, it was possible to move straight onto indexing. Table 5-1 shows the pre-defined concepts and examples. Since the semiconductor industry belongs to the security-sensitive sector, the hiring event in the semiconductor industry is a relatively sensitive issue, so the interviewees tend to be reserved and respond to the interview questions in an indirect way. In order not to miss any valuable aspect of the data, the data was divided into distinctive *meaning units* (Wertz, 1983; Rennie et al., 1988). Meaning units are usually parts of the data that even if standing out of the context, would communicate sufficient information to provide a piece of meaning to the reader (Elliott & Timulak, 2005). As the meaning units are delineated, the data can be shortened by getting rid of redundancies that do not change the meaning contained in them (Elliott & Timulak, 2005). The meaning units are categorised by discerning regularities or similarities in the interview data (Glaser & Strauss, 2017) within each of the domains. The obvious redundancies, repetitions and unimportant digressions are removed.

4. *Sorting the data by theme or concept.* The data establishes categories of the first order that categorise meaning units, categories of the second order are condensed meaning units that are close to the original text, the categories of the third categories are revised order, as shown in Appendix F. The categorising is processed by using NVivo as well as being processed manually with a paper and pen by looking at both original and translated versions. However, putting the data into a qualitative analysis software package does not analyse the data automatically, rather it is simply an effective way of organising the data so that they are accessible for the analysis process (Gale et al., 2013). For this research, tables were designed to summarise the data by category from each transcript. These captured any data link to key themes, as well as any other interesting observations or comments. Table 5-1 below shows the process of deductive analysis and Table 5-2 shows a sample of data analysis (coding process). The full table can be viewed in Appendix F.

Table 5-1 Deductive analysis process

Concept	Definition	Example		Coding process
Distant knowledge	The difference in knowledge between the hired engineer's knowledge and the hiring firm's core technological domain (Song et al., 2003).	The engineer's knowledge does not exist in the hiring firm or it is not in the firm's core technological domain then this is considered as distant knowledge.		**Process of coding the data (data analysis table) to fit it into a pre-existing coding frame (as shown in Table 5-2)**
Familiar knowledge	The engineers' knowledge is already available in the firm or matched with the firm's core technological domain, this is considered as familiar or similar knowledge.	The engineers' knowledge is already available in the firm or matched with the firm's core technological domain, this is considered as familiar knowledge as opposed to distance.		
Exploratory innovation	Exploratory innovation is defined as the innovation to pursue new technology and develop new technology, brings in new methods or material novel to a given firm (Quintana-García & Benavides-Velasco, 2008; Benner & Tushman, 2003; Karamanos, 2012).			
Exploitative innovation	Exploitative innovation is defined to pursue building upon existing technology and reinforce existing technology, improves the existing methods or materials used by firms to achieve their goal (Quintana-García & Benavides-Velasco, 2008; Benner & Tushman, 2003; Karamanos, 2012).			

Table 5-2 Sample of data analysis (coding process)

Concept	Codes/categories	Condensed meaning unites (close to the text)	Example quotations
Distant knowledge and exploratory innovation	Hiring engineers whose knowledge is unavailable to develop new technology	• I was developing NROM Memory related elements • The current firm was hiring in similar technology • The firm had no such technology • I develop in this part of the technology	"When I was in the previous firm, I was developing NROM Memory related element, I moved to the current firm because the current firm was hiring engineers who were doing similar technology, so I came here. At the time, this firm had no such technology, so I did contribution to develop in this part of technology." (A3)
	Hire unavailable knowledge and set new team to develop the new technological field	• In charge of the back-end process • Find someone to set up this part themselves	"The part I am in charge of is very special, it is the back-end part. The back-end production process and equipment processing. At the time, it was too expensive to find a factory to do this part for us, so the firm hoped to find someone to set up a team and do this part themselves. So I came here for this reason." (B1)
Familiar knowledge and exploitative innovation	Same technological area and refining existing technology	• Working in different factories within a firm • Keep doing the same thing • Did 8inches in the previous firm and the hiring firm did 8 inches at the time	"When I was newly hired I was doing what I had done in the previous firm, … they also sent me to different factory keep doing the same thing, when I was in the previous firm I did 8 inches after I came here, they do 8 inches, which this firm just initiated 8inch at the time. When I just came they did 40 and 28nm." (A2)
	Solving the problem, efficiency improvement, Cost down in accordance with existing technology	• Doing the same technological field • Solving system related problem • Efficiency improvement • Cost reduction • Refinement in the process • Not designing new technology	"I used to work at Alpha firm (leading firm) before I moved here, doing the same technological field, CMP (Chemical Mechanical Polishing) in manufacturing. In terms of technology, I basically solve the problem in the process (systematic improvement) also help to produce manufacturing process cost reduction, or projects that need efficiency improvement (reduce the time). So, from this point of view, we are not designing new technology, but do some refinement in the process." (C2)
Knowledge integration & Collaboration	Combining new methods and material	• Hire different areas to develop new technology • Add a new process, a new material that firms doesn't have	"We hire engineers who can bring knowledge that our firm does not possess. For instance, the firm didn't have EUV (Extreme ultraviolet lithography), so in order to develop EUV, which is the technology required in lithography (we have), … hire from B (also competitor, even though that firm is not specialising in EUV). But this person is at least aware of how to develop EUV, he can supervise in the firm for rapid development… save much time." (A2)

The primary findings emerged: knowledge of hired engineers is identified as distant or not distant (familiar). Knowledge of hired engineers is not difficult to identify as distant knowledge is often new and unavailable to the hiring firm while familiar knowledge is already existing within the hiring firm. Secondly, in order to investigate the effect of this knowledge on the hiring firm's different dimensions of innovation, this study carefully investigated the association between knowledge (distant and familiar) and innovation by identifying it into exploratory and exploitative innovation. Exploratory innovation appears as 'new technological field', 'new technological element' 'new business' that are new to the firm while exploitative embeds 'solving a technological problem', 'efficiency improvement', 'improving technological understanding' in accordance with improving existing technology. Innovative activity between fabless firms and fabrication manufactures has a distinctive difference. For fabless firms, exploratory innovation often involves new business targeting new technological fields as the business model of fabless is in design and sell the products, the evidence shows that fabless firms often change business fields according to the needs of the market. On the other hand, for foundry, a complete transformation of the technology may not be easy unless they open new plants, thus, problem-solving and efficiency improvement is clarified as exploitative innovation as which is based on the existing technology, while facilitating in the new technological field, new technological elements are clarified as exploratory innovation. Consequently, the evidence reveals that depending on the knowledge of hired engineers, their contribution leads to different results; the role of technological distance increases the potential for facilitating a firm's exploratory innovation while familiar knowledge may contribute more to a firm's exploitative innovation.

This study also discussed knowledge integration and collaboration, whether distant (or familiar) knowledge increases the potential for knowledge integration that leads to exploratory or exploitative innovation. Knowledge integration is especially necessary for foundry firms where combining new fabrication processes and new materials is often considered an important process. In terms of collaboration between engineers, this study found some interesting points that have not been pointed out by previous studies, the finding exposed that having incumbent engineers who are able to support the hired engineers is exceptionally important. This study also found the facility in place plays an important role in supporting hired engineers for the innovative activity within a new firm. The facility in place determines the hired engineers' contribution to the firm's exploratory and exploitative innovation. The finding reveals that even the firms hire engineers with distant knowledge, but if the hiring firms are not able to provide the facility for hired engineers to access, the engineers whose knowledge is distant may have to follow the firm's existing trajectory. On the other hand, when the hiring firms are able to provide the new facility to support hired engineers with distant knowledge, then the potential for them to contribute exploratory innovation will be greater. Moreover, some other factors such as language do not cause many barriers to collaboration. As a result, the findings of this study are divided into two subsections including distant and familiar knowledge and knowledge integration, collaboration. In the next section, the detailed findings of each theme will be discussed.

5.3.1 Distant knowledge

Identifying the knowledge of hired engineers provides a clear view in terms of their contribution to the firm's innovation. Knowledge of hired engineers, whether knowledge is distant or not from that of the hiring firm's core technology domain is carefully identified. In many of our interviewed cases, engineers entailing distant knowledge emphasized that their knowledge includes their 'experience' 'knowhow' 'methods' in a specific technology is 'new or unavailable' to the hiring firm when engineers are initially hired. It is clearly explained by interviewees, there are no incumbent engineers who possess the same knowledge. Acquiring such knowledge through hiring engineers may contribute to both the firm's exploitative innovation or exploratory innovation, so careful identification is required in regard to the terms that interviewees mention. Specifically, foundry firms hire engineers whose knowledge is distant to initiate the firm's new technological development, which is explicitly mentioned by interviewees as 'new technological field', 'new technological element'. For instance, firms hire engineers with distant knowledge to initiate new technological fields such as back-end and equipment process that was not available within a firm. The hiring firms often hire engineers in this specific field and set up a new team for them to develop new technology.

> *"The part I am in charge of is very special, it is the back-end part. The back-end production process and equipment processing. At the time, it was too expensive to find a factory to do this part for us, so the firm hoped to find someone to set up a team and do this part themselves. So I came here for this reason" (B1).*

Also, firms hiring engineers in order to develop a firm's new technological elements. Due to no experience in a specific technology such as 40nm immersion lithography and 28nm metal gate, firms hire engineers who specialise in it and develop such technology. This is reflected in the statement of the interviewee: *"There is no one who can do a firm's new things, so we find people to fill in, the other case is a new technology, the firm doesn't have an experience like 40nm immersion lithography, 28nm metal gate. So it depends on what field we don't have" (A2).*

In many of the interview cases, from the hired engineers' perspective, engineers were assigned to new projects. Often, hired engineers found the hiring firm did not possess the technology they are specializing in when they arrived, so they usually conduct innovative activity in the new firm in the manner they did in the previous firms, yet it is often the exploratory activity for the hiring firm. 9 out of 10 interviewees state that they carry the same technological activity. For instance: *"When I was in the previous firm, I was developing NROM Memory related element, I moved to the current firm because* *the current firm was hiring engineers who were doing similar technology, so I came here. At the time, this firm had no such technology, so I did contribution to development in this part of technology." (A3)* The finding revealed a direct association between hiring engineers with distant knowledge that is new and unavailable tends to contribute to a firm's new technological development. A local director has concluded well:

> *"Hired engineers do what they did in their previous firm, but this is new for our firm… when hiring from a leading firm, we mainly focus on exploitation rather than exploration as hired engineers already have done in the previous firm … this is why we use hiring to make us develop new technology and then upgrade this new technology." (A5)*

Furthermore, for the case of fabless firms, interviewees often mentioned opening up for 'new business' when firms initiate a new technological field. Unlike foundry firms, fabless firms often transform or explore new technological products more rapidly. Fabless firms often change their development of specific products according to the needs of the market. Therefore, firms often have to hire engineers who specialise in the target field by hiring a number of engineers and creating management teams in such technology. This is reflected by one of the interviewees: *"We used to make MP3, and then develop technology based on android, and then making technology relating to camera, when changing from music player to camera, increased the engineers or management team to make new technology." (H2)* However, hired engineers in the fabless firms that participated in the interview would not admit that they are conducting the same innovative activity as that which they did in the previous firm even though the domain is the same, this is reflected in the statement of one of the interviewees:

> *"I don't do what I used to do in the previous firm, from the design perspective, the domain has no change, but in detail, it is completely different from what I did before. It is in the same domain. The things I did in the previous firm, it is something we don't have in this firm. so different from what I did. Some experience, the background is there, but doing a different thing, the foundation is the same."(G1)*

This answer is often reasonable for the sake of the legal problem that engineers are forbidden to work for a competitor firm. This is reflected in the statement of one of the interviewees that hired engineers cannot directly bring the technology of their previous firm and use it in the current firm due to the legal problem. However, when the products that are produced in the previous firm and the current firm are not the same, there seems to be no problem moving to other firms: *"In order to prevent engineers mobility between competitors, we have to sign the non-compete clause, I signed it too, (but working for the competitor) so I do the different working task, slightly different, … it is alright as long as you don't* *do the same direction as what you did in your previous firm if I used to do mobile chip, now I do coffee chip then it is ok because there are not competitive relations." (I1).*

Engineers entail distant knowledge which is often new to the firm, this is not new in the industry. *"new for the firm but not new in the market."* (F1) It is probably because follower firms are still in the catching-up process, so more knowledge is available for them to learn. Hiring engineers who already have experience in specific technology can shorten the learning cycle when the firms attempt to develop new technology because firms are less likely to go through the winding road by repeatedly making experiments. All of the interviewees shared the same view that hired engineers with distant knowledge can help firms to initiate new technological development rapidly without consuming much time, and it is always better than starting from zero. Therefore, *"When engineers have experience in this, he will know how to do it, probably half year can make it, it will be faster and less possibility to go winding road, winding road consumes not only time but also money." (A1)*

Familiar knowledge

On the other hand, engineers with familiar knowledge are also identified. The researcher initially looked at whether the knowledge had already existed before the engineers were hired. Similar to the distant knowledge, hired engineers also exploit their own knowledge and carry on the innovative activity that is similar to what they did in the previous firm based on their knowledge field in the current firm. However, when the knowledge is already available within a firm when engineers were initially hired, these engineers tend to focus on conduct innovative activity based on the firms' existing technology rather than developing new technology. Specifically, hired engineers whose knowledge is already available within a firm, are often in charge of 'solving a technological problem', 'efficiency improvement' and 'technological understanding' based on existing technology.

The abnormal product often occurs during the process, and the symptoms can be different, hired engineers are required to find the reason why the problem occurs and find a solution to the problem. Hired engineers are expected to solve the weak part of technology by suggesting the solution based on the know-how and experience they build in their previous firm. Sometimes hired engineers do not necessarily know how to do it, which is more likely to be like coffee-making, as long as hired engineers are aware of how to do it, whether he or she really knows or not is not important. Technological problems often cause failed products at the final stage of the process, the crack may occur in the products, so engineers who know that better methodology can be applied to the current process reduce the problem caused during the process. All interviewees (10 out of 10) whose knowledge already existed before they joined the hiring firms, explicitly stated that they are not inventing new technology but focusing on 'problem-solving' and 'debugging problem'.

"A firm hired us to solve the problem… a solving problem means that the factory has abnormal product every day, you have to find out the reason for this, the symptoms may not be the same, and there is a problem with the yield test, and when the problem occurs in the final stage then you have to chase back to see where the production process has problems." (A1)

Furthermore, efficiency improvement is also important for fabrication. All the hired engineers whose knowledge is already available within a firm when they were initially hired were assigned the project to improve technological efficiency. The cost and time are considered as the most important factors for efficiency improvement for the foundry. Hired engineers in the new firm help to reduce the cost per process steps by applying cheaper material and reduction of the processing time. Interviewee (A1) explicitly stated: *hired engineers are asked to solve the problem relating to the cost, for example, sometimes firms require to cost down 10 %, then you have to find cheap material, then you have to attempt different experimentation, so you have to fix the recipe, it is like making an around shaped cup, making 100 or 1000 round cups and all of them should be 10cm* (A1).

The local director (C1) stressed that when the failure occurs too often during the process, it means more products are contaminated that cause the loss of money. Firms often hire engineers who already have experience can reduce the possibility of making failed products. The finding clearly shows that there are close relations between hiring engineers whose knowledge is not distant and efficiency improvement of existing technology. Engineers whose knowledge is available within a firm when they were hired often carry innovative activities in improving efficiency by reducing the cost and time rather than developing new technology. One of the interviewees stated: *"I used to work at Alpha firm (Leading firm) before I moved here, doing the same technological field, Chemical Mechanical Polishing (CMP) in manufacturing. In terms of technology, I basically solve the problem in the process (systematic improvement) also help to produce manufacturing process cost reduction, or projects that need efficiency improvement (reduce the time). So, from this point of view, we are not designing new technology, but do some refinement in the process… I think my advantage is to look more clearly about what the problem is, that is, able to solve the problem more thoroughly or systematic improvement, if you cannot clearly see the problem, solving one problem brings new problems so I cannot get out of the problem, I think my contribution is in this." (C2)*

Moreover, participants also expressed that firms hire engineers to increase technological understanding of a specific technology. Even though the technology is existing within a firm, it is often not mature so firms often are lack understanding in terms of technology. In such cases, firms hire engineers to improve their understanding of a specific technology.

"In my case, my expertise is line monitor (inspection & metrology), the firm didn't understand too well and details, how to implement those technologies and methodology to do yield improvement well. The technology is not new for the firm, they didn't have a suitable manager for my field...so I was hired." (C2)

5.3.2 Knowledge integration and collaboration

Information processing theorists stress that distant knowledge stimulates intensive experimentation with a new combination that results in novel creation (Van Knippenberg & Schippers, 2007). In line with it, this study finds that technological distance increased opportunities for the combination of knowledge. Technology in a foundry is largely involved with complex processes, so exploration usually rests on a combination of new methods into the existing one. Every foundry possesses different methods concerning their use of the material and its know-how, so hiring engineers with distant knowledge is expected to bring a method that is new for the hiring firm and combine it into the existing one. The interview finding shows that upgrading to new technology does not mean changing the whole process into a new one, rather a part of the process can be upgraded into the new one, combining existing technology with 'new material' or 'new method' is often attempted. It is stated by one of the interviewees as *"when we hire a different technological area, that means we need to develop new technology. For us, to upgrade the technology you need to add a completely new process, new materials that our firm doesn't have, so it is new for us." (A5)*

Hired engineers understand how to combine a new method or material into the existing one, thereby upgrading the existing one into new technology. For example, firms, in order to develop Extreme ultraviolet lithography (EUV) which is required for the technology in lithography (that is available within a firm), hired engineers who have experience in EUV to help the firm to develop EUV that is not previously available. The process technology in the semiconductor is often described as a baking process, depending on what recipes are used, can determine the quality of the process and products, but it requires engineers who can bake the proper way for the combination. Properly combining know-how is important, hired engineers who had experience in using a new material or method understand how to combine it into the existing one, and lead it in the right direction. Otherwise, firms have to go in the wrong direction with multiple experimentations by consuming both time and cost.

"We hire engineers who can bring knowledge that our firm does not possess. For instance, the firm didn't have Extreme Ultraviolet Lithography (EUV), so in order to develop EUV, which is the technology required in lithography (we have), … hire from B (also competitor, even though that firm is not specialising in EUV). But this person is at least aware of how to develop EUV, he can supervise in the firm for rapid development… save much time." (A2)

Collaboration is necessary for knowledge integration. In a semiconductor, the technological task is closely associated with teamwork, having incumbent engineers be able to collaborate with hired engineers is important. All the interviewees (10 out of 10) stated that since the semiconductor is closely associated with teamwork, even star engineers cannot work alone without team members to collaborate with them or support them. Hiring one or two experts has limited efficiency as they can only solve a part of the problem while hiring a team can be more efficient but hiring a team is often not possible. For instance, one of our interviewees stressed that: *poaching the team may catch big attention, this action is too big (B1).* This is because the semiconductor industry belongs to the highly sensitive sector so hiring a team may cause much attention from their competitors. For a reason, firms often hire one or two engineers and then make a new team for them to work with hired engineers. 9 out of 10 interviewees stressed the significance of incumbent engineers to be able to support hired engineers.

> *"Hiring a person like me can solve one part of the problem, you want to solve the whole problem, and do you think that is possible? Not possible. … even hiring a star engineer, if he has no team, then you have to make the team for him, and he has a request for a team, they should be able to do this, know to do this, they have to co-operate. This team has to have a certain capability." (C1)*

Team members are required to be able to support hired engineers but when incumbent engineers are not able to support hired engineers, they will have to train incumbent engineers once they are hired. Training incumbent engineers is a necessary procedure, but training consumes much time, so hired engineers often cannot get into work immediately once they are hired. *"Hiring the whole team from the leading firm can be more effective, but it is not possible hiring the whole team, so usually we hire one expert and make a new team for him … but team members are not much capable of supporting him…training them takes time… so basically the team cannot immediately get into work."(A1)* In addition, when incumbent engineers are not able to support hired engineers, firms often replace their team members by hiring more engineers. Making a new team for hired engineers to lead. Alternatively, providing that no engineers within a firm can support hired engineers then it is more likely the hired engineers would conduct innovative activity by themselves, perhaps ineffectively. This is reflected in the statements of the interviewee: *"When engineers are not able to support the hired engineers, then he will be conducting innovative activity by himself, but the efficiency is not great." (A5)*

Hired engineers do not feel there is difficulty working with incumbent engineers. Hired engineers often feel the knowledge and technical skill can easily be shared with incumbent engineers. However, the interesting finding shows that no matter whether the engineers' knowledge is distant or not, there is no issue relating to language in the technological task. Most of the interviewees (9 out of 10) mentioned that the language in technological tasks did not cause any problem even though the engineers are from different countries. Engineers principally use English and numbers when they carry out technological task. And they are not required to have high English language skills because they usually use the same technical terms and sentences. The semiconductor industry is a special case as it was initially invented by the U.S., the technological vocabulary, terms, and symbols are the same all over the world, even though engineers do not share the same language, there seems to be no language barrier when carrying the technological work. This is reflected in the statement of the interviewee:

> *"The industry is very special, communication problems are not big, South Korea, Japan, Taiwanese, the industry's professional words are all in English because semiconductor is invented by the U.S., so this is not a problem." (C1)*

> *"In terms of language in work, we use similar words and sentences so not many problems when working." (E1)*

The evidence reveals that there is often a 'mindset' issue at the hired engineers' side while this is not an issue at the local director and incumbent engineers' side. On the one hand, whether the knowledge is distant or not, it seems not to breed a common mindset between hired and incumbent engineers. Hired engineers often feel 'mindset' relates to the learning and working attitude of incumbent engineers is unsatisfactory, pointing that incumbent engineers are half-hearted, lack a strong will to learn and carry the innovative activity. Incumbent engineers that do not follow specification and standard procedures, often result in many problems on the production line. The 'mindset' is directly pointed to as an important factor in learning, and hired engineers who lead the team think that, if incumbent engineers do not have the right mindset, they will not be able to learn properly and solve the problem when they meet a new problem. On the other hand, local managers and incumbent engineers did not mention there is a mindset issue. Incumbent engineers feel they are willing to learn from hired engineers and build their capability and they will do as how hired engineers supervised.

> *"I tell them what to do, does not mean they will do as you supervised, I give them 1,2,3,4,5 things, but they only do 1,2,3, their learning attitude is not that good. The way how they work is not detail, the self-requirement is not high. They don't care about quality." (C1)*

> *"The other important thing is the mindset, if the local engineers cannot change their mindset when they meet a new problem, they still don't know how to do it or the wrong direction. A mindset like accountability, honesty, what you say is what you do, data, not guess. When we work together, I can see their attitude and what they think, most people don't pursue excellence, part of the truth to cover the mistake." (A2)*

Furthermore, hiring engineers whose knowledge is available within a firm indicates the facility and equipment in place for hired engineers to access. Hired engineers with familiar knowledge would find it is more comfortable to work in the new firm. Otherwise, the different facilities and equipment in the new firms would cause some inconvenience. For semiconductor technology, the facilities involving technological tasks are especially important. The evidence reveals that when hired engineers are hired by a foundry, the facility relating to process technology is in place for hired engineers to access. Particularly, for foundry firms, the facility relating to the process is important for maximising the performance of hired engineers. When the facility that is used in the current firm is not similar to what they had used in the previous firm, hired engineers may often feel uncomfortable working in the new firm. It is reflected in the statement of the interviewee:

> *"The support investing in new technology may not be similar between B and C firm, C firm may not be able to provide the same support as B firm did. So engineers may find it inconvenient (Bu shun shou) ... Star engineers also need the facility, the development also requires enough common engineers to collaborate" (A2)*

On the other hand, an interesting additional finding in this respect is that the fabless is relatively less engaged with facility issues compare to foundry firms. When it is necessary, firms may purchase new resources such as software for hired engineers to access. The facility supporting hired engineers may be less costly compared to foundry firms where the production line operates as a set, therefore, fabless firms can afford to provide facilities for hired engineers with distant knowledge to access and rapidly operate to develop new technology. It is often the reason why fabless firms can easily open a new business or transform their technological products. The interviewees have explained clearly: *"For design firms the facility will be less crucial than foundry firms, where the production line runs as a set, for us, hiring one engineer may not be able to conduct the whole process, but it will be faster, and the cost of investment is not as much as foundry, so it is possible for firms to purchase new thing such as software, so we operate it faster by hiring engineers." (H1)*

5.4 Discussion

Drawing on the findings of numbers of follower firms that employed engineers from leading firms, this study tests propositions about hiring engineers with distant knowledge effects on a firm's exploratory and exploitative innovation. This study explicitly focuses on hired engineers' knowledge specifically experienced with distant knowledge on the hiring firm's innovation by distinguishing it into exploratory and exploitative innovation. The results of the interview findings generally support the established propositions. The findings show that when P1a) hiring engineers whose knowledge is distant from that of the hiring firm's core technological domain is more likely to facilitate the firm's exploratory innovation rather than exploitative innovation, P1b) hiring engineers whose knowledge is not distant from the hiring firm's core technological domain is more likely to facilitate the firm's exploitative innovation rather than exploratory innovation.

Technological distance and exploratory & exploitative innovation

As discussed in the literature review in Section 2.2.2, firms can hire for generating exploratory innovation by developing new technology or for exploitative innovation by reinforcing existing technology. According to information processing theorists, acquiring distant knowledge can be vital to success in exploratory innovation (Hambrick et al., 1998; West, 2000; Dahlin et al., 2005) because distant knowledge allows firms to access knowledge that is different from what these firms already possess and allow firms to 'think outside the box' (Martin et al., 2009). The interview data in this research shows that firms hire engineers whose knowledge is distant, often their knowledge is new or unavailable within a firm. These aspects are closely related to the stream of literature identifying that hiring engineers with distant knowledge stimulates learning (Simon, 1991; Song et al., 2003), and helps firms to access new knowledge (e.g. Almeida & Kogut, 1999; Rosenkopf & Almeida, 2003). This research further shows that such knowledge enables firms to facilitate exploratory innovation by developing new technological fields and elements. The findings of this research clearly show that the hiring firm's intention is to generate new technology through hiring engineers with distant knowledge. Indeed hiring engineers with distant knowledge can provide a firm with internal capability to generate exploratory innovation.

On the other hand, the findings of this research explicitly show that when hired engineers whose knowledge is not distant, but familiar for the hiring firm increases the possibility of reinforcing the firm's existing technology. In fact, when firms hire engineers, whose knowledge is familiar, their knowledge is often available within a firm, so the hired engineers will tend to conduct the project to reinforce a firm's existing technology. The analysis of interview data in this research has shown that while hired engineers with distant knowledge are mainly assigned a new project for new technological development, engineers whose knowledge is familiar to the hiring firm will be less likely to be given opportunities in developing new technology but more likely to be assigned with a role in reinforcing existing technology. Exploitative innovation through reinforcing existing technology often involves technological problem solving, enhancing efficiency and increasing technological understanding. Continuous problem solving and efficiency enhancement are the main activities of the foundry aimed at increasing the performance of current technology. This research also shows that hired engineers with familiar knowledge are necessary to enhance technological understanding. This is the case that when firms, who have just initiated new technology, are lacking the ability to understand this technology, so engineers with familiar knowledge are hired to improve the firm's technological understanding of a newly introduced technology.

This research also reveals that hiring firms are still in the catching-up process, more knowledge is available for them to learn. Hiring engineers with distant knowledge is often new to the firm, but it is not necessarily new to the industry as such knowledge is likely available in the hired engineer's previous firm. The finding also strongly supports the literature that hired engineers usually carry knowledge from their prior firms (Rosenkopf & Almeida, 2003). The interview data in this research shows that whether the knowledge of hired engineers is distant or not, once engineers are hired by the new firm, they tend to conduct innovative activity reflecting what they did in their previous firms, this is supported by the finding of Singh and Agrawal (2011) that hired engineers tend to exploit their prior ideas and knowledge. However, the findings of this research suggest that even though the knowledge was carried from the prior employers and that hired engineers with distant knowledge conduct a similar innovative activity, it is an exploratory activity for the hiring firm.

Knowledge integration & Collaboration

Based on information processing theory, accessing distant knowledge yields great chances for enhancing the exploratory content of novel combinations of knowledge (Audia & Goncalo, 2007; Dahlin et al., 2005; Hambrick et al., 1998). The data shows that technological distance increases the opportunity for knowledge integration by combining knowledge that was not previously attempted. The findings in this research suggest that knowledge integration often indicates different methods, methodology, ways of doing things and ideas, are combined into the existing one, therefore, results in exploratory innovation. This is echoed by Wadhaw and Kotha (2006), in that exploratory innovation is achieved through recombination of new methods when the knowledge is distant from that of the hiring firms, the opportunities for new invention through combination may be greater (Fleming, 2001). The findings have not only reasserted that distant knowledge increases the potential for knowledge integration that lead to exploratory innovation but also emphasise the effect of the proper combination. Hired engineers are aware of how to combine the knowledge precisely so as to be able to lead firms in the right direction without attempting too much experimentation. This, in turn, saves time and cost in generating exploratory innovation derived from knowledge integration.

Furthermore, the finding shows that having incumbent engineers collaborate with hired engineers plays a significant role in building the firm's innovation. In particular, for foundry, the technological task is closely associated with the team task, having incumbent engineers be able to collaborate with hired engineers is crucial to conduct the innovative activity. The previous studies show that when incumbent engineers are able to support hired engineers, the performance of hired engineers will be increased, otherwise, the performance of hired engineers with the exploratory role will be decreased because there are no colleagues to support them (Groysberg & Lee, 2009). The findings of this study show that when firms hire engineers, having incumbent engineers collaborate with the hired engineers is significant when the technological task is closely related to teamwork.

Researchers have long highlighted the importance of existing team members to be able to collaborate with hired engineers (Groysberg et al., 2008), but this study further suggests that when firms can create a team for them then having no incumbent engineers within a new firm to support hired engineers may not necessarily lead to a negative result. It is because the possibility that firms will create a new team to collaborate with hired engineers will be increased. The finding also shows that firms often create a new team for hired engineers to lead or supervise, but when no incumbent engineers support hired engineers within a firm, firms will newly hire engineers to support the previously hired engineers. Otherwise, hired engineers will train incumbent engineers initially and lead the team. This, in turn, increases the potential for hired engineers with distant knowledge to contribute to the hiring firm's exploratory innovation. Of course, it is based on the precondition that the hiring firms are able to create a team for newly hired engineers with distant knowledge. Otherwise, there is a greater possibility that newly hired engineers will conduct innovative activities by themselves. This, in turn, decreases the performance of engineers and the efficacy of technological distance on a firm's exploratory innovation.

Furthermore, the findings have shown that having incumbent engineers in collaboration with hired engineers is not necessarily important for fabless firms. For fabless firms, the technological task is less associated with teamwork, engineers can take their innovative ideas with them to the new firm, and apply them just as well for one employer as for another. In addition, even a small number of engineers can conduct the innovative activity, so to have incumbent engineers be able to collaborate with hired engineers is less important than in a foundry.

However, the evidence reveals that the collaboration between engineers with familiar knowledge creates easy knowledge integration, this is supported by the categorisation theorists in suggesting that collaboration between engineers with familiar knowledge is easier for knowledge integration (Dahlin et al., 2005). Hired engineers and incumbent engineers working together may share a similar understanding of how technologies work, have similar methods and approaches to the problem, and search for new solutions to the existing problem when the knowledge is familiar for both engineers (Makri et al., 2010). The data shows that hired engineers with familiar knowledge increase the collaboration between engineers, the knowledge can easily be shared without much difficulty in understanding each other. Incumbent engineers can gain a deep understanding of hired engineers' guidance without unnecessary risks of confusion and misunderstanding (Broekel & Boschma, 2012).

The previous study shows that engineers with familiar knowledge share a common language for understanding (Inkpen & Wang, 2006) and a technological mindset (Phene et al., 2012). Interestingly, the findings of this study have shown that there is no issue relating to technological language no matter whether hired engineers are with distant or familiar knowledge. It is because the semiconductor was initially invented in the U.S., where the language is English, so even when engineers do not share a common language, no language barrier occurs during the process of carrying out technological tasks. Specifically, the technical term is in English, so engineers can share the technical terms. Furthermore, an unusual aspect of the finding is that it does not matter whether the hired engineer’s knowledge is distant or not, which seems not to support the idea that it increases the likelihood of a common mindset of engineers within a team. Prior research has suggested that engineers with similar knowledge may enhance the likelihood of a common technological mindset (Phene et al., 2012). However, the findings of this study suggest that hired engineers with familiar knowledge do not necessarily lead to a common mindset. Instead, the mindset issue that is related to learning attitude has been pointed out. The finding reveals that attitude in terms of learning and working on the incumbent engineers’ side becomes the obstacle that reduces the working efficiency and collaboration.

The findings of this study also underline the importance of the facility for hired engineers to access can play a stronger role in determining different consequences of innovation. The scholars (Levinthal & March, 1993; Song et al., 2003) have suggested that when firms hire engineers whose knowledge matches the hiring firm’s core technological area, hired engineers will be likely to follow inside a framework constituted in a particular way or follow established practices and procedures in the hiring firm use within which it operates. An analysis of the data in this research has shown that when firms are hiring engineers with familiar knowledge, the facilities are already in place for hired engineers to access. When the facility is already in place for hired engineers to access, hired engineers will be more likely to adapt to the current facility, thereby conducting innovative activity based on existing technology.

Overall, the evidence supports that hiring engineers whose knowledge is distant, enables the access of new and unavailable knowledge and increase the integration of knowledge; therefore, this is more likely to facilitate the hiring firm's exploratory innovation, rather than their exploitative innovation. On the other hand, the evidence also supports that hiring engineers whose knowledge is familiar increases the access of available knowledge, therefore, in this case, it is more likely to facilitate the hiring firm's exploitative innovation, rather than exploratory innovation.

5.5 Summary

The aim of this study was to investigate how technological distance affects the hiring firm's innovation by categorising it into exploratory and exploitative innovation. In doing so, the study builds upon the idea of knowledge spillover but borrowing the lens of information processing and categorisation perspective. From the perspective of knowledge spillover literature, this study extends knowledge about learning by hiring focusing on the knowledge of hired engineers. Whereas prior studies have provided the beneficial effect of hiring engineers on the hiring firm's innovation (Rosenkopf & Almeida, 2003; Song et al., 2003; Simonen & McCann, 2008; Parrotta & Pozzoli, 2012; Agrawal et al., 2015; Kaiser et al., 2018), our knowledge of how hiring affects a firm's innovation is somehow limited. This study advances this line of inquiry by investigating the roles of distant or familiar knowledge resulting in different consequences on the innovation of the hiring firm.

Taking an information processing and categorisation approach, the findings of this study support explanations linked to the different dimensions of innovation: exploratory and exploitative innovation. Hiring engineers with distant knowledge is more likely to facilitate the firm's exploratory innovation, by bringing in the knowledge that is new or unavailable within a firm. Distant knowledge increases the access of the knowledge that is new to the firm, this enhances the potential for knowledge integration that results in exploratory innovation. Conversely, based on the categorisation perspective, this study found that hiring engineers with familiar knowledge is more likely to facilitate the firm's exploitative innovation by bringing in the knowledge that is already available within a firm. Hired engineers carry along with familiar knowledge often contribute to reinforce existing technology through problem-solving, efficiency improvement and the enhancement of technological understanding.

Chapter 6 How does status distance between the hired and incumbent engineers affect knowledge flows and the perceived psychological safety of newly hired engineers?

6.1 Introduction

One of the most prominent and persistent ways of building innovation is through hiring high-status engineers from other firms. Previous studies on international knowledge spillover have shown that hiring high-status engineers contribute to building a firm's innovation by bringing in a great amount of knowledge to the firm (Song et al., 2003; Simonen & McCann, 2008; Tzabbar, 2009; Singh & Agrawal, 2011; Agrawal et al., 2015; Rahko, 2017; Kaiser et al., 2018), and have enhanced our understanding of the role of high-status engineers. However, these studies have mainly focused on the extent of hiring on the firm's innovation by assuming that the status is embedded in engineers. That is, the status of hired engineers has not been brought to the centre of the discussion, therefore, it is unclear how the status of hired engineers affect the hiring firm' innovation building. It presents an important research gap. To address this research gap, this study explicitly explores the status of new hires. Hiring high-status engineers play an important role in building a firm's innovation, this study, therefore, instead of discovering the effect of hiring high-status engineers on the hiring firm's innovation, will explore the linkage relationship by leveraging status literature.

The term "status" refers to the prestige accorded to actors "due to the hierarchical positions they occupy in a social structure" (Jensen & Roy, 2008; Podolny, 1993; Prato & Ferraro, 2018). A recent study has shown, for instance, that the effect of hiring is contingent upon incumbents' status (Slavova et al., 2016; Prato & Ferraro, 2018). It is likely that hiring has different effects based on the status distance between newly hired and incumbent engineers. Status distance refers to the difference between individuals with respect to the status they hold (Blau, 1970; Smith-Lovin & Mcpherson, 1987). When firms hire engineers from other firms, the bargaining power of those engineers increases (Groysberg et al., 2011), therefore, they are, in general, placed in a high level of structural power within a team (Oldroyd & Morris, 2012), which is likely to give a rise to the status distance between newly hired and incumbent engineers. Scholars argue that status distance between engineers can affect learning and knowledge flow (Tzabbar, 2009; Bunderson & Reagans, 2011) because of the various advantages (Lynn et al., 2009), including the opportunities, resources and attention that is conferred more on high status than low status (Reschke et al., 2017; Prato & Ferraro, 2018). High-status engineers, therefore, may have more freedom to, and opportunities for contributing their knowledge to their current firm.

In order for newly hired engineers to generate innovation, they must feel psychological safety, which can motivate them to share their knowledge in the new firms. Psychological safety is "a shared belief that the team is safe for interpersonal risk-taking" (Edmondson, 1999, p.354). The evidence suggests that status distance creates an environment in which low-status engineers do not feel safe for learning, risk-taking (Nembhard & Edmondson, 2006) and engaging in an innovative activity (Bunderson & Reagans, 2011). Although the perceived psychological safety seems closely associated with those of lower status who are considered in the disadvantaged position relative to those of higher status, the status distance between them may also have adverse effects on the perceived psychological safety of hired engineers with higher status. High-status engineers that engage in questionable behaviour may face higher penalties than their low-status counterparts under some circumstances (Fragale et al., 2009). Put simply, this implies that high-status engineers may have more to lose compared to lower status engineers. It is more likely when status distance emerges between newly hired engineers and incumbent engineers because the status distance may result in division by categorising them into an ingroup or outgroup (Van Knippenberg & Schippers, 2007). When newly hired engineers are categorised as outgroup by incumbents, their perceived concern and insecurity may be increased. Hence, newly hired engineers with their high status would feel more reluctant to share their knowledge with others within a new firm (Contu & Willmott, 2003; Bunderson & Reagans, 2011).

Notwithstanding these important insights, the extant literature on international knowledge spillover is not brought the status of engineers into the centre of the discussion instead assumed that status embeds in hired engineers, hence, we have little understanding. In the existing literature, the main strand is preoccupied with the knowledge of newly hired engineers in the hiring firm's innovation (Song et al., 2003; Rosenkopf & Almeida, 2003; Simonen & McCann, 2008; Tzabbar, 2009; Singh & Agrawal, 2011; Agrawal et al., 2015; Rahko, 2017; Kaiser et al., 2018) and incumbent engineers' performance and learning through collaboration and knowledge sharing (Azoulay et al., 2010; Groysberg et al., 2011; Oettl, 2012; Tzabbar & Vestal, 2015; Agrawal et al., 2017). Such studies have provided that the benefits of hiring to the firm's innovation by focusing on the knowledge that has been carried by newly hired engineers. Moreover, some outlying studies examined the negative effects of the arrival of engineers on other engineers by constraining their opportunities and resources (Kehoe & Tzabbar, 2015; Slavova et al., 2016), which is particularly to do so to low-status engineers (Prato & Ferraro, 2018). Such studies implicitly examined the effect of hired engineers' status on incumbent engineers. As a consequence, the status has not been explicitly brought into the centre of the discussion in the previous studies on technological learning by hiring.

The lack of status research is particularly unfortunate when it comes to understanding the importance of hiring from other firms. It is especially so, in contexts where engineers have to collaborate to some degree to perform interdependent tasks. To address these research gaps, this study takes a further step towards analysing hiring engineers by taking account of the effect of the status distance between newly hired and incumbent engineers. In so doing, this study moves away from simply investigating the effect of hiring high-status engineers on the firm's innovation, which is often the feature of existing studies based on quantitative studies (Song et al., 2003; Rosenkopf & Almeida, 2003; Simonen & McCann, 2008; Tzabbar, 2009; Singh & Agrawal, 2011; Agrawal et al., 2015; Rahko, 2017; Kaiser et al., 2018). This study replicates previous findings that hiring engineers from other firms benefit the hiring firm's innovation (Simonen & McCann, 2008; Tzabbar, 2009; Singh & Agrawal, 2011; Agrawal et al., 2015; Rahko, 2017; Kaiser et al., 2018), but underscores that the role of status distance by exploring the linkage relationship. Specifically, this study aims to explore *How does status distance between the hired and incumbent engineers affect knowledge flows and the perceived psychological safety of newly hired engineers?* The findings, in turn, help provide new insights into technological learning by hiring and broaden our understanding of the significance and complexity associated with hiring engineers.

Overall, this study offers two primary contributions to the literature. First, it views the new hire's status that has not been brought into the centre of the discussion in the previous literature, into the account. This study will explicitly explore the role of status distance in technological learning by hiring study. It, therefore, uses the insight of two traditions that have mainly examined intergroup relations, the information processing and categorisation views, to offer insight for the status distance. Second, although this study replicates previous findings that hiring engineers benefit their firm's innovation (Simonen & McCann, 2008; Tzabbar, 2009; Singh & Agrawal, 2011; Agrawal et al., 2015; Rahko, 2017; Kaiser et al., 2018), this study transcends prior findings by leveraging status literature – contending status distance between hired and incumbent engineers affect knowledge flows (Bunderson & Reagans, 2011; Tzabbar & Vestal, 2015) and the perceived psychological safety of engineers (Edmondson, 1999, 2003). Unlike the previous studies that have primarily paid attention to the psychological safety of lower status (Edmondson, 2003; Bunderson & Reagans, 2011), this study will shift the attention to the psychological safety of high-status new hires who plays a critical role in the firm's innovative activity, yet remains unexplored. This study, in so doing, contributes to the international knowledge spillover literature by explicitly exploring the role of status distance. In addition, this study adds scholarly work to international knowledge spillover literature by studying the individual level.

6.2 Literature review

Status distance and innovation

The status is defined as the prestige accorded to actors "due to the hierarchical positions they occupy in a social structure" (Jensen & Roy, 2008; Podolny, 1993; Prato & Ferraro, 2018). When firms hire engineers from other firms, newly hired engineers are endowed with expert power due to their experience built in their previous firms (Oldroyd & Morris, 2012). This results in the emergence of the status distance between newly hired and incumbent engineers. Status distance refers to the difference between individuals with respect to the status they hold (Blau, 1977; McPherson & Smith-Lovin, 1987). Status distance between engineers can influence how engineers build the innovation of the hiring firm. According to the information processing perspective, status distance is an important source for building a firm's innovation as engineers can bring their knowledge anchored in their different status – knowledge embedded to both high-status and low-status engineers. Status distance enables differing contributions to teams, as the team covers broader information, a broader range of perspectives and can better solve problems, enhance creativity, innovation (Ancona & Caldwell, 1992; Blau, 1970). In line with this logic, some studies have found that individuals with different status can have a positive impact on the performance through enhancement in the innovation, knowledge that is brought by different individuals (e.g., Earley & Mosakowski, 2000; Rink & Ellemers, 2006; Chung & Hossain,2009).

Status distance allows engineers to be exposed to knowledge held by high-status and low-status engineers. Information processing views that engineers working with each other may come up with a mostly different idea and way of thinking, yield a greater chance to create a better idea (West, 2000). Specifically, the status distance between engineers differs in their sharing and use of unique knowledge. For instance, new hires may bring in advanced and unique knowledge that may differ from that which the incumbent engineers possess, whose knowledge may be largely available within a firm. Their advanced and different knowledge, perspective, and approach to the problem, their way of thinking and ideas can be vital to success in innovation (e.g. Hambrick et al., 1998; West, 2000; Dahlin et al., 2005) through the combination of advanced knowledge that is possessed by new hires and incumbent engineers' typical way of doing things based on the existing technology. Moreover, differences in perspective and experience make it possible for engineers to learn from one another through knowledge transfer, thereby coming out with creative ideas.

Empirical evidence implicitly supports that hiring high-status engineers have positive effects on the hiring firms' innovation. For instance, research suggests that hiring high-status engineers provide exposure to significant knowledge and learning opportunities to their colleagues and generating their new firm's patent-related innovation (see Song et al., 2003; Rosenkopf & Almeida, 2003; Simonen &

McCann, 2008; Tzabbar, 2009; Singh & Agrawal, 2011; Agrawal et al., 2015; Rahko, 2017; Kaiser et al., 2018). The evidence indicates, however, hiring high-status engineers involves more complicated factors than simply translating into a firm's innovation, particularly when status distance emerges between engineers. For instance, Kehoe and Tzabbar (2015) found that the arrival of high-status individuals leads to benefits in low-status engineers' productivity through collaboration, yet working with the high-status individual causes low-status individuals to become more dependent on high-status for ideas and they will be less likely to generate new ideas autonomously. This implies that status distance between engineers may enable high-status engineers to facilitate the learning of low-status engineers, but at the same time, limiting the innovative activity of incumbent engineers.

Innovation requires engineers' knowledge sharing by exposing engineers to a larger and richer pool of knowledge (West, 2000), in order to do so, engineers should feel psychological safety (Bunderson & Reagans, 2011). According to the categorisation perspective, the status distance may result in salient categorisation between engineers as people tend to categorise others and themselves in accordance with perceived similarity and difference (Tajfel, 1982; Van Knippenberg & Schippers, 2007). When such categorisations occur within a salient member boundary, engineers may be differentiated on the basis of the status they hold, that is, high-status new hires and low-status incumbent engineers may be categorised as such. Categorisation often leads to a division that results in difficult relations between engineers, the knowledge exchange process may be thwarted by this division (Williams & O'Reilly, 1998). Such categorisations result in engineer's tendency to favour ingroup engineers over outgroup engineers, trust ingroup more than outgroup and are more willing to cooperate with ingroup than with outgroup (Van Knippenberg & Schippers, 2007). When perceived categorisation leads to unfavourable affective reactions, such as enhanced conflict and decreased integration, this will decrease a potentially positive relationship between engineers with different status (Van Knippenberg & Schippers, 2007; De Dreu et al., 2011), thus, in turn, negatively affect the psychological safety of engineers. This will be discussed in more detail below.

In line with this logic, this study assumes that status distance leads to innovation through closely associating with knowledge flows among engineers and the perceived psychological safety of new hires. The following sections, based on the above discussion as the core argument, will discuss how status distance affects knowledge flows among engineers and the psychological safety of engineers by leveraging status literature.

Knowledge flows

Knowledge flows are the directionality of the knowledge being transferred, distinguished top-down, bottom-up, and horizontal knowledge flows (Mom, 2006). Status distance between new hires and incumbents is likely to determine how knowledge flows because status distance exerts power and influence over others, which may affect the relative participation of members and the level of consideration that engineers' contributions are given (Alkire et al., 1968). More authority given to newly hired engineers enables their greater participation and contribution to innovative activity (Bunderson & Boumgarden, 2010; Nickerson & Zenger, 2004). For instance, Clark and Fujimoto (1991) suggest that substantial influence and authority is required to be a product manager for developing new products. It is because the authority given to engineers reduces the frequency of conflicts and ambiguity with regard to roles and guidelines while increasing task coordination (Bunderson & Boumgarden, 2010). Status distance circumvents the conflict that may be caused by a different point of view in conducting technological tasks between high-status and low-status engineers. High-status engineers can resolve differences of opinion about technical tasks and related innovative activities among those with lower status (Groysberg et al., 2011) and reach a rapid consensus. High-status engineers are likely to receive many requests for advice and information from low-status engineers when conducting innovative activities (Oldroyd & Morris, 2012). In other words, they will make it easier for others to have their information and perspectives heard (Bunderson, 2003) and can direct attention to the technological part that needs enhancement by reflecting their knowledge. In doing so, newly hired engineers' unique or advanced knowledge can be more likely to be introduced or reflected in a firm's innovation.

Conversely, the status distance may increase the reliance of low-status engineers which limits their autonomous contribution to innovative ideas. Kehoe and Tzabbar (2015) suggested that hiring high-status in organizations might be a mixed blessing for their colleagues; although they enhance their colleagues' productivity, their colleagues become more dependent on them and contribute fewer innovative ideas. In a similar vein, Jensen and Wang (2018) found that the hierarchical relations between workers weakened the performance of firms. Brooks (1994) found that R&D team members perceived less free to engage in group reflection and process improvement when there is a team member who had power over others. It may be because a high-status individual is more dominant within a team, exercising authority and directing the actions of others within a team (Conner & Prahalad, 1996; Macher, 2006), which limiting opportunities and the freedom of low-status engineers in conducting innovative activity (Galinsky et al., 2003; Kehoe & Tzabbar, 2015; Prato & Ferraro, 2018), and impeding the rise of the viewpoint of the low-status engineers.

Perceived psychological safety

Psychological safety is "a shared belief that the team is safe for interpersonal risk-taking" (Edmondson, 1999, p354). Engineer's perceived psychological safety may be a significant factor that affects the engineer's engagement in facilitating innovation. The previous studies have suggested that engineers must feel they have psychological safety to engage innovation (Baer & Frese, 2003; Nembhard & Edmondson, 2006; Bunderson & Boumgarden, 2010), otherwise, when perceived psychological safety is low, engineers will be less likely to engage in innovative activity and knowledge sharing.

Status distance is strongly accompanied by the perceived psychological safety of engineers (Edmondson, 2002). It is often noted that status distance is more likely to influence low-status engineers than high-status engineers. Lower status engineers perceive their group to be less safe for learning and risk-taking (Bunderson & Reagans, 2011; Prato & Ferraro, 2018) than engineers with higher status. For instance, Nembhard and Edmondson (2006) found that lower-status individuals have lower levels of psychological safety than higher-status individuals, as a result, were less engaged in learning. In a similar vein, Edmondson (2002) also found that status distance was negatively related to psychological safety and learning in manufacturing product development. It is because low-status engineers tend to feel the fear of failure to take initiatives and explore new development (Chandler et al., 2000). Status distance impedes low-status engineer's engagement in group reflection and process improvement due to the power exerted over them by high-status engineers (Brooks, 1994). Lower status engineers working with higher status engineers may feel less psychological safety to take the risk of proposing a new idea because they have a fear that their new idea is not accepted by their team leaders and lead to an attack.

Status distance may also affect knowledge create an environment in which high-status engineers do not feel psychologically safe. The study of Contu and Willmott (2003) found that technicians strategically represented and applied their knowledge of photocopier repair in order not to lose control over their work to managers who sought to limit their power. Although the technicians are of lower status than their managers, this may imply that individuals who possess valuable knowledge may be hesitant to share their knowledge to preserve their value in the firm. So as to preserve the value, individuals may be passive in sharing their knowledge by allowing only certain parts or pieces of what they know or only sharing at strategic times (Bunderson & Reagans, 2011) or unless extracting some "political" advantage from doing so (Wittenbaum et al., 2004). If this is given, the status distance may therefore affect the psychological safety of newly hired engineers with higher status.

6.3 Analysis and results

In this section, this study presents the analysis and concrete findings to answer the question of how status distance affects knowledge flows among engineers and the perceived psychological safety of engineers. The inductive data analysis would not be driven by the researcher's theoretical interest in the topic, but it is data-driven, the themes are identified are strongly related to the data themselves through open coding (Gale et al., 2013; Patton, 1990), without trying to fit it into a pre-existing coding frame. However, the inductive approach does not necessarily mean that the researcher should begin from nothing or without using the knowledge of others, but the researcher should use the literature, assume that it is correct and critically analyse it all as a whole, deconstructing the concept to identify the attributes or characteristics, assumptions, gaps, limitations, different perspectives, and different forms of the concept for different functions (Morse & Mitcham, 2002). For this study, the researcher began with the use of knowledge spillover through hiring literature and leveraging status literature as underlying knowledge.

This study adopted qualitative research of inductive data analysis based on the following steps.

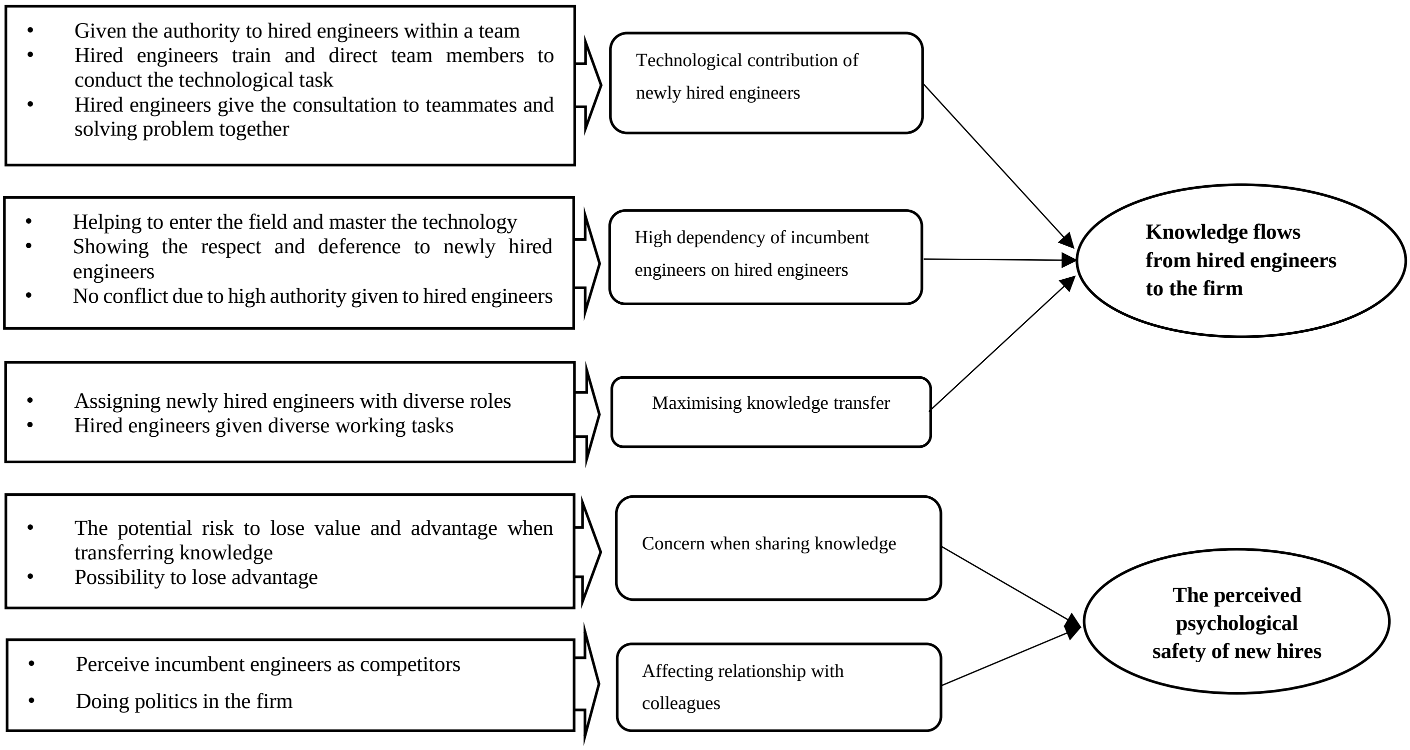
1. *Becoming familiar with the data.* An inductive approach is data-driven (Schreier, 2015) moves from the data to a theoretical understanding. As an initial step, the researcher read through the data in detail to gain a holistic understanding of what was said (Gale et al., 2013) and digest the data to make sense of the whole set of data with open-mindedness and following the rationale of interviewees' narratives (Azungah, 2018). The second stage is a close reading of the text. The researcher attempted to become familiar with the whole interview, re-read the original text before translating it into English. After familiarisation with the interview, the original text of the interview was translated into English. The researcher has re-read the whole data set in the original version to capture the original meaning and detailed information that may be lost after translation. In this stage of the analysis, the researcher gains the whole picture of the studies phenomena and writes down the insights and understanding.

2. *Deriving themes from data through the raw data*. After several readings of the transcripts, and then going through the data line by line thoroughly and assigning codes to paragraphs or segments of texts as concepts (Bradley et al., 2007; Thomas, 2006). During the analysis, overlapping categories were identified and refined by clustering. The categories or themes are created from meaning unites that is actual phrases used in specific text segments. Meaning units are usually parts of the data that even if standing out of the context, would communicate sufficient information to provide a piece of meaning to the reader (Elliott & Timulak, 2005). In exploratory research and research using complex interview data, the meaning unit is known to

be the appropriate unit of analysis since it is less likely of decontextualizing what the respondent saying (Garrison et al., 2006). As the meaning units are delineated, the data can be shortened by getting rid of redundancies that do not change the meaning contained in them (Elliott & Timulak, 2005).

3. *Sorting the data by theme or concept.* The goal of this study was to illustrate status distance on the firm's innovation, which was reported under two categories: (1) 'knowledge flow' and (2) 'the perceived psychological safety' followed with the detailed coding process. This study establishes categories of the first order that categorise meaning units, categories of the second order is condensed meaning units that are close to the original text, the categories of the third categories are revised order that categories of the second orders and followed with final themes. Table 6-1 below shows an overview of the data structure. The full table of the process can be viewed in Appendix G.

Figure 6-1 Overview of data structure



This section presents details of the findings, mainly focus on how the status distance is associated with knowledge flows and the perceived psychological safety of engineers. The evidence reveals that the status distance plays play a substantial role in facilitating a firm's innovation because it determines how knowledge flows and the perceived psychological safety of engineers.

Hiring engineers from leading firms are a frequently used way for follower firms to acquire advanced knowledge thereby building a firm's innovation. The interview data clearly shows that engineers who are hired by follower firms from leading firms, their status also increases. They are, in general, gain expert power regardless of their previous status in the previous firm, so in general, they are placed in the position of a team leader or a manager, therefore, give rise to the status distance between new hires and incumbent engineers. Put simply, newly hired engineers have higher status than their team members because of the experience that engineers built at the leading firms. As shown in Figure 6-1 (the overview of data structure), the finding of this study identified two factors involving knowledge flows and the psychological safety of engineers. Specifically, the finding shows that status distance between newly hired and incumbent engineers, directly affects how knowledge flows. Interestingly, the unanticipated finding shows that newly hired engineers are given a status in the new firm often assigned with diverse roles, which new hires often perceive as chores. This reflects the firm's intention to maximise knowledge transfer.

Further, the finding shows that status distance between newly hired and incumbent engineers is closely associated with the perceived psychological safety of engineers. The interview finding shows that even newly hired engineers have higher status than incumbent engineers (team members), which can also create an environment in which high-status engineers do not feel safe engaging in key behaviour such as knowledge sharing. Newly hired engineers may have the concern over losing the advantage that is initially given by the hiring firms, which prevent their willingness to actively share their knowledge with others. In the next section, the detailed findings of each theme will be discussed

6.3.1 Knowledge flows from hired engineers to the firm

Initially, the status of newly hired engineers is carefully identified. The researcher selected newly hired engineers who have experience working at leading firms in their respective industries and further identified whether engineers' knowledge built in the leading firms is highly valued in the current firm. 10 out of the newly hired engineers' working experience in the leading firms was highly valued in the current firm, therefore, their position and strength are most likely to be increased. Most engineers shared the same view that *"the current firm offer better positions that's why I moved here." (J1)* Engineers who are hired from leading firms are often offered a higher position in the current firm as team leaders or managers. Even some of the hired engineers who were engineer level in the previous firm, once their movement occurs, were given a higher position by gaining an expert level position within a firm, so hired engineers often feel more satisfied working in the current (new) firm. For instance: *"in the previous firm, I was just an engineer, but here they treat me as an expert, so for me working environment is much better here than in the previous firm."(E1)* Some of our interviewees directly mentioned that their movement eventually increased their value due to their working experience in a leading firm.

Newly hired engineers are often given authority, control or influence over the team. In the interview findings, it is common to find that once hired, the firm will create a team for those engineers and make them training team members, and are leading or directing them to conduct the innovative activity. Sometimes, newly hired engineers get involved in many of the diverse processes, such as setting up a team from scratch and, training and directing team members to conduct the technological task. Increased involvement of new hires eventually enhances their authority within a team to influence others. *"..., when I just came I was an assistant, when I just came there were no one with me, but after 3 months, we had around 10 to 12 engineers, so the team was established. After setting up a team, I direct the work slowly, training slowly, doing technological tasks slowly. " (C1)* Besides, newly hired engineers often feel it is easy for them to work in the current firm. In many of the interviewed cases, engineers feel the current firms are supportive of them in conducting technological tasks within a firm. The authority provided to engineers enables them to conduct tasks across other departments without much difficulty. Easy access to other departments is important especially when the technological task involves many departments' associations. Newly hired engineers can freely access what they want for their work such as the firm's human resources resulting in increasing communication with other engineers. Most of the interviewees shared the same view that:

> *"Unlike other industries, the semiconductor industry has to integrate with many departments and the sales and technical communication are important so the firm provides fair support for this… in order to maximise the performance for individual engineer and specifically selected departments, we are given the authority to drive or control other departments." (A3)*

Status distance between newly hired and incumbent engineers may increase the dependency of incumbents on newly hired engineers. Since the team is led by newly hired engineers, they often provide technical consultancy to their team members, guiding them in the right direction, and solving the technical problems together in order to find the right answers when there is technological disagreement. Often incumbent engineers ask for the technological solution to the problem, then newly hired engineers have to provide advice and comprehensive direction to them. Newly hired engineers help incumbent engineers to solve a technological problem that incumbent engineers cannot solve, by doing so, incumbent engineers can resolve the problem themselves when they encounter the same problem next time. Besides this, newly hired engineers often have to train incumbent engineers as a part of their job.

For instance, hired engineers help incumbent engineers to enter the field and master the specific technology, and this eventually helps incumbent engineers to build experience and capability. Therefore, the project that has been previously conducted by newly hired engineers independently can be handed over to incumbent engineers or they can be given new projects in the future:

> *"There is a one who has 15 years experience in our team, they usually lead us to enter and master (technology) and provide the direction like a supervisor." …"They help us to enter the field, later they will help us develop us depending on which direction we want to develop in the field, I can learn much, and if we encounter a problem we cannot solve then we will ask them, sometimes I will be given the working task what they did if there is a problem then ask them first because they know it well as they did before." (H3)*

As a result of the authority given to newly hired engineers, the possible conflicts that may result in difficult integration are impeded. Incumbent engineers whose status is lower than hired engineers would not raise the problems and challenges when working with hired engineers. The interview finding shows that incumbent engineers show their respect and deference to newly hired engineers because they possess more experience in the field. Incumbent engineers described it as hired engineers being like supervisors or seniors, so incumbent engineers often have to show their respect toward the hired engineer. That is, incumbent engineers with lower status would not easily raise their voice to newly hired engineers when their viewpoint is different from the viewpoint of newly hired engineers. Most interviewees (incumbent engineers) explicitly stated that they will show their respect to newly hired engineers and that they are willing to learn from them:

> *"When experts were hired, everyone shows respect, no one arise conflict with them, you must admire him, his authority is higher than yours… when they are hired, integration into a firm has no problem because when they are initially hired, they will be given a certain level of authority, so no problem to get adapted in the firm." (H1)*

From a newly hired engineer's perspective, they often feel that they are given higher authority than their team members, so not many problems are encountered working in the new firm. Adapting to new firms seems to be easy for them as no other team members raise a conflict or a challenge with them. Newly hired engineers often feel that they are treated as an expert, so when they conduct the technological task with other engineers or carry the cooperative task, the team is harmonised. *"In the previous firm, I was just an engineer, but here they treat me as an expert, so for me, the working environment is much better here than in the previous firm… the most technological task is cooperative work so harmony is important, in terms of work, we are harmonised."(E1)* One of our interviewees (local director - A5) concluded it is better that their firm should not place two high-status engineers in one team because there is a possibility that there would be friction between high-status engineers. Therefore, when engineers came from leading firms, they were put in charge of leading a team and firms find other engineers to support hired engineers.

Interestingly, an unanticipated finding shows that firms tend to focus on maximising knowledge transfer. In order to do so, the hiring firms often inherited newly hired engineers with diverse roles. The interview finding shows that newly hired engineers do not only conduct the technological task in areas of their own specialisation but also are in charge of diverse tasks that are not necessarily related to their expertise. 10 out of 10 hired engineers stressed that their roles in the current firm are more diverse than their previous firm where they could only carry on what they specialise in. *"The atmosphere is similar, but I have to deal with external things and have many chores (Zashi), More times I deal with things and Zashi (chores) with the outside of the firm, more things to do with management. When I was in the previous firm, I didn't do these things, I only did what I had to do." (G1)* Basically, the working task does not only focus on what they are specialising in but tends to take various roles that may not be directly related to the engineers' expertise.

The "Zashi" (Chores) concept was repeatedly mentioned by our interviewees. 9 out of 10 engineers who are hired by the current firm described it as "Zashi" in Chinese, the meaning of "Zashi" embedded the meaning of not significant things or one's main task, the meaning is close to 'chores' 'odds and ends' work. Most of the interviewees shared the same view that their role is more diversified than what they did in their previous firms, this is different from their previous firm where they only needed to focus on what they were specialising in. For instance, they often carry on the technological project that is related to their expertise, yet at the same time, dealing with management tasks including the cost reduction for production capacity, security-related issues, and recruitment etc. 9 out of 10 engineers explicitly stated:

> *"Many times, I do things that are not related to my expertise, it is like Zashi (Chores), relating to security, has somehow related to my expertise but it is not absolute… What I said that I have never done before means I do manage the cost or to calculate the production capacity, how many machines we need to buy to produce, then I have to find the indicators, the cost of machine and material and so on."(C1)*

However, assigning diverse roles limits hired engineers' focus on their main task. Most interviewees explicitly stated that they are short of time for focusing on their main working task because they have to deal with many things that are not related to their speciality: *"I have a lot of Zashi (chores), for instance, work about the public security, the production safety, there is a management team in charge of production safety, but now I manage the production safety of our department…I have to help, this is* *not my expertise (profession), so my time is dialled away. …When I was just hired, I was doing my expertise (Huang guan) and training other engineers." (A2)* Furthermore, hired engineers have to carry out the tasks that are not related to their speciality, so they also have to learn or ask other engineers while doing so. Often, hired engineers fear disadvantages if they do not do it.

> "*I don't know how to do then I learn and ask. I did not know about the operation of the factory at R&D before, but for these few years I learned concept, so when I went back to my original expertise (profession), I will consider these, for instance, the cost down, I will consider if what I am doing is affect the cost or will it help." (C1)*

Firms often rotate newly hired engineers from one team to another to maximise knowledge transfer. Firms expect hired engineers to transfer their advanced knowledge to the firm by being rotated among different teams and factories (plants), so there will be more engineers who can possess the same knowledge within a firm. It is reflected by one of the local directors: *"Within the firm, engineers are often to be rotated, so the standard operating procedure has to be made as a recipe when one goes from A team to B team, he has to bring SOP together. The technology has to be shared between teams, the firm will make hired engineers sufficiently share their knowledge, I have four teams under me, for example, A team make the most advanced technology, the hired engineer from A team will be sent to the B team to setup technology, share their knowledge, so more teams can conduct same technology." (A4)* Firms aim to absorb their advanced knowledge, so engineers will be asked to do what they used to do and then develop new technology. However, if hired engineers are not able to develop the firm's new technology, then they will be assigned a role focusing on diffusing their knowledge to other engineers by working in different plants, so hired engineers keep conducting the same innovative activity. The local director concluded well that

> *"Firm hire engineers for a reason, hired engineers do what they used to do, or he will train other engineers, and there is a possibility he may continue to develop the next generation of technology. Usually, the purpose of hiring is to absorb advanced knowledge so he will be asked to do what he had done before and then develop new technology, but if he is not able to develop the next generation, if he still has value, he will train other engineers to diffuse the knowledge to more engineers so that more engineers can do the same technology." (A4)*

On the other hand, newly hired engineers can transfer their knowledge to their team members, however, promoting a new idea to the firm seems not always to be accepted. Newly hired engineers attempt to suggest new ideas that can help firms to improve and refine current engineering conditions, however, these ideas are not always acceptable to the top management (who possess a higher status than newly hired engineers' status). This is reflected in the statement of the interviewee: *"You feel there is* *something good, you think it should be done, this new thing you suggest your department but they may not agree with you, this is to say, the firm looked for an expert, the firm thinks this expert got a lot of good things, that has to transfer to others, refining the current efficiency and some engineering conditions, but the boss in this team may not accept. Promoting your idea is really challenging. People here are not good at adjusting to each other (Mohe), so the expert has no way to promote these good things. What is the point to hire experts? This is also the reason I want to leave…. (A2)* It shows the hiring firm's clear tendency towards hiring aims to maximise knowledge transfer.

6.3.2 The perceived psychological safety of hired engineers

Psychological safety is considered by the interviewees as an important factor that is affected by status distance. In learning by hiring, to what extent hired engineers to share their knowledge is contingent on their perceived psychological safety in the new firm. Newly hired engineers often feel concerned that their value within a new firm will be decreased once the knowledge is learnt by incumbent engineers. Hired engineers often concern once the knowledge that has been brought by them becomes mature within a firm, and firms can make themselves without them, which will be a risk for them. *"The firm cannot operate by depending on one or two persons, so we have to remain (since 2002), now they already learn certain degree about 8 inches, for the 12 inches, the firm will directly hire experts from other firms, we also feel risky because 8inch become a mature technology, they can make themselves without us."(A2)* The local director (C2) added that when newly hired engineers cannot keep contributing to new technological development, especially when the team members become more capable than their team leader, then they will have no value, therefore losing the advantage. There is a potential risk for them to be replaced and lose their benefits such as a special incentive that has been initially offered by the firm. Although there is a knowledge gap between hired and incumbent engineers, hired engineers often feel the decision whether firms keep reaming the special incentives to newly hired engineers depends on the hiring firm. It is reflected by one of the interviewees:

> *"Technology of this firm is behind another company when I decided to come here in 2012. Everybody said I was crazy. We gain special incentives for new technology, is it long term? If the local guy can learn does the company keep the special incentive? This is a potential risk for us. Even the local guy still has a gap with us, but it depends on how the firm thinks, it is not controlled by ourselves."(A1)*

Hired engineer's concern over losing the value within the firm results in their strategical knowledge sharing. Some engineers explicitly expressed that the value of new hires will be decreased once they transfer all the knowledge to the firm, therefore, they tend to share their knowledge strategically by partly sharing the knowledge. When the knowledge is critical they will avoid sharing it with other engineers in order not to lose the value of hired engineers. One of the interviewees emphasised that *"I train them and teach them how to do it, about methodology, but in terms of know-how once I transfer it then there will be no value for me. We see know-how as an idea… I teach them, I teach what I have to teach, but not all of what I know" (C1).* Some hired engineers have emphasised that they have to keep learning to retain their value within a new firm. One of the interviewees has explicitly mentioned that hired engineers in order to keep the competitiveness while transferring their knowledge to incumbent engineers, will have to keep learning themselves to keep a gap with incumbent engineers. On the other hand, from the incumbent engineers' perspective, they also feel newly hired engineers share their knowledge with them but are also reluctant to share much of the knowledge, so they feel that they did not learn much from hired engineers. They are aware that it is risky for hired engineers to share all the knowledge with their team members. It is reflected by one of the incumbent engineers who work with a hired engineer.

> *"I don't think I learn that much by working with newly hired engineers, not much has changed for me, I just do my own work, if a project leader teaches team members too much, he will have a risky, my boss will teach us but he does not want to teach all, he does not want to teach you too much." (M1)*

The finding also shows that the local manager or director often feel that hired engineers perceive their team members as their competitors rather than co-operators. The evidence reveals that from the eyes of a local manager and directors, hired engineers do not build a good relationship with their team members, which worsen the working environment. Since hired engineers can power over and influence other engineers within a team, they often stand for the opposite for the sake of opposition. It is often because hired engineers often perceive their team members as competitors. Besides, hired engineers tend to do "politics" within a team, so often causing team members to leave the team, thereby declining the working efficiency. Firms can hire engineers to fill the knowledge gap but when other engineers leave the firm, it will slow down the development progress as the technological task is operated by teamwork and collaboration. This is reflected in the statement of the local director:

> *"Some hired engineers are not good at building a good relationship with people or when it has a destructive effect on a team atmosphere, this will negatively influence their team working capability. It may depend on the power within a team, more power, more influential so can make a great influence on others in terms of technology and integration. For instance, hired engineers have great capability, but tend to do office politics, and cause other engineers to leave, even though the technology gap can be filled but if lack of basic human resource can slow down the development progress." (A5)*

"When the experts come to the firm, they have to integrate or get along (Mohe)with their team members who are a lower position of them. But they cannot really get along, they stand opposite for the sake of opposition. Experts see other members as competitors." (A2)

6.4 Discussion

Drawing on the finding of the interview data in which hiring engineers by follower firms from leading firms, this study attempted to investigate the effect of status of new hires on the hiring firm's innovation. As previously discussed (section 5.2), information processing views that status distance leads to innovation resulted from different knowledge possessed by engineers with different status (West, 2000). The findings of this study suggest that status distance between engineers is closely related to how knowledge flows among engineers and the perceived psychological safety of newly hired engineers that affect a firm's innovation. This study will discuss in detail how status distance is associated with knowledge flows and the perceived psychological safety of newly hired engineers, therefore, leading to innovation and derive propositions accordingly.

6.4.1 Propositions

Status distance promotes the knowledge contribution of newly hired engineers. When firms hire engineers from the leading firms, firms render a certain authority to newly hired engineers by placing them in a high level of structural power within a team. The finding of this study reveals that newly hired engineers play a more dominant role in exercising authority and directing the actions of others within a team increased their knowledge reflection to the technological task. The past research has suggested that members with unequal status, higher-status members play a more participative role (Larson et al., 1998). The findings of this research show that high-status new hires play a more active role by directing and guiding the incumbent engineer in conducting the technological task. They resolve differences of opinion in terms of technical tasks and the related innovative activities among those with lower status (Groysberg et al., 2011). That is, new hires may find it easy to have their information and perspective heard when they have a higher status (Bunderson & Boumgarden, 2010). So, their advanced and unique knowledge that is built in their previous firms is more likely reflected in the technological task. Furthermore, since new hires are often provided with a high position, they are able to access the human resource and other departments. Accessing resources and other departments can be important in the fields like semiconductors due to the nature of a technological task that requires collaboration and interdependency. The finding revealed that newly hired engineers are able to access human resources and other departments without much restriction in the new firm eventually stimulated their involvement and engagement in innovative activity.

On the other hand, the findings of this study explicitly show that the status distance limits the knowledge contribution of incumbent engineers. When hired engineers present in the firm, they will enhance their colleagues' productivity (Allison & Long, 1990) and facilitate the learning and increasing the performance of their team members (Rosenkopf & Almeida, 2003; Song et al., 2003; Kehoe & Tzabbar, 2015). The finding shows that newly hired engineers provide learning opportunities to incumbent engineers (team members) by helping them to master the knowledge and enter the field. However, incumbent engineers working with high-status new hires will have less responsibility in knowledge contribution as they will often rely on the hired engineer's consultation, technological direction and technological problem-solving. That is, incumbent engineers whose status is lower than newly hired engineers will have a weak willingness to create an innovative idea, instead, they will tend to depend on the knowledge of high-status new hires. This finding is echoed by the previous studies that suggest that hired engineers are more dominant within a team by exercising authority and direct the actions of others within a team (Conner & Prahalad, 1996; Macher, 2006), the dependency of the team members on hired engineers increase, this diminishes the likelihood that team members look for a new idea (Atuahene-Gima, 2003; Kehoe & Tzabbar, 2015).

Status distance is known to prevent the engineers from reaching a rapid consensus and will enhance information processing as engineers will try to understand the divergent positions, reflecting information processing perspective (Van Knippenberg & Schippers, 2007). However, in this study, the consensus is reached quickly because there is respect for power differences. The finding also reveals that incumbent engineers who work with hired engineers whose status is higher, would not easily raise their different viewpoints. Incumbent engineers often perceive hired engineers as a senior or a supervisor, therefore, they will show their respect and defer to them. This is particularly to do so in highly hierarchical societies, such as China, where people have to respect and deference to people whose status is higher or whose experience is greater. Engineers will pay their respect and deference to newly hired engineers who are considered as more experienced and higher status than themselves, therefore, working with high-status engineers, the incumbent engineer will tend to follow their direction or supervision and is less likely to raise their voice or different viewpoints to higher status engineers.

Status distance may impede unnecessary conflict that may be caused between newly hired and incumbent engineers, yet at the same time, hamper effective communication and the open exchange of knowledge between engineers (Brabander & Thiers, 1984). The knowledge possessed by lower-status engineers are less likely to be acknowledged or accepted, and they will less likely to share what they know. The findings of this study indicate the integration of knowledge possessed by different status is limited under hierarchy relations due to the great reliance of incumbent engineers on newly hired engineers regardless of their unique knowledge that may be helpful for the firm's innovation. As a result, the status distance between engineers eventually increases the dependency of incumbent engineers on newly hired engineers.

The finding also reveals how a firm maximises knowledge transfer. When firms hire engineers from other firms, the bargaining power of engineers also increases (Groysberg et al., 2008), therefore, more organisational resources such as salary is given to hired engineers (Prato & Ferraro, 2018). The finding shows that the hiring firms promise attractive offers such as higher salaries or other incentives in order to poach them away from leading firms. Increasing the budgets to lure away engineers eventually increase the firm's expectation of maximising the benefit from the hiring. Fascinatingly, the finding shows that the hiring firms assign hired engineers with diverse roles to maximise the knowledge transfer. This may be the reason why hired engineers are given a higher status in the team and lead and direct their team members. Hired engineers are placed in the higher structural power, in charge of the technical task they are specialising in, at the same time, also carry on diverse roles that are not necessarily related to their expertise such as tasks relating to management, security and training. Hired engineers often described this as 'chores' that embed meaning of unimportant work or work not necessarily related to their expertise. Furthermore, the hiring firms often rotate engineers from team to team for knowledge transfer, therefore, the knowledge of hired engineers will be available to more engineers. This finding reflects a firm's intention to focus on maximising knowledge transfer of newly hired engineers by providing them with a higher status than their team members.

The evidence suggests when engineers with status distance, the assumption that engineers will leverage the knowledge and insights of different status engineers appears highly questionable. Rather, it seems clear that when relations of status are asymmetric, equal consideration of knowledge by different status is decreased. The knowledge of those higher in the hierarchy tends to be more contributed to the firm's innovation than those with lower status. That is, status distance tends to spur knowledge flows coming from hired engineers. Hence,

> **Proposition 1:** The status distance between newly hired engineers and incumbent engineers spurs knowledge flows from newly hired engineers to the hiring firm.

Status distance is closely associated with the new hire's perceived psychological safety. Psychological safety is crucial for all creation and knowledge sharing (Kale et al., 2000; Nonaka et al., 2000; Dovey, 2009) because engineers must feel psychologically safe to share their knowledge and engage in generating the firm's innovation (West, 2000; Bunderson & Reagans, 2011). It is noted that hierarchical relations make engineers' relations and interaction more predictable and remove uncertainty, which breeds intragroup trust (Edmondson, 2004), lower defences and fosters psychological safety within a team (Bunderson & Boumgarden, 2010). The existing studies have suggested that the effect of status distance on the perceived psychological safety of the higher status individual who feels higher levels of psychological safety than lower status engineers who often feel less safe engaging in key behaviours (Nembhard & Edmondson, 2006; Bunderson & Reagans, 2011). The finding of this study also shows that the status distance between engineers leads hired engineers to be easily noticed and heard by others, therefore, can interact with greater confidence in the outcome of interactions in the new firm.

However, the status distance also creates an environment in which decrease the perceived psychological safety of higher status new hires. The perceived psychological safety may be influenced by the fact that new hires perceive themselves as an outgroup rather than an ingroup. The categorisation perspective views status distance as a division (Williams & O'Reilly, 1998), and this division may be more salient when engineers are hired from other firms. The status distance would categorise hired and incumbent engineers between ingroup and outgroup, and engineers who are categorised as outgroup members will suffer more insecurity (Van Knippenberg & Schippers, 2007). The finding of this study shows that hired engineers even with high status may be categorised as the outgroup, this seems to decrease the perceived psychological safety of newly hired engineers in the new firm.

Like many work settings, the privileges or advantages are based on one's status (Lynn et al., 2009), it is particularly to do so when engineers are hired from other firms, they will be offered with many benefits by a hiring firm that does not only include the higher position, salary, but also the incentives and other working conditions. This also means that high-status engineers gain more and have more to lose. The finding shows that status distance between high-status new hires and incumbent engineers results in the hesitation of the knowledge sharing by high-status new hires because the concern over their value may be declined once their knowledge is shared by incumbent engineers. Knowledge sharing increases the risk they will lose the benefits that have been offered by the firm. The concern over new hires is closely related to their insecurity that they will be replaced once the knowledge is transferred to the firm.

Newly hired engineers, in order to preserve their value, tend to be passive in sharing knowledge by allowing only certain pieces of what they know, or only sharing at strategic times (Bunderson & Reagans, 2011). When the knowledge is critical or highly valuable, they would feel more reluctant to share with others, so they tend to share their knowledge strategically by only sharing part of their knowledge or taking a long time to share the knowledge. This is similar to the finding of Contu and Willam (2004) that technicians strategically represented and applied their knowledge in the firm in order not to lose power over their work to a manager who sought to constrain their power. From the incumbent's perspective, when the incumbent engineers work with newly hired engineers, they often feel that newly hired engineers do not transfer all the knowledge to them, hence, they can only learn part of the knowledge from newly hired engineers. It is probably because engineers are hired from other firms for the sake of their valuable or advanced knowledge, so even these engineers are placed in the higher structural position within a new firm, they would feel once the knowledge is transferred to the firm, the value of them will be declined.

The findings of this study further show high-status new hires do not always possess the best skills in collaboration with local colleagues (Groysberg et al., 2011). Newly hired engineers often give the perception that they do not get along with other engineers, so worsen the working atmosphere. The previous study suggests that the possession of valuable knowledge or information provides power to the individual, they may be hesitant to simply share their knowledge or information without extracting some "political" advantage from doing so (Wittenbaum et al., 2004). Newly hired engineers tend to do the politics within a new firm and this cause other team members to leave the firm, therefore, decrease the working efficiency. When engineers leave the firm, firms will have to find new engineers to fill the gap of absent engineers, this sometimes slows down the development process. Newly hired engineers perceive their team members as their competitors rather than co-operators, it is probably because they are hired from other firms, so even they are with higher status, they will have a concern to be replaced.

Put it together, the finding of this study shows that the perceived psychological safety is closely associated with their employment status. Even newly hired engineers have a higher status than incumbent engineers, their perceived psychological safety is also negatively influenced. When hired engineers do not feel secure in the new firm, knowledge sharing may be impeded. That is, newly hired engineers who possess unique and valuable knowledge may be hesitant to actively share their knowledge with others when their perceived psychological safety is decreased. Thus, this study proposes:

> **Proposition 2**: Status distance decreases the perceived psychological safety of high-status new hires, which negatively affect their willingness to share the knowledge in the new firm.

6.5 Summary

While the importance of hiring high-status engineers on the hiring firm's innovation (see Agrawal et al., 2017; Ulrich Kaiser et al., 2018; Rosenkopf & Almeida, 2003; Simonen & McCann, 2008; Singh & Agrawal, 2011; Song et al., 2003b; Tzabbar, 2009) and the effect of hiring high-status engineer have been examined in prior research (Azoulay et al., 2010; Groysberg et al., 2011; Oettl, 2012; Tzabbar & Vestal, 2015; Prato & Ferraro, 2018). These studies had the assumption that status is embedded in hired engineers and did not bring into the centre of the discussion. To fill this gap, this study explicitly paid attention to the status of newly hired engineers and explore how the status distance between hired and incumbent engineers affect innovation by exploring the linkage relationships. In doing so, this study shifts the focus from looking at whether hiring high-status engineers contribute to a firm's innovation, to how the status of new hires affects knowledge flows and the perceived psychological safety of new hires. Our findings enrich existing research on learning by hiring by bringing in the status of engineers into the centre of the discussion.

The status of newly hired engineers is found to play an important role in building a firm's innovation, especially when status distance emerges between new hires and incumbent engineers. Our findings reveal two dynamic factors involves knowledge flows and the perceived psychological safety of newly hired engineers that is closely associated with the status distance between new hires and incumbent engineers. This aspect has been underexplored theoretically and empirically in the literature of knowledge spillover through hiring. Status distance determines how knowledge flows, that newly hired engineers' knowledge is more likely to flow to the firm and contributing firm's innovation. That is, status distance spurs knowledge flows coming from new hires to the firm. This study also reveals that the firm's intention has focused on maximising knowledge transfer by assigning newly hired engineers with diverse roles.

In addition to that, the study finds that status distance does not only influence the lower status engineers as most previous studies suggested but also have a negative influence on the perceived psychological safety of high-status new hires. Having status provides newly hired engineers with various advantages, but which also results in the hesitation of their knowledge sharing in order not to lose their advantages given based on their status. Even though new hires are given higher status than their team members, it does not mean their perceived psychological safety is not influenced in the new firm. It is partly due to the fact that when engineers are hired from other firms, they will perceive themselves as an outgroup rather than an ingroup.

Chapter 7 Conclusions

7.1 Introduction

The aim of this research, as stated in chapter one, was to increase insight into followers' technological learning by hiring and to investigate its effect on the firms' innovation. This thesis began in Chapter 2 by explaining how followers' technological learning by hiring affects innovation, despite the significance of technological learning by hiring, hiring as a method of knowledge acquisition has not been paid sufficient attention in previous studies (Guo & Guo, 2011; Hobday, 1995; Kim, 1997; Lall, 1992; Mathews, 2004; Powell et al., 1994). In short, within the extant literature, there has been a gap in understanding about how technological learning by hiring affects the firms' innovation within the context of followers in the high-technology industry.

Informants from 14 semiconductor firms including foundry and fabless businesses model have provided the data for this study. A total of 29 managers, hired engineers and incumbent engineers from follower firms were interviewed, along with managers from global leaders. The findings provide how technological learning by hiring affect the hiring firms' innovation by breaking into three studies approached from the sectoral, firm and individual level. This chapter presents the summary of findings, contributions of the research, the implications for practice, limitations and future research at the end.

7.2 Summary of findings

In order to investigate the effect of technological learning by hiring on innovation within the context of follower firms in the high-technology industry, this research approached from sectoral to firm and the individual level. Firstly, this thesis presented China's semiconductor industry as the research setting that helps to have a better view in terms of the second and third studies. Therefore, the first research questions are *what is the catching up process of China's semiconductor industry?* and *How do sectoral factors affect the catching up of the Chinese semiconductor industry?*

The first study presented the catching-up process by classifying it into two distinct periods: catching up through inward internationalisation and catching up through indigenous capability by considering the main actors, strategies in knowledge acquisition and policy throughout the time period. Although China's semiconductor industry has a long history, the records of catching up including market share by segments, patent data and process technology showed there is a limited achievement. To determine the reason, this study examined the factors that affect catching up by using the transnational dimension of the sectoral system perspective.

This study identified the sectoral factors that are closely associated with the semiconductor industry including the regime of technology and knowledge, market regimes, internal and external institutions and networks including internal and global production networks. The finding shows that sectoral factors play the role of windows of opportunities for catching up (Lee et al., 2008; Lee & Ki, 2017; Mu & Lee, 2005; Xie, 2004) may also cause the barriers in their catching-up process. As discussed in chapter 4, for instance, the semiconductor industry has a short cycle time in technology, this may lead to the opportunity to have a rapid catching up when possessing capability (Park & Lee, 2006; Perez & Soete, 1988). The finding of this study shows that technological regimes result in hardship in catching up when lacking a pool of experienced engineers and talents in the sector. Although the firms are able to purchase advanced equipment and facilities, experienced engineers are required to operate it, however, it is often lacking for followers which cause difficulty.

Furthermore, Chinese semiconductor firms often encounter difficulty in accessing foreign semiconductor technology. While previous followers such as Korean and Taiwanese firms benefited from the US's technology transfer, Chinese semiconductor firms are restricted to access the most recent technology. The external institutions are often designed to restrict advanced technology transferring to China since the early catching up period, which slows the learning. Also, the semiconductor industry is highly globalised and integrated, the important segments of the production value chain are controlled by advanced economies, which often result in the restriction of key inputs such as advanced equipment and material to China. Therefore, Chinese semiconductor firms often find it much difficult in accessing advanced technology from global leaders. As a consequence, the sectoral environment surrounding the semiconductor industry enhances the importance of hiring engineers from global leaders and its necessity for followers in their catching-up process.

Follower firms that hire engineers from global leaders, knowledge of hired engineers may be distant or not distant from the hiring firms' core technological domain. Depending on the knowledge of hired engineers, the effect may be different because distant knowledge may indicate firms have more new knowledge to learn (Mowery et al., 1998; Song et al., 2003) while familiar knowledge indicates firms are more likely to learn as familiar knowledge have the greater relative absorptive capacity (Lane & Lubatkin, 1998). Therefore, the second study attempted to look at the technological distance from the firm level by specifically investigating the research question: *How does the technological distance between the hired engineer and the hiring firm affect the firm's exploratory versus exploitative innovation?*

This study draws on information processing and categorisation theories and tests the propositions – Hiring engineers whose knowledge is distant from that of the hiring firm's core technological domain is more likely to facilitate the firm's exploratory innovation rather than their exploitative innovation.

On the other hand, hiring engineers whose knowledge is not distant (but familiar) to the hiring firm's core technological domain is more likely to facilitate the firm's exploitative innovation rather than exploratory innovation. The knowledge of hired engineers is identified into distant and familiar and investigate whether their effect is on exploratory or exploitative innovation. The finding supported the propositions showing that when firms hire engineers whose knowledge is distant, the knowledge of hired engineers is often new and not available within a firm and which increases the knowledge integration that leads to creating the new technology. Conversely, when firms hire engineers whose knowledge is not distant but familiar, their knowledge is often already available or existing within a firm (e.g. the firms are already operating such technology), they tend to solve the technical problem, enhance efficiency and increase technological understanding in accordance with existing technology, and is thereby more likely to facilitate exploitative innovation rather than exploratory innovation.

Technological learning by hiring is a complex input that also involves the sociological factor. Engineers once hired, the interaction between hired and incumbent engineers is necessary for transferring their knowledge to the firm (Ebersberger et al., 2021), and the status of engineers play a critical role in their interaction (Edmondson, 2003). Hence, the last study is particularly focused on exploring the role of the status distance between hired and incumbent engineers. As previous studies have already suggested that hiring high-status engineers contribute to the hiring firms' innovation (Groysberg & Lee, 2009; Jain, 2016; Prato & Ferraro, 2018; Song et al., 2003; Tzabbar, 2009; Tzabbar et al., 2015), this study explored the linkage relations by answering the research question: *How does status distance between the hired and incumbent engineers affect knowledge flows and the perceived psychological safety of newly hired engineers?*

As a result, this study has given rise to several interesting findings. The main finding of this chapter shows that the status distance between newly hired engineers and incumbent engineers spurs knowledge flows from newly hired engineers to the hiring firm. It is because engineers with more authority can have greater participation and contribution to innovative activity (Bunderson & Boumgarden, 2010; Nickerson & Zenger, 2004), while increasing the dependency of incumbent engineers to the hired engineers within a team, resulting in knowledge flow from hired engineers to the firm. In addition to this, the finding also shows that firms tend to assign hired engineers with diverse roles which shows the intention of the firms in maximising knowledge transferring from hired engineers to the firms.

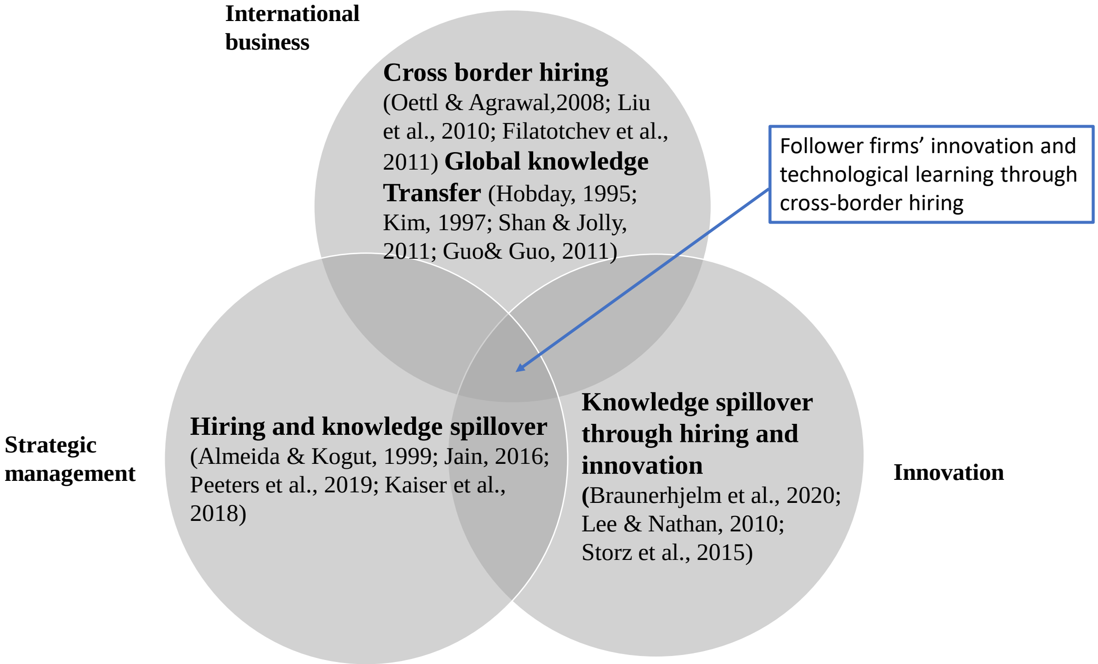
Moreover, while the previous studies found lower-status individuals have lower levels of psychological safety than higher-status individuals (Nembhard & Edmondson, 2006), which negatively influence their learning and risk-taking (Bunderson & Reagans, 2011; Nembhard & Edmondson, 2006; Prato & Ferraro, 2018). However, this study looked at the perceived psychological safety of high-status engineers and found that status distance may also decrease the perceived psychological safety of high-status engineers, which in turn negatively affects their willingness to share the knowledge with and in the new firm. The study found that it is partly because engineers are hired from other firms, hence, even though their status is higher than incumbent engineers within a team, they also perceive insecurity. In the next section, the contribution of this research is considered.

7.3 Theoretical contribution of this thesis

This section discusses the contribution of this research. Firstly, from the perspective of international business studies, the findings of this study extend knowledge about international knowledge spillover. Examining technological learning by hiring from the perspective of international knowledge spillover, the findings show how the recipient firms benefit from hiring engineers from global leaders, particularly, how the recipient firms' innovation is differently affected by depending on the knowledge of hired engineers. For instance, firms that access knowledge that is distant from their technology and, how such knowledge turns into a new opportunity for the firms while accessing familiar knowledge, how such knowledge benefits the firms' existing technology. However, until now, international business literature has been unable to provide a full explanation about it by linking technological learning by hiring and innovation.

Since international business studies have not been sufficient in explaining such links, this research, using innovation and strategic management studies that have examined hiring engineers from other firms as the method for driving knowledge flows between firms and the firms' innovation (Almeida & Kogut, 1999; Braunerhjelm et al., 2020; Jain, 2016; Kaiser et al., 2015; Lee & Nathan, 2010; Peeters et al., 2019; Rosenkopf & Almeida, 2003; Slavova et al., 2016; Storz et al., 2015) to enhance our understanding in terms of technological learning by hiring and innovation within the context of follower firms. Figure 7-1 provides the coverage of literature streams this research has used.

Figure 7-1 The coverage of literature streams



Furthermore, previous research conventionally approached this from a quantitative study viewpoint and mostly provided data on the extension of technological learning by hiring and the extent to which this affects knowledge flows and the hiring firm's innovation (e.g. Song et al., 2003; Irwin & Klenow, 1994; Parrotta, & Pozzoli, 2012; Tzabbar et al., 2015; Slavova et al., 2016; Braunerhjelm et al., 2017; Kaiser et al., 2018). In contrast, this study employed qualitative research that enabled us to have new insights into technological learning by hiring by investigating 'how' question and extended research into international knowledge spillover literature.

Further insights may be deduced from this research regarding sociological factors. This study's main contribution was to identify the status distance between hired and incumbent engineers in technological learning by hiring and explore the effect of status distance. Literature in knowledge spillover that addresses the status of hired engineers has focused on its influence on incumbent's performance (Agrawal et al., 2017; Oettl, 2012; Prato & Ferraro, 2018) and most studies have not brought it into the centre of the discussion (e.g. Slavova et al., 2016; Song et al., 2003; Tzabbar et al., 2015). This study adds new value to the literature by exploring the status distance between hired to incumbent engineers by leveraging status literature. The findings point to the status distance between hired and incumbent engineers playing an important role in determining how knowledge flows within a firm and the perceived psychological safety of hired engineers that influences their knowledge sharing within the firm. This research suggests that the role of status distance should be taken more into consideration in the international business field because status distance determines the interaction between two entities and that in turn has an influence on the potential for innovation. Accordingly, this study contributes to the international knowledge spillover literature by exploring the role of status distance. Furthermore, while the existing literature on international knowledge spillover has mainly focused on the sectoral or organisational level (Almeida & Kogut, 1999; Kogut & Zander, 1992; Song et al., 2003; Tzabbar et al., 2015), this study adds scholarly work to the literature of international knowledge spillover by focusing on the individual level.

Simultaneously, this research contributes to the literature on catching up since it presents the factors that affect catching up by looking into the transnational dimension of the sectoral system of innovation. Until now, as regards existing research on catching up, there is a lack of a holistic understanding of the Chinese semiconductor industry in respect to its catching-up process (Grimes & Du, 2020; Kong et al., 2016; Rho et al., 2015). This study, along with the sectoral factors that have been identified as the basis of catching up (Lee et al., 2008; Lee & Ki, 2017; Mu & Lee, 2005; Xie, 2004), takes into account the global production network and external institutions and thereby extends the existing framework of the sectoral system of innovation.

7.4 Practical implications

7.4.1 Implications for managers

This study has found that hiring as a method of knowledge acquisition is particularly suitable for firms that seek to narrow the technological gap between themselves and global leaders. Follower firms often build innovative capability by acquiring knowledge from global leaders by establishing strategic partnerships with global leaders (Fan, 2006; Hobday, 1995; Kim, 1997, 1998; Malerba & Mani, 2009; Xie, 2004), however, such strategies often prevent follower firms from acquiring advanced knowledge from their foreign partners. This study suggests that a hiring mechanism can be used to fill this gap, that is, adopting the concept of hiring as a means to acquire advanced knowledge. Moreover, the absorptive capability is required to effectively acquire and use the externally acquired knowledge (Kim, 1997; Lall, 1992; Lane & Lubatkin, 1998), this hiring method is especially effective for followers whose absorptive capability is relatively weak as it helps followers to build the high-quality human capital that increases the absorptive capability of them.

Secondly, the findings suggest that there may be two different motives for managers to hire engineers from global leaders. On the one hand, firms that are developing innovative capability in accordance with existing technology may be more likely to hire engineers whose knowledge is not distant. Hiring these engineers means that the human capital and facility are already in place for them to access, hence, the existence of a greater possibility that hired engineers will conduct innovative activity and reinforce existing technology based on the already established technological trajectories. On the other hand, when a firm hires engineers whose knowledge is distant, the motive of the firm is to seek new technological opportunities. Firms may open up technological direction for exploration when firms are able to provide sufficient support to hired engineers. For instance, when the technological task is closely associated with teamwork, the managers hiring engineers whose knowledge is distant should provide team members who are able to support the hired engineers for the effective use of distant knowledge. Also, the firms may need to provide the facilities for hired engineers with distant knowledge to access, otherwise, hired engineers are more likely to conduct innovative activity by accessing the facilities already in place, which may bring fewer opportunities to facilitate exploratory innovation. This also means that when managers do not have the capability to support hired engineers whose knowledge is distant, the effect of hiring technologically distant knowledge may be less effective in its use to build exploratory innovation (see Chapter 5).

Another interesting finding is that while one may suspect that language can be a barrier when hiring engineers with distant knowledge as there will be a lack of common language (Jain, 2016), the finding of this research shows that it is less likely to lead to problems in the technology-intensive industry where technical terms are commonly shared (Cohen & Levinthal, 1990; Grant, 1996). This finding suggests that managers that aim to acquire external knowledge through hiring in a technology-intensive industry may encounter fewer barriers concerning the technological language.

Furthermore, knowledge flows within a firm require active sharing among engineers (Singh & Agrawal, 2011; Tzabbar et al., 2015). Status distance between hired and incumbent engineers may play an important role in facilitating knowledge flows (see Chapter 6). That is, managers should be aware that designing the appropriate structure of the team may determine its knowledge flows. This study found when the status distance exists between hired and incumbent engineers, it spurs knowledge flows from hired engineers to the firms as the contribution from high-status new hires may be greater. This finding implies that managers expect knowledge flows from new hires and that a hierarchical team structure may be helpful. The hierarchical relationship, if supported, also results in fewer conflicts between hired engineers and incumbent engineers as the latter would be less likely to raise conflicts. However, managers need to recognise that the team is structured with hierarchical relationship may not be effective for new knowledge combination that leads to the creation of new technology as incumbent engineers with lower status will be less motivated in conducting innovative activity (Kehoe & Tzabbar, 2015; Prato & Ferraro, 2018).

Moreover, it is important to consider the perceived psychological safety of engineers in the context of learning by hiring. The managers should be aware that status distance also affects the perceived psychological safety of hired engineers, even though they are rendered with higher power within a firm. Hired engineers often have the concern that their value in the firm will diminish once their knowledge is transferred to the firm, which causes them to share knowledge strategically. This is often because hired engineers perceive themselves as an outgroup, rather than an ingroup. This study suggests that to ensure that their valuable knowledge is fully shared in the new firm, managers should provide an environment in which newly hired engineers can feel inclusive as an ingroup within the new firm.

7.4.2 Implications for policymakers

The findings in this study also provide meaningful implications for policymakers. It is important to recognise the sectoral environment surrounding the semiconductor industry and to understand the sectoral factors that affect catching up (see Chapter 4). Presently there are various sectoral factors that affect the catching up, these sectoral factors that have been identified in this study can open a window for catching up when followers seize these opportunities (Lee & Malerba, 2017), otherwise, it may also turn into barriers. Thus, countries that aim to upgrade their industry should prepare for sector-specific capabilities that support actors, their network within internal and global production networks, and institutions (Lee & Malerba, 2017).

Among the various factors, this study suggests that lacking talents and experienced engineers is especially vital for followers in their effort to catch up (see section 4.5.2). Cultivating talents and experienced engineers takes time, which often causes difficulty to an industry in which the cycle time is short, technological knowledge is highly accumulative and the industrial technology is largely tacit. However, the followers are often involved less in collaboration with external actors such as universities, research institutes, and especially foreign institutes (Yu et al., 2017). This study suggests that the policy should be more complimentary that support interactions between firms, the university, research institute and external actors in involving in innovation, that may help to develop human resources.

The finding of this study also shows the imbalanced distribution of the talents within the semiconductor industry that talents are short-handed in the manufacturing sector but it is not the case in design sectors (see Chapter 4). The policymakers should endeavour to provide sufficient and, probably significant funding to encourage or direct greater numbers of talented students to work in the semiconductor manufacturing sector. However, in the short term, the lack of experienced and talented engineers may be fulfilled by hiring engineers from abroad. The government could consider implementing a policy to promote the recruitment of experienced engineers or retired engineers from abroad, especially from leading firms by easing the entry barriers and providing funding to encourage knowledge transfer to the industry.

7.5 The limitations of this study and suggestions for future research

This thesis has limitations that are important to address in future research. Firstly, qualitative research is an important strength of this study, this is distinct from the existing studies where the spotlight is often on the patent as a proxy of knowledge spillover through hiring as well as the recipient's innovation through quantitative research. Although the semiconductor industry is representative of technology-intensive industries, and patents are important in this field, semiconductor technology is largely involved with knowledge that cannot be codified. Qualitative research has enabled us to pursue a deeper investigation and has led to unique findings on technological learning by hiring that is not constrained to patent-related knowledge only, and provides a broader knowledge in regard to how the knowledge of hired engineers leads to different consequences on the firm's innovation. Nevertheless, the researcher is also aware of the disadvantages of qualitative research. Even though generalisability is not the major purpose of qualitative research, and qualitative research is virtually always weak in the form of population validity, further interviews can be conducted in the future by accessing the inner part of the firms. The researcher initially attempted to interview managers and engineers by accessing the inner part of the firms. However, due to the highly sensitive nature of the industry and high tension in the sector during the fieldwork, the researcher was not able to access the inner part of the firms and conduct further interviews. In future research, the researcher aims to conduct further interviews by accessing the inner part of the firms.

This study focused on the Chinese semiconductor industry as a research setting. To defend a more robust generalisation of these research findings, future research needs to explore other industries. A comparison of the technological distance across other industries will provide yet more valuable insights and evidence into how technological distance affects followers' exploratory versus exploitative innovation. Furthermore, the inductively derived propositions from Chapter 5 can be tested by conducting the survey in a future study. In particular, further study may be needed in the perceived psychological safety of hired engineers by using the survey and investigate its effect on the hiring firm's innovation.

In addition, this study only focused on the achieved status, one's status in the working place, but future studies should examine ascribed status. Ascribed status involves the diverse characteristics of an individual, including their ethnic and cultural background, race, age, and gender. In the study of international business, the ascribed status may be a very important component that could affect the firms' innovation and, maybe particularly crucial when the firms hire engineers from other countries. The future study can consider ascribed status in learning by hiring study into account.

List of References

Agrawal, A., McHale, J., & Oettl, A. (2017). How stars matter: Recruiting and peer effects in evolutionary biology. *Research Policy*, 46(4), 853-867.

Alkire, A. A., Collum, M. E., & Kaswan, J. (1968). Information exchange and accuracy of verbal communication under social power conditions. *Journal of Personality and Social Psychology*, 9(4), 301.

Allison, P. D., & Long, J. S. (1990). Departmental effects on scientific productivity. *American Sociological Review*, 469-478.

Almeida, P., & Kogut, B. (1999). Localization of knowledge and the mobility of engineers in regional networks. *Management Science*, 45(7), 905-917.

Ancona, D. G., & Caldwell, D. F. (1992). Demography and design: Predictors of new product team performance. *Organization Science*, 3(3), 321-341.

Argote, L., Ingram, P., Levine, J. M., & Moreland, R. L. (2000). Knowledge transfer in organizations: Learning from the experience of others. *Organizational Behavior and Human Decision Processes*, 82(1), 1-8.

Armat, M. R., Assarroudi, A., Rad, M., Sharifi, H., & Heydari, A. (2018). Inductive and deductive: Ambiguous labels in qualitative content analysis. *The Qualitative Report*, 23(1), 219-221.

Athreye, S., & Godley, A. (2009). Internationalization and technological leapfrogging in the pharmaceutical industry. *Industrial and Corporate Change*, 18(2), 295-323.

Atuahene-Gima, K. (2003). The effects of centrifugal and centripetal forces on product development speed and quality: How does problem solving matter?. *Academy of Management Journal*, 46(3), 359-373.

Audia, P. G., & Goncalo, J. A. (2007). Past success and creativity over time: A study of inventors in the hard disk drive industry. *Management Science*, 53(1), 1-15.

Azoulay, P., Graff Zivin, J. S., & Wang, J. (2010). Superstar extinction. *The Quarterly Journal of Economics*, 125(2), 549-589.

Azungah, T. (2018). Qualitative research: deductive and inductive approaches to data analysis. *Qualitative Research Journal*.

Baer, M., & Frese, M. (2003). Innovation is not enough: Climates for initiative and psychological safety, process innovations, and firm performance. *Journal of Organizational Behavior: The International Journal of Industrial, Occupational and Organizational Psychology and Behavior*, 24(1), 45-68.

Bantel, K. A., & Jackson, S. E. (1989). Top management and innovations in banking: Does the composition of the top team make a difference?. *Strategic Management Journal*, 10(S1), 107-124.

Benner, M. J., & Tushman, M. L. (2003). Exploitation, exploration, and process management: The productivity dilemma revisited. *Academy of Management Review*, 28(2), 238-256.

Benner, M., & Waldfogel, J. (2008). Close to you? Bias and precision in patent-based measures of technological proximity. *Research Policy*, 37(9), 1556-1567.

Bierly III, P. E., Damanpour, F., & Santoro, M. D. (2009). The application of external knowledge: organizational conditions for exploration and exploitation. *Journal of Management Studies*, 46(3), 481-509.

Bitektine, A. (2008). Prospective case study design: qualitative method for deductive theory testing. *Organizational Research Methods*, 11(1), 160-180.

Blau, P. M. (1970). A formal theory of differentiation in organizations. *American Sociological Review*, 201-218.

Bown, C. P. (2020). How the United States marched the semiconductor industry into its trade war with China. *East Asian Economic Review*, 24(4), 349-388.

Bradley, E. H., Curry, L. A., & Devers, K. J. (2007). Qualitative data analysis for health services research: developing taxonomy, themes, and theory. *Health Services Research*, 42(4), 1758-1772.

Braunerhjelm, P., Ding, D., & Thulin, P. (2017). Labour Mobility, Knowledge Flows and Innovation". Working Paper 54, Swedish Entrepreneurship Forum, Stockholm.

Braunerhjelm, P., Ding, D., & Thulin, P. (2020). Labour market mobility, knowledge diffusion and innovation. *European Economic Review*, *123*, 103386.

Breschi, S., Malerba, F., & Orsenigo, L. (2000). Technological regimes and Schumpeterian patterns of innovation. *The Economic Journal*, 110(463), 388-410.

Broekel, T., & Boschma, R. (2012). Knowledge networks in the Dutch aviation industry: the proximity paradox. *Journal of Economic Geography*, 12(2), 409-433.

Brooks, A. K. (1994). Power and the production of knowledge: Collective team learning in work organizations. *Human Resource Development Quarterly*, 5(3), 213-235.

Brown, C., Linden, G., & Macher, J. T. (2005). Offshoring in the semiconductor industry: A historical perspective [with comment and discussion]. *Brookings trade forum*. Brookings Institution Press. 279-333

Buckley, P. J., Chapman, M., Clegg, J., & Gajewska-De Mattos, H. (2014). A linguistic and philosophical analysis of emic and etic and their use in international business research. *Management International Review*, 54(3), 307-324.

Bunderson, J. S., & Boumgarden, P. (2010). Structure and learning in self-managed teams: Why “bureaucratic” teams can be better learners. *Organization Science*, 21(3), 609-624.

Bunderson, J. S., & Reagans, R. E. (2011). Power, status, and learning in organizations. *Organization Science*, 22(5), 1182-1194.

Byrne, D. E. (1971). *The attraction paradigm* (Vol. 462). Academic Press.

Cantner, U., & Meder, A. (2007). Technological proximity and the choice of cooperation partner. *Journal of Economic Interaction and Coordination*, 2(1), 45-65.

Chen, D.C., & Toyama, R. (2006). Catch up of semiconductor latecomers in China. *International Journal of Emerging Markets*.

Chen, J., & Qu, W. G. (2003). A new technological learning in China. *Technovation*, 23(11), 861-867.

Chen, L., & Xue, L. (2010). Global production network and the upgrading of China's integrated Circuit Industry. *China & World Economy*, 18(6), 109-126.

Chou, T. L., Chang, J. Y., & Li, T. C. (2014). Government support, FDI clustering and semiconductor sustainability in china: Case studies of Shanghai, Suzhou and Wuxi in the Yangtze delta. *Sustainability*, 6(9), 5655-5681.

Cohen, W. M., & Levinthal, D. A. (1990). Absorptive capacity: A new perspective on learning and innovation. *Administrative Science Quarterly*, 128-152.

Conner, K. R., & Prahalad, C. K. (1996). A resource-based theory of the firm: Knowledge versus opportunism. *Organization Science*, 7(5), 477-501.

Contu, A., & Willmott, H. (2003). Re-embedding situatedness: The importance of power relations in learning theory. *Organization Science*, 14(3), 283-296.

Corbin, J. M., & Strauss, A. (1990). Grounded theory research: Procedures, canons, and evaluative criteria. *Qualitative Sociology*, 13(1), 3-21.

Cox, T. H., & Blake, S. (1991). Managing cultural diversity: Implications for organizational competitiveness. *Academy of Management Perspectives*, 5(3), 45-56.

Creswell, J. W. (1998). Choosing among five traditions. *Qualitative inquiry and research design*.

Dahlin, K. B., Weingart, L. R., & Hinds, P. J. (2005). Team diversity and information use. *Academy of Management Journal*, *4*8(6), 1107-1123.

De Brabander, B., & Thiers, G. (1984). Successful information system development in relation to situational factors which affect effective communication between MIS-users and EDP-specialists. *Management Science*, 30(2), 137-155.

De Dreu, C. K., Nijstad, B. A., Bechtoldt, M. N., & Baas, M. (2011). Group creativity and innovation: A motivated information processing perspective. *Psychology of Aesthetics, Creativity, and the Arts*, 5(1), 81.

De Massis, A., & Kotlar, J. (2014). The case study method in family business research: Guidelines for qualitative scholarship. *Journal of Family Business Strategy*, 5(1), 15-29.

Doz, Y. (2011). Qualitative research for international business. *Journal of International Business Studies*, 42(5), 582-590.

Easterby-Smith, M., Graca, M., Antonacopoulou, E., & Ferdinand, J. (2008). Absorptive capacity: A process perspective. *Management Learning*, 39(5), 483-501.

Edmondson, A. (1999). Psychological safety and learning behavior in work teams. *Administrative science quarterly*, 44(2), 350-383.

Edmondson, A. C. (2002). The local and variegated nature of learning in organizations: A group-level perspective. *Organization Science*, 13(2), 128-146.

Edmondson, A. C. (2003). Speaking up in the operating room: How team leaders promote learning in interdisciplinary action teams. *Journal of Management Studies*, 40(6), 1419-1452.

Edmondson, A. C., Kramer, R. M., & Cook, K. S. (2004). Psychological safety, trust, and learning in organizations: A group-level lens. *Trust and distrust in organizations: Dilemmas and approaches*, 12, 239-272.

Edmondson, A. C., & McManus, S. E. (2007). Methodological fit in management field research. *Academy of Management Review*, 32(4), 1246-1264.

Egelhoff, W. G. (1991). Information-processing theory and the multinational enterprise. *Journal of International Business Studies*, 22(3), 341-368.

Elliott, R., & Timulak, L. (2005). Descriptive and interpretive approaches to qualitative research. *A Handbook of Research Methods for Clinical and Health Psychology*, 1(7), 147-159.

Erlingsson, C., & Brysiewicz, P. (2013). Orientation among multiple truths: An introduction to qualitative research. *African Journal of Emergency Medicine*, 3(2), 92-99.

Evered, R., & Louis, M. R. (1981). Alternative perspectives in the organizational sciences: “inquiry from the inside” and “inquiry from the outside”. *Academy of Management Review*, 6(3), 385-395.

Fallah, M. H., & Ibrahim, S. (2004, April). Knowledge spillover and innovation in technological clusters. In *Proceedings, IAMOT 2004 Conference, Washington, DC*, 1-16.

Fan, P. (2006). Catching up through developing innovation capability: evidence from China's telecom-equipment industry. *Technovation*, 26(3), 359-368.

Filatotchev, I., Liu, X., Lu, J., & Wright, M. (2011). Knowledge spillovers through human mobility across national borders: Evidence from Zhongguancun Science Park in China. *Research Policy*, 40(3), 453-462.

Fleming, L. (2001). Recombinant uncertainty in technological search. *Management Science*, 47(1), 117-132.

Fragale, A. R., Rosen, B., Xu, C., & Merideth, I. (2009). The higher they are, the harder they fall: The effects of wrongdoer status on observer punishment recommendations and intentionality attributions. *Organizational Behavior and Human Decision Processes*, 108(1), 53-65.

Fuller, D. B. (2005a). *Creating ladders out of chains: China's technological development in a world of global production* (Doctoral dissertation, Massachusetts Institute of Technology).

Fuller, D. B. (2005b). The changing limits and the limits of change: the state, private firms, international industry and China in the evolution of Taiwan's electronics industry. *Journal of Contemporary China*, 14(44), 483-506.

Gale, N. K., Heath, G., Cameron, E., Rashid, S., & Redwood, S. (2013). Using the framework method for the analysis of qualitative data in multi-disciplinary health research. *BMC medical research methodology*, 13(1), 1-8.

Galinsky, A. D., Gruenfeld, D. H., & Magee, J. C. (2003). From power to action. *Journal of Personality and Social Psychology*, 85(3), 453.

Garrison, D. R., Cleveland-Innes, M., Koole, M., & Kappelman, J. (2006). Revisiting methodological issues in transcript analysis: Negotiated coding and reliability. *The Internet and Higher Education*, 9(1), 1-8.

Gelo, O., Braakmann, D., & Benetka, G. (2009). Quantitative and qualitative research: Beyond the debate. *Integrative Psychological and Behavioral Science*, 43(4), 406.

Gephart Jr, R. P. (2004). Qualitative research and the Academy of Management Journal.

Glaser, B. G., & Strauss, A. L. (2017). *Discovery of grounded theory: Strategies for qualitative research*. Routledge.

Golden, B. R. (1992). The past is the past—or is it? The use of retrospective accounts as indicators of past strategy. *Academy of Management Journal*, 35(4), 848-860.

Graebner, M. E. (2009). Caveat venditor: Trust asymmetries in acquisitions of entrepreneurial firms. *Academy of Management Journal*, 52(3), 435-472.

Grant, R. M. (1996). Toward a knowledge-based theory of the firm. *Strategic Management Journal*, 17(S2), 109-122.

Grimes, S., & Du, D. (2020). China's emerging role in the global semiconductor value chain. *Telecommunications Policy*, 101959.

Groysberg, B., Lee, L. E., & Nanda, A. (2008). Can they take it with them? The portability of star knowledge workers' performance. *Management Science*, 54(7), 1213-1230.

Groysberg, B., & Lee, L. E. (2009). Hiring stars and their colleagues: Exploration and exploitation in professional service firms. *Organization Science*, 20(4), 740-758.

Groysberg, B., Polzer, J. T., & Elfenbein, H. A. (2011). Too many cooks spoil the broth: How high-status individuals decrease group effectiveness. *Organization Science*, 22(3), 722-737.

Guo, B., & Guo, J. J. (2011). Patterns of technological learning within the knowledge systems of industrial clusters in emerging economies: Evidence from China. *Technovation*, 31(2-3), 87-104.

Hambrick, D. C., Davison, S. C., Snell, S. A., & Snow, C. C. (1998). When groups consist of multiple nationalities: Towards a new understanding of the implications. *Organization Studies*, 19(2), 181-205.

Herring, C. (2009). Does diversity pay?: Race, gender, and the business case for diversity. *American sociological review*, 74(2), 208-224.

Hobday, M. (1995). East Asian latecomer firms: learning the technology of electronics. *World Development*, 23(7), 1171-1193.

Huahong Semiconductor Limited (2019). Annual Report 2019. Available at: media-huahonggrace.todayir.com/20200408121602642992293 55_en.pdf (Accessed 12 May 2020)

Huahong Semiconductor Limited (2018). Annual Report 2018. Available at: media-huahonggrace.todayir.com/20190404122002000334548 91_en.pdf (Accessed 12 May 2020)

Huy, Q. N. (2012). Improving the odds of publishing inductive qualitative research in premier academic journals. *The Journal of Applied Behavioral Science*, 48(2), 282-287.

Hyde, K. F. (2000). Recognising deductive processes in qualitative research. *Qualitative Market Research: An International Journal*.

Inkpen, A. C., & Pien, W. (2006). An examination of collaboration and knowledge transfer: China–Singapore Suzhou Industrial Park. *Journal of Management Studies*, 43(4), 779-811.

Irwin, D. A., & Klenow, P. J. (1994). Learning-by-doing spillovers in the semiconductor industry. *Journal of Political Economy*, 102(6), 1200-1227.

Jain, A. (2016). Learning by hiring and change to organizational knowledge: Countering obsolescence as organizations age. *Strategic Management Journal*, 37(8), 1667-1687.

Jehn, K. A., Northcraft, G. B., & Neale, M. A. (1999). Why differences make a difference: A field study of diversity, conflict and performance in workgroups. *Administrative Science Quarterly*, 44(4), 741-763.

Jensen, M., & Roy, A. (2008). Staging exchange partner choices: When do status and reputation matter?. *Academy of Management Journal*, 51(3), 495-516.

Kaiser, U., Kongsted, H. C., Laursen, K., & Ejsing, A. K. (2018). Experience matters: The role of academic scientist mobility for industrial innovation. *Strategic Management Journal*, 39(7), 1935-1958.

Karamanos, A. G. (2012). Leveraging micro-and macro-structures of embeddedness in alliance networks for exploratory innovation in biotechnology. *R&D Management*, 42(1), 71-89.

Kehoe, R. R., & Tzabbar, D. (2015). Lighting the way or stealing the shine? An examination of the duality in star scientists' effects on firm innovative performance. *Strategic Management Journal*, 36(5), 709-727.

Khan, S. N. (2014). Qualitative research method: Grounded theory. *International Journal of Business and Management*, 9(11), 224-233.

Kim, L. (1997). The dynamics of Samsung's technological learning in semiconductors. *California Management Review*, 39(3), 86-100.

Kim, L. (1998). Crisis construction and organizational learning: Capability building in catching-up at Hyundai Motor. *Organization Science*, 9(4), 506-521.

Knoben, J., & Oerlemans, L. A. (2006). Proximity and inter-organizational collaboration: A literature review. *International Journal of Management Reviews*, 8(2), 71-89.

Kogut, B., & Zander, U. (1992). Knowledge of the firm, combinative capabilities, and the replication of technology. *Organization Science*, 3(3), 383-397.

Kong, X. X., Zhang, M., & Ramu, S. C. (2016). China's semiconductor industry in global value chains. *Asia Pacific Business Review*, 22(1), 150-164.

Kwak, K., & Yoon, H. D. (2020). Unpacking transnational industry legitimacy dynamics, windows of opportunity, and latecomers' catch-up in complex product systems. *Research Policy*, 49(4), 103954.

Lall, S. (1992). Technological capabilities and industrialization. *World Development*, 20(2), 165-186.

Lall, S. (2000). The Technological structure and performance of developing country manufactured exports, 1985-98. *Oxford Development Studies*, 28(3), 337-369.

Lane, P. J., & Lubatkin, M. (1998). Relative absorptive capacity and interorganizational learning. *Strategic Management Journal*, 19(5), 461-477.

Larson Jr, J. R., Foster-Fishman, P. G., & Franz, T. M. (1998). Leadership style and the discussion of shared and unshared information in decision-making groups. *Personality and Social Psychology Bulletin*, 24(5), 482-495.

Lee, J. J., & Yoon, H. (2015). A comparative study of technological learning and organizational capability development in complex products systems: Distinctive paths of three latecomers in military aircraft industry. *Research Policy*, 44(7), 1296-1313.

Lee, K., Cho, S. J., & Jin, J. (2009). Dynamics of catch-up in mobile phones and automobiles in China: Sectoral systems of innovation perspective. *China Economic Journal*, 2(1), 25-53.

Lee, K., Gao, X., & Li, X. (2017). Industrial catch-up in China: a sectoral systems of innovation perspective. *Cambridge Journal of Regions, Economy and Society*, 10(1), 59-76.

Lee, K., & Ki, J. H. (2017). Rise of latecomers and catch-up cycles in the world steel industry. *Research Policy*, 46(2), 365-375.

Lee, K., & Lim, C. (2001). Technological regimes, catching-up and leapfrogging: findings from the Korean industries. *Research Policy*, 30(3), 459-483.

Lee, K., & Malerba, F. (2017). Catch-up cycles and changes in industrial leadership: Windows of opportunity and responses of firms and countries in the evolution of sectoral systems. *Research Policy*, 46(2), 338-351.

Levinthal, D. A., & March, J. G. (1993). The myopia of learning. *Strategic Management Journal*, 14(S2), 95-112.

Lewis, J. A. (2019). Learning the Superior Techniques of the Barbarians.

Li, D., Capone, G., & Malerba, F. (2019). The long march to catch-up: a history-friendly model of China's mobile communications industry. *Research Policy*, 48(3), 649-664.

Li, H., He, H., Shan, J., & Cai, J. (2019). Innovation efficiency of semiconductor industry in China: A new framework based on generalized three-stage DEA analysis. *Socio-Economic Planning Sciences*, 66, 136-148.

Li, Y. (2011). *From Classic Failures to Global Competitors: Business Organization and Economic Development in the Chinese Semiconductor Industry* (Doctoral dissertation, University of Massachusetts at Lowell).

Lin, B. W., Chen, C. J., & Wu, H. L. (2006). Patent portfolio diversity, technology strategy, and firm value. *IEEE Transactions on Engineering Management*, 53(1), 17-26.

Linneberg, M. S., & Korsgaard, S. (2019). Coding qualitative data: A synthesis guiding the novice. *Qualitative research journal*.

Liu, P. Q., Ga, Y. H., & Gu, Q. (2007). Study on the upgrading of China integrated circuit (IC) industry up to the global value chain: a case study. *Management Science and Engineering*, 1(2), 14-21.

Liu, X., Lu, J., Filatotchev, I., Buck, T., & Wright, M. (2010). Returnee entrepreneurs, knowledge spillovers and innovation in high-tech firms in emerging economies. *Journal of International Business Studies*, *41*(7), 1183-1197.

Lynn, F. B., Podolny, J. M., & Tao, L. (2009). A sociological (de) construction of the relationship between status and quality. *American Journal of Sociology*, 115(3), 755-804.

Macher, J. T. (2006). Technological development and the boundaries of the firm: A knowledge-based examination in semiconductor manufacturing. *Management Science*, 52(6), 826-843.

Makri, M., Hitt, M. A., & Lane, P. J. (2010). Complementary technologies, knowledge relatedness, and invention outcomes in high technology mergers and acquisitions. *Strategic Management Journal*, 31(6), 602-628.

Marschan-Piekkari, R., & Reis, C. (2004). Language and languages in cross-cultural interviewing. *Handbook of qualitative research methods for international business*, *1*, 224-244.

Malerba, F. (2002). Sectoral systems of innovation and production. *Research Policy*, 31(2), 247-264.

Malerba, F., & Mani, S. (2009). Sectoral systems of innovation and production in developing countries: an introduction. *Sectoral systems of innovation and production in developing countries: Actors, structure and evolution*, 3-24.

Malerba, F., & Nelson, R. (2011). Learning and catching up in different sectoral systems: evidence from six industries. *Industrial and Corporate Change*, 20(6), 1645-1675.

Marino, M., Parrotta, P., & Pozzoli, D. (2012). Does labor diversity promote entrepreneurship?. *Economics Letters*, 116(1), 15-19.

Mathews, J. A. (2004). Competitiveness, FDI and technological activity in East Asia. *Research Policy*, 33(6-7), 1060-1062.

Mayring, P. (2014). Qualitative content analysis: theoretical foundation, basic procedures and software solution.

Merton, R. K. (1968). The Matthew effect in science: The reward and communication systems of science are considered. *Science*, 159(3810), 56-63.

Michailova, S., Piekkari, R., Plakoyiannaki, E., Ritvala, T., Mihailova, I., & Salmi, A. (2014). Breaking the silence about exiting fieldwork: A relational approach and its implications for theorizing. *Academy of Management Review*, 39(2), 138-161.

Miles, M. B., & Huberman, A. M. (1994). *Qualitative data analysis: An expanded sourcebook*. sage.

Mom, T. (2006). *Managers' exploration and exploitation activities: The influence of organizational factors and knowledge inflows* (No. 79).

Morse, J. M., & Mitcham, C. (2002). Exploring qualitatively-derived concepts: Inductive—deductive pitfalls. *International Journal of Qualitative Methods*, 1(4), 28-35.

Mowery, D. C., Oxley, J. E., & Silverman, B. S. (1998). Technological overlap and interfirm cooperation: implications for the resource-based view of the firm. *Research Policy*, 27(5), 507-523.

Mu, Q., & Lee, K. (2005). Knowledge diffusion, market segmentation and technological catch-up: The case of the telecommunication industry in China. *Research Policy*, 34(6), 759-783.

Nembhard, I. M., & Edmondson, A. C. (2006). Making it safe: The effects of leader inclusiveness and professional status on psychological safety and improvement efforts in health care teams. *Journal of*

Organizational Behavior: The International Journal of Industrial, Occupational and Organizational Psychology and Behavior, 27(7), 941-966.

Nickerson, J. A., & Zenger, T. R. (2004). A knowledge-based theory of the firm—The problem-solving perspective. *Organization Science*, 15(6), 617-632.

Oettl, A. (2012). Reconceptualizing stars: Scientist helpfulness and peer performance. *Management Science,* 58(6), 1122-1140.

Oettl, A., & Agrawal, A. (2008). International labor mobility and knowledge flow externalities. *Journal of International Business Studies*, 39(8), 1242-1260.

Oldroyd, J. B., & Morris, S. S. (2012). Catching falling stars: A human resource response to social capital's detrimental effect of information overload on star employees. *Academy of Management Review*, 37(3), 396-418.

Olson, B. J., Parayitam, S., & Bao, Y. (2007). Strategic decision making: The effects of cognitive diversity, conflict, and trust on decision outcomes. *Journal of Management,* 33(2), 196-222.

Park, K. H., & Lee, K. (2006). Linking the technological regime to the technological catch-up: analyzing Korea and Taiwan using the US patent data. *Industrial and Corporate Change*, 15(4), 715-753.

Parrotta, P., & Pozzoli, D. (2012). The effect of learning by hiring on productivity. *The RAND Journal of Economics*, 43(1), 167-185.

Parrotta, P., Pozzoli, D., & Pytlikova, M. (2014). Labor diversity and firm productivity. *European Economic Review*, 66, 144-179.

Patton, M. Q. (1990). *Qualitative evaluation and research methods*. SAGE Publications, inc.

Patton, M. Q. (2015). Qualitative research & evaluation methods: Integrating theory and practice.

Peeters, T. L., Mills, B. M., Pennings, E., & Sung, H. (2019). Manager migration, learning-by-hiring, and cultural distance in international soccer. *Global Strategy Journal*.

Perez, C & Soete, L. (1988). Catching up in technology: entry barriers and windows of opportunity. *Technical Change and Economic Theory*, 458-479.

Phene, A., Tallman, S., & Almeida, P. (2012). When do acquisitions facilitate technological exploration and exploitation?. *Journal of Management*, 38(3), 753-783.

Platzer, M., Sargent Jr, J. F., & Sutter, K. M. (2020). *Semiconductors : U . S . Industry , Global Competition, and Federal Policy*. Congressional Research Service. CRS Report

Podolny, J. M. (1993). A status-based model of market competition. *American Journal of Sociology*, 98(4), 829-872.

Prato, M., & Ferraro, F. (2018). Starstruck: How hiring high-status employees affects incumbents' performance. *Organization Science*, 29(5), 755-774.

Quintana-García, C., & Benavides-Velasco, C. A. (2008). Innovative competence, exploration and exploitation: The influence of technological diversification. *Research Policy*, 37(3), 492-507.

Rahko, J. (2017). Knowledge spillovers through inventor mobility: the effect on firm-level patenting. *The Journal of Technology Transfer*, 42(3), 585-614.

Rasiah, R., Kong, X., & Lin, Y. (2010). Innovation and learning in the integrated circuits industry in Taiwan and China. *Journal of the Asia Pacific Economy*, 15(3), 225-246.

Reschke, B. P., Azoulay, P., & Stuart, T. E. (2018). Status spillovers: The effect of status-conferring prizes on the allocation of attention. *Administrative Science Quarterly*, 63(4), 819-847.

Rho, S., Lee, K., & Kim, S. H. (2015). Limited catch-up in China's semiconductor industry: A sectoral innovation system perspective. *Millennial Asia*, 6(2), 147-175.

Rosenkopf, L., & Almeida, P. (2003). Overcoming local search through alliances and mobility. *Management Science*, 49(6), 751-766.

Schaefer, K. J. (2020). Catching up by hiring: The case of Huawei. *Journal of International Business Studies*, 1-16.

Schreier, M. (2015). Qualitaive Data Analysis. In Katic Metzier (Ed.), *Sage Publications*

Schulz, M. (2001). The uncertain relevance of newness: Organizational learning and knowledge flows. *Academy of Management Journal*, 44(4), 661-681.

Semiconductor Manufacturing International Corporation. *Annual Report* 2014-2020. Available at: https://www.smics.com/ en/site/company_financialSummary?year=2019#page_slide_1 (Accessed: 22 January 2020).

Shilov, A. (2020). SMIC: Advanced Process Technologies and Gov’t Funding. *EE Times*. Available at: https://www.eetimes.com/smic-advanced-process-technologies-and-govt-funding/# (Accessed 1 January 2021).

Shin, J. S. (2017). Dynamic catch-up strategy, capability expansion and changing windows of opportunity in the memory industry. *Research Policy*, 46(2), 404-416.

Simon, D. F., & Rehn, D. (1987). Innovation in China's semiconductor components industry: The case of Shanghai. *Research Policy*, 16(5), 259-277.

Simonen, J., & McCann, P. (2008). Innovation, R&D cooperation and labor recruitment: Evidence from Finland. *Small Business Economics*, 31(2), 181-194.

Singh, J., & Agrawal, A. (2011). Recruiting for ideas: How firms exploit the prior inventions of new hires. *Management Science*, 57(1), 129-150.

Slavova, K., Fosfuri, A., & De Castro, J. O. (2016). Learning by hiring: The effects of scientists’ inbound mobility on research performance in academia. *Organization Science*, 27(1), 72-89.

Smith-Lovin, L., & McPherson, J. M. (1987). Homophily in voluntary organizations: Status distance and the composition of face-to-face groups. *American Sociological Review*, 370-379.

Song, J., Almeida, P., & Wu, G. (2003). Learning–by–hiring: When is mobility more likely to facilitate interfirm knowledge transfer?. *Management Science*, 49(4), 351-365.

Stahl, G. K., Maznevski, M. L., Voigt, A., & Jonsen, K. (2010). Unraveling the effects of cultural diversity in teams: A meta-analysis of research on multicultural work groups. *Journal of International Business Studies*, 41(4), 690-709.

Storz, C., Riboldazzi, F., & John, M. (2015). Mobility and innovation: A cross-country comparison in the video games industry. *Research Policy*, 44(1), 121-137.

Tajfel, H. (1982). Social psychology of intergroup relations. *Annual Review of Psychology*, 33(1), 1-39.

Taiwan Semiconductor Manufacturing Co Ltd. (2015-2020). Available at:

https://www.tsmc.com/english/aboutTSMC/dc_annual_report (Accessed 12 December 2020).

Teece, D. J. (1982). Towards an economic theory of the multiproduct firm. *Journal of Economic Behavior & Organization*, 3(1), 39-63.

Teece, D. J., Pisano, G., & Shuen, A. (1997). Dynamic capabilities and strategic management. *Strategic Management Journal*, 18(7), 509-533.

Thomas, D. R. (2006). A general inductive approach for analyzing qualitative evaluation data. *American Journal of Evaluation*, 27(2), 237-246.

To, Y. (2021). China chases semiconductor self-sufficiency. *East Asia Forum*

Tsui, A. S., Egan, T. D., & O'Reilly III, C. A. (1992). Being different: Relational demography and organizational attachment. *Administrative Science Quarterly*, 549-579.

Tzabbar, D. (2009). When does scientist recruitment affect technological repositioning?. *Academy of Management Journal*, 52(5), 873-896.

Tzabbar, D., Silverman, B. S., & Aharonson, B. S. (2015). Learning by hiring or hiring to avoid learning?. *Journal of Managerial Psychology*.

Tzabbar, D., & Vestal, A. (2015). Bridging the social chasm in geographically distributed R&D teams: The moderating effects of relational strength and status asymmetry on the novelty of team innovation. *Organization Science*, 26(3), 811-829.

van der Wouden, F., & Rigby, D. L. (2021). Inventor mobility and productivity: a long-run perspective. *Industry and Innovation*, *28*(6), 677-703.

Van Knippenberg, D., & Schippers, M. C. (2007). Work group diversity. *Annu. Rev. Psychol.*, 58, 515-541.

Varas, A., Varadarajan, R., Goodrich, J., & Yinug, F. (2020). Government Incentives and US Competitiveness in Semiconductor Manufacturing. *BCG Global.*

VerWey, J. (2019). Chinese semiconductor industrial policy: Past and present. *Journal of International Commerce and Economics*, 01

Wagner, W. G., Pfeffer, J., & O'Reilly III, C. A. (1984). Organizational demography and turnover in top-management group. *Administrative Science Quarterly*, 74-92.

West, J. (2000). Institutions, information processing, and organization structure in research and development: evidence from the semiconductor industry. *Research Policy*, 29(3), 349-373.

Williams, C. (2007). Research methods. *Journal of Business & Economics Research (JBER)*, 5(3).

Williams, K. Y., & Charles, A. O. (1998). 'Reilly. 1998. Demography and diversity in organizations: A review of 40 years of research. *Research in Organizational Behavior*, 20(20), 77-140.

Winter, S. G. (1984). Schumpeterian competition in alternative technological regimes. *Journal of Economic Behavior & Organization*, 5(3-4), 287-320.

Xie, W. (2004). Technological learning in China's colour TV (CTV) industry. *Technovation*, 24(6), 499-512.

Wright, L. L. (1996). Qualitative international management research. *Handbook for international management research*, *63*:81.

Yauch, C. A., & Steudel, H. J. (2003). Complementary use of qualitative and quantitative cultural assessment methods. *Organizational Research Methods*, 6(4), 465-481.

Yinug, F. (2009). Challenges to foreign investment in high-tech semiconductor production in China. *J. Int'l Com. & Econ.*, 2, 97.

Yu, J., Malerba, F., Adams, P., & Zhang, Y. (2017). Related yet diverging sectoral systems: telecommunications equipment and semiconductors in China. *Industry and Innovation*, 24(2), 190-212.

Zhang, Y., Yu, J., Chen, R., & Liu, Y. (2013). Evolutionary dynamics of high technology industry: modeling of semiconductor sector in China. *Chinese Management Studies*. 7(2), 194-214.

Zhang, Z. (2020). China's Incentives for Integrated Circuit, Software Enterprises. China Briefing.

Available at: https://www.china-briefing.com/news/china-integrated-circuit-software-enterprises-tax-incentives/ (Accessed: 21 January 2020).

Zhou, K. Z., & Li, C. B. (2012). How knowledge affects radical innovation: Knowledge base, market knowledge acquisition, and internal knowledge sharing. *Strategic Management Journal*, 33(9), 1090-1102.

Zucker, L. G., & Darby, M. R. (2006). *Movement of star scientists and engineers and high-tech firm entry* (No. w12172). National Bureau of Economic Research.

Zucker, L. G., & Darby, M. R. (1997). Present at the biotechnological revolution: transformation of technological identity for a large incumbent pharmaceutical firm. *Research Policy*, 26(4-5), 429-446.

List of Abbreviations

APT	Assembly, Testing and Packaging
CDMA	Code-division multiple access
CMOS	Complementary metal-oxide-semiconductor
COCOM	Coordinating Committee for Multilateral Export Control
CSET	Centre for Security and Emerging Technology
EDA	Electronic design automation
EUV	Extreme ultraviolet lithography
DRAM	Dynamic Random-Access Memory
IBM	International Business Machines Corporation
IC	Integrated Circuit
IDM	Integrated device manufacturer
IMEC	Interuniversity Microelectronics Centre
IP	Intellectual Property
IPC	International Patent Classification
IPR	Intellectual Property Rights

JV	Joint venture
M&A	Mergers and Acquisitions
NIE	Newly Industrialised Economies
OECD	Organisation for Economic Co-operation and Development
OEM	Original equipment manufacturer
RAM	Random-Access Memory
R&D	Research and development
SIA	Semiconductor Industry Association
SMIC	Semiconductor Manufacturing International Corporation
SEMI	Semiconductor Equipment and Materials International
TSMC	Taiwan Semiconductor Manufacturing Company
UMC	United Microelectronics Corporation
USPTO	The United States Patent and Trademark Office
VLSI	Very Large Scale Integration
WSTS	World Semiconductor Trade Statistic

Appendix A: History of the Chinese semiconductor industry

1950s	1960s	1970s	1980s
Beginning from semi materials, research semi device with self-reliance	IC initial development stage[20]		
			Until 80, the autonomous development of semi tech for military use[21]
1956: Listed semiconductor technology as one of the four national emergency measures.	The Chinese Academy of Science established the semiconductor research Institute in Beijing and Hebei Semiconductor Research Institute	Yongchuan Semi Research Institute (No, 24), the No 14 plant and Beijing 878 Factory successively developed NMOS circuits, later developed into a CMOS circuit	1982: China 1st time has introduced IC technology from abroad[22]. 1983: Shanghai formed JVs with Belgium's ITT and the Netherland's Philips, establishing Shanghai Bell[23].
The Institute of Applied Physics of the Chinese Academy of Sciences initially held a short-term training course on semiconductor devices.	1962: Tianjin produced a Gallium arsenide single crystal (GaAs), which laid for the development of another compound semi.	1972: China's 1st PMOS-type LSI circuit was developed.	1988: Based on the Shanghai Component 5 plant, Shangwu No.7 Plant and No.19 plant jointly engaged in tech project, the company established a Sino-foreign JV

[20] Developing its 1st semi in 1956 and its 1st IC in 1964, which R&D undertook by state labs and IC manufacturing by state-owned factories (Li,2016)

[21] Manufacturer of computing and consumer-electronics products

[22] The IC production line of Jiangnan Radio Equipment Factory (742) in Wuxi, Jiangsu was completed and put into production. This was a comprehensive production line of colour and black and white TV IC from Toshiba Corporation of Japan. It does not mean only possess packaging manufacturing but also possess 3-inch new process equipment. Not only introduce hardware such as equipment and purification plants and power equipment, but also manufacturing process technology software

[23] Its chip fabrication arm was later spun-off as Shanghai Belling in 1988 and Shanghai Philips in 1989 (later renamed to ASMC with a change in foreign partners)

	China developed the silicon epitaxial process and began photolithography.		company – Shanghai Philips Semiconductor[24]. 1988: Tsinghua Unigroup was found
	1963: The semi Research Institute of Hebei developed Silicon Planar Transistors	1973: 7 Institutes imported equipment from abroad, to build seven 3-inch process lines.	1989: 742 Factory and Yongchuan Semi Research Institute Wuxi Branch merged to form China Huajing Electronics Group Co., Ltd.
	1964: SRI of Hebei developed a silicon epitaxial planar transistor 1964: The Institute of Semiconductors under the Chinese Academy of Sciences developed China's 1st IC.	1976: The Institute of Computing Technology of the Chinese Academy of Sciences developed 10 million large-scale electronic computers. The circuit used was an ECL type(Emitter-coupled logic) circuit developed by the 109 the factory of the Chinese Academy of Sciences (now the Microelectronics Centre of Chinese Academy of Science)	
	1968: The State-owned 1st Optoelectronics Factory (878) and Shanghai Radio 19 Plant were established and completed and put into		

[24] Advanced Semiconductor Manufacturing Corporation Limited (ASMC) was initially incorporated as Shanghai Philips Semiconductor, renamed in as ASMC in 1995

	operation in 1970, forming the IC industry. The Shanghai Radio 14factory developed PMOS (P-type Metal-Oxide Semi) circuit (MOSIC).		
1990s	2000s	2010s	
Back-end process (assembly & test) by foreign investment	High value-added design[25]	Advanced fabrication	
1993: NEC and Shougang found Shougang NEC Electronics Co. Ltd. Manufactures semiconductor IC[26].	2000: SMIC was found by Taiwanese expatriate	2010: Intel opened the 1st China Dalian Chip fab – Fab 68, process technology 65nm, wafer 300mm	
	2003: IC design firm Hangzhou Silan became a listed company.	2014: Samsung found memory fabrication (NAND flash memory chip), abased of process technology node somewhere between 10 and 19nm.	

[25] The growth of IC design, the drop of packing and testing

[26] First wafer fabrication plant in China

	2003: Motorola Inc. sold the fab in China to SMIC[27].		
1993: 1st 256 K DRAM (Huajing dianzi)	2005: R&D facility set up in Shanghai 2005: Intel opened its assembly and testing facility.	2016: TSMC[28] established in Nanjing, (12-inch wafer) process technology node in 16nm. 2016: Chang Jiang memory (3D NAND), Jinhua liandian (DRAM), Zouyi Chuang Xin Hebei (DRAM). 2016: Innotron[29] (manufacture) JHICC[30] (manufacture)TMTC (IDM)[31] and XMC[32] were found.	

[27] Motorola China Electronics Ltd. Has signed an agreement to sell its MOS-17chip fabrication plant in the north-eastern Chinese city of Tianjin to SMIC (Infoworld, 2003)

[28] Taiwan foundry

[29] Innotron has been focusing on mobile DRAM, a key product of major foreign memory makers

[30] Fujian Jinhua Integrated Circuit Co., Ltd, IC manufacturing enterprise

[31] Yangtze Memory Technologies Co., Ltd, an IDM memory solutions company (company website), a subsidiary of Tsinghua Unigroup

[32] 300mm foundry service

1996: Intel manufacturing facility in Shanghai(test, package and assembly)[33].		2017: YMCT successfully designed and manufactured the first 3D NAND flash chip in China.	
1997: Shanghai Huahong and Japanese NEC JV Shanghai Huahong NEC Electronics (2nd wafer).		2018: JHICC partnered with Taiwan-based UMC to develop its 22nm DRAM manufacturing tech.	
1998: Beijing Huahong NEC IC Design Co., Ltd was established[34]. 1998: The production line of Japan's Fujitsu equipment and technology were introduced by Huayue IC[35]. 1998: China's 1st CMOS micro-colour camera chip was successfully designed and developed[36]			

[33] Intel began to build wholly-owned chip test and packaging plants in coastal area, mainly for assembling its Pentium microprocessors, Intel did not enter chip fabrication activities until 2010.

[34] The newly established JV Company has a design capability of annual about 200 IC typrs, and Huahong NEC production line provides processing orders for20, 000 pieces of 8-inch silicon wafers per year.

[35] The production line is based on bipolar process technology, taking into account Bi-CMOS technology, 2 micron technology level, and investing 5-inches of silicon per year. It has a production capacity of 150,000 pieces and an annual production line and power matching system with an annual output of 100million IC chips.

[36] by Xi'an Jiaotong Uni Kaiyuan Group Microelectronics Technology Co., Ltd.,

1999: Shanghai Huahong NEC Electronics Co., Ltd. Built a test film, and the process tech grade was upgraded from 0.5 micron to 0.35 micron, and the leading product 64M synchronous dynamic memory(S-DRAM)[37]			

[37] The construction of this production line marks the beginning of China's own deep sub-micron ultra-large scale IC chip

Appendix B: Participant Consent Form

Consent to take part in **[Technological learning by hiring in China's high-tech industry]**	Add your initials next to the statement if you agree
I confirm that I have read and understand the information sheet/ letter explaining the above research project and I have had the opportunity to ask questions about the project.	
I agree to take part in the project. Taking part in the project will include being interviewed at a mutually convenient time up until 1 December 2019.	
I understand that my participation is voluntary and that I am free to withdraw at any time by email without giving any reason and without there being any negative consequences. If I choose to withdraw, all data related to me will be disposed of. Contacts: Min gyeong Jeon PhD, International Business Division, Faculty of Business, University of Leeds Tel:(UK)+44 7873 981890 Email: ml11mj@leeds.ac.uk Research Supervisors: Prof. Wei Email: y.wei@leeds.ac.uk Dr. Blackburne Email: g.d.blackburne@leeds.ac.uk Dr. Yoon Email: h.yoon@leeds.ac.uk	
I understand that the latest I can withdraw from this research project is the 1st of February 2019. After the 1st of February 2019, it will not be possible to withdraw.	
I give permission for members of the research team to have access to my anonymised responses. I understand that my name will not be linked with the research materials, and I will not be identified or identifiable in the report or reports that result from the research. I understand that my responses will be kept strictly confidential.	
I understand my personal details such as phone number and address will not be revealed to people outside the project.	
I understand that my words may be quoted anonymously in thesis/dissertation, publications, reports and other research outputs.	

Name of participant	

Participant’s signature	
Date	
Name of lead researcher	Min gyeong Jeon
Signature	
Date*	09/07/2018

*To be signed and dated in the presence of the participant.

Once this has been signed by all parties the participant should receive a copy of the signed and dated participant consent form, the letter/ pre-written script/ information sheet and any other written information provided to the participants. A copy of the signed and dated consent form should be kept with the project’s main documents which must be kept in a secure location.

Appendix C: Information Sheet

INFORMATION SHEET

Research Title

<u>Technological learning by hiring in China's high-tech industry</u>

Invitation

You are being invited to take part in a research study entitled **'Learning by hiring in China's high-tech industry.** Please take time to read the following information carefully and please do not hesitate to ask me for clarifications or more information.

What is the purpose of the project?

I am working on this research project as part of my PhD study in the School of Business at the University of Leeds, UK. This study aims to investigate learning and knowledge acquisition through hiring foreign highly skilled individuals in China's high-tech industry. It will do so by examining the process of learning and the knowledge that is learnt through hiring. My project supervisors are Prof. Yingqi Wei, Dr. Giles Blackburne and Dr. Hyungseok Yoon. The project has been approved by the University of Leeds Research Ethics Committee (reference number:).

What will happen?

You will be interviewed by me in a one-on-one or one-on-group setting at your office or an agreed upon location of your convenience. You will be asked a series of questions, in English or Chinese, and your response will be recorded for use in my research. I may ask you to provide information, recount events, describe your experiences and understanding about issues related to learning by hiring, and more. The interview should take around 60-90 minutes. With your permission, the interview will be recorded in digital audio and subsequently transcribed. Once the transcript is finished, the voice recording will be disposed of.

What are my rights?

You can refuse to participate. You have the right to omit or refuse to answer or respond to any question that I may ask. You will be given the right to withdraw any point up to 31 October 2018. You also have the right to ask that any data you have supplied to me during the interview be withdrawn or destroyed. If you wish to withdraw from this study, please kindly let me know by phone or email at any time. My contact details are

Min-gyeong Jeon

PhD Candidate

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Will my taking part in this project by kept confidential?

Participants will remain anonymous unless they explicitly wish to be named in the research. If you prefer anonymity, the data will contain no personal information. With your permission, I may include information on your occupation but this requires your explicit approval and the interview does not depend on it. The data collected during this study may be used in presentation at conferences or in publications. However, all anonymity will be preserved.

Who do I contact for further information?

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Appendix D: Interview Protocols

Managers
Q.1. What in your view, is the most important technology (knowledge) required in the semiconductor sector in China? (sector of industry from design, fabrication to assembly and package)
Q.2. What technology (knowledge) is required to catch up with world leaders for Chinese semiconductor firms?
Q.3. The following strategies can all be used for knowledge acquisition from leading firms, but could you please rank in order in terms of their importance? 1) R&D cooperation 2) Mergers & Acquisition 3) Licensing 4) Direct hiring experts (can you explain the reason)
Q.4. In your view, how acquiring knowledge through hiring experts is different from other strategies?
Q.5. In your view, do your company use hiring to acquire core knowledge?
Q.6. How do you know that acquiring external knowledge through hiring is valuable to the firm?
Q.7. Can firms better understand/assimilate knowledge acquired through hiring? Why
Q.8. What can a firm do to utilise acquired knowledge through hiring?
Q.9. How long they have been in the firm? (basic characteristics)
Q.10. Is there any type of specific firms targeting? What kind of firm are they?
Q.11. What role are they mainly given in the firm? (the position) (And describe what the main works 【responsibilities】they are given)?
Q.12. Is there a policy to integrate hired experts into firm （with other workers）?
EX) Weekly meeting,
Q.13. In terms of their main knowledge area, are they more likely to re-do (repeat) what they did in their previous firm, or more likely to develop new technology which they might have never done before?
Q.14. What in your view, have been the major influence of your firm's technological capability brought by experienced individuals? How?
Q.15. Other influences?
Q.16. In your view, how do hired experts to influence other employees (technician, engineers) in terms of their technology capability?
Q.17. How does firm measure whether they (novice workers) learned from hired experts?
Q.18. Long-term and short-term outcomes?
Q.19. What are the main barriers faced to induce these experts from leading firms (both inside and outside of China) to your firm?
Q.20. What are the main barriers faced by hired experts (foreign experts) in your firm?

Q.21. What in your view, is the main barrier or challenge that affect the work between hired experts and team members?

Hired experts
Q.1. Can you tell me about your background including your country of origin, nationality, working experience, etc. ?
Q.2. What was your last position in your previous firm?
Q.3. What made you want to leave your last job from a previous firm?
Q.4. What was your main role (position, working domain) when you were hired?
Q.5. What is your main role (Position, working domain) now? Can you explain all of them?
Q.6. In your view, how is your main role in the current firm different compare to your previous firm?
Q.7. What is your main expertise in terms of knowledge area?
Q.8. In your view, in your current firm do you feel you are more likely to do projects you are specialised in or projects which are not your specialised knowledge domain?
Q.9. In your view, in terms of your main knowledge area, do you find you are more likely to re-use (repeat) what you did in the previous firm, or more likely to develop (upgrade) new knowledge?
Q.10. Could you please explain what major influence you brought to your firm's technology capability (based on the main project you are working on)?
Q.11. Could you please explain how you influenced your team colleague's technology capability?
Q.12. In your view, do you think they learn your technology (knowledge) capability?
Q.13. What are the main challenges working in China? (Family, Language, Culture)
Q.14. What are the major challenges working in the current firm, working with local people?
Q.15. Do you think LBH is effective for the firm?

Incumbent (novice) work with hired engineers			
Age	**Qualification(experience)**	**education background**	**position**
Q.1. Can you explain how long you have been working in current firm?			
Q.2. Do you work with an experienced individual who is hired from another leading firm?			
Q.3. Can you describe how you work together with them?			
Q.4. What type of technologies that have you learnt?			
Q.5. How do you find you learnt their knowledge, how does it different before working with them and after working with them?			
Q.6. What in your view, is the main barrier or challenge working with hired experts (e.g. team leader)?			
Q.7. What if there are foreigners?			

Appendix E: Sample Interviews

1. Interview A

The interview questions were structured beginning with background, position, past experience. Some information that may reveal the identity of interviewees is excluded.

The researcher: What in your view, is the most important technology (knowledge) required in the semiconductor sector in China? (sector of industry from design, fabrication to assembly and package)?

Interviewee A: Design, fabrication, assembly are all important, but assembly doesn't require high technology, design can rapidly reach a certain level of development, fabrication is having restrictions, in order to develop fab part it requires a good environment. In order to be self-sufficient in semi-conductor fabrication is really important. Develop fabrication can booths semi-conductor industry as a whole. Fab requires high demand for knowledge, and investment can be risky.

The researcher: What technology (knowledge) is required to catch up with world leaders for Chinese semiconductor firms?

Interviewee A: In terms of the technological gap, fabrication is the widest. The process gets smaller and smaller, in the semiconductor industry there is Moore's Law, we manufacture chips, every 18 months we have to upgrade once. For instance, like 28, 14, 10, 7 nanometres, shrinking the size. This is how technological leaders follow the theory, if you do not follow this theory then you cannot be considered a leader…. But realistically, fabrication technology is different from design technology. The advanced process requires high costs and experienced talents. Firms when entering new generation technology, they have to have accumulated technology, engineers must have the experience, and able to redo the new generation technology from the beginning, leading firms they have the experience to develop 14 nm so they can develop 10 nm in around two years, but Foundry A may need 5 years to develop same technology.

It is also related to the firm's system. Making a chip is a very delicate process, and it requires accumulated experience, firms hire engineers who have experience in 14 nanometres, but the firm has no experience so when the firm has to newly start when they develop 10 nanometres. The firm's system, experience, and accumulated technology determine whether the firm can rapidly develop new technology. for design firms, they already reached certain development and it is easy to cultivate talents, but fabrication technology requires development step by step, requires time to accumulate technology.

The researcher: The following strategies can all be used for knowledge acquisition from leading firms, but could you please rank in order in terms of their importance? 1) R&D cooperation 2) Mergers &

Acquisition 3) Licensing 4) Direct hiring experts from other firms. (can you explain the reason). In your view, how acquiring knowledge through hiring experts is different from other strategies?

Interviewee A: Hiring is more efficient. It is less restricted and easy to hire but it also consumes time to use their knowledge. For licensing the assimilation is difficult, we used to buy a license from the global leader (A firm) but did not know and completely assimilate how to use it, so in this case, the money is wasted. Firms can only tell you how to produce but do not tell you why it is made that way. In the case of R&D cooperation with other firms consume too much time, and it might not have output because it might only be the research. Merge and acquire other firms may help the firm to acquire knowledge in a short time but it has environmental restrictions like the US's restriction to Chinese M&A. M&A is not easy. In terms of the value of the knowledge, R&D cooperation, the firms can know the process because you are doing the whole process together. Hiring is used to develop that technology so he knows how to do it, he might not be able to explain why certain technology is developed this way. M&A might not be able to provide the firm with advanced technology, M&A is more like that your firm advertises that you are doing this business, in terms of licensing, you do not know how to do it, you will know what technology is, but you do not know how to do it. Our firm used to do all of them, but hiring is the viable approach.

The researcher: In your view, do your company use hiring to acquire core knowledge?

Interviewee A: ----------------------

The researcher: How do you know that acquiring external knowledge through hiring is valuable to the firm?

Interviewee A: The knowledge is in their head, they have experience, they know how to do it, has experience in logic so firms are aware of their value…

For us, to catch up with A leader, the importance of hiring experienced individual account for 60% of 100%. This sector requires accumulated technology, if a firm can cultivate internal talents, of course, it is the best, ad it is the best way for a firm's long term development. As China's semiconductor industry is currently booming, hiring experienced engineers is definitely the most important way. Let the firm survive and establish its own technological foundation is the priority for now. Our company recruits a lot of experienced individuals, at present, using recruiting an experienced individual to catch up with international leading enterprise accounts 60%.

The researcher: What can a firm do to utilise acquired knowledge through hiring?

Interviewee A: Firms hire for a reason, he will do the technological task he has done before, otherwise, he will train other engineers, and he may continue to develop the next generation technology. Generally speaking, the purpose of hiring is to absorb advanced technology so let him do the technological task he has done before, and then develop the next generation. But if he cannot develop the next generation, he will train other engineers if he has value… transferring their knowledge to other engineers so that more engineers can do the same technology… Within the firm, hired engineers are often to be rotated, so the standard operating procedure (SOP) has to be made as a recipe when one goes from A team to B team, he has to bring SOP together. The technology has to be shared between teams, the firm will make hired engineers sufficiently share their knowledge, I have four teams under me, for example, A team make the most advanced technology, the hired engineer from A team will be sent to the B team to setup technology, share their knowledge, so more teams can conduct same technology.

The researcher: Can firms better understand/assimilate knowledge acquired through hiring? Why

Interviewee A: In terms of hiring, that person knows how to do it, the methods of technology so it is relatively easy assimilation and use.

The researcher: In terms of their main knowledge area, are they more likely to re-do (repeat) what they did in their previous firm, or more likely to develop new technology which they might have never done before?

Interviewee A: He will be asked to do what he did before and then develop new technology, but if he is not able to develop new technology then he will be asked to do something else…For us, develop a new product and process means the product and process are not available and new for the firm. We will hire to develop new technology, open new business, we tend to hire engineers who can make a more delicious cake, as we are not a leader.

The researcher: How long they have been in the firm? (basic characteristics)

Interviewee A: That depends on the person, everyone is different, and depend on how much they are needed for the firm.

The researcher: Is there any type of specific firms targeting? What kind of firm are they?

Interviewee A: Hire from global leaders. we tend to hire from abroad, within China we will be the best, but not in the world. We cannot find engineers who can improve the firm's technology within China. The global leaders within China, will not bring the most advanced technology to China but remain it in their home country. So we tend to hire from abroad.

The researcher: What role are they mainly given in the firm? (the position) (And describe what the main works【responsibilities】they are given)?

Interviewee A: If he has state-of-the-art knowledge, we will hire them to be a project manager or leader. Their salary and position will be higher and have 10 to 15 years of experience.

The researcher: Is there a policy to integrate hired experts into firm（with other workers）?

Interviewee A: For newcomers, there is a course (inform them what to do, rules, and educate them), top management meeting, participate internal meetings, but for those who are experienced they can choose whether they do it or not.

The researcher: In terms of their main knowledge area, are they more likely to re-do (repeat) what they did in their previous firm, or more likely to develop a new invention which they might have never done before?

Interviewee A: They will do the project related to their knowledge, and then develop new technology, if they are not able to do it they will be asked to do something else. They will do the same technological task as what they did in their previous firms.

The researcher: What in your view, has been the major influence of your firm's technological capability brought by experienced individuals? How?

Interviewee A: Acquiring their knowledge and transferring their experience and logic to other engineers. hired engineers definitely contribute to the firm, in this sector, if hire engineers then it will help to improve the firm’s technology, but hiring talent in management, the answer is not necessarily yes, they may not improve firm’s technology, but it may also cause conflicts, prevent moving forward (development), it has the possibility to go backwards. Hiring is helpful to establish the technology, but develop nest generation process technology may not that helpful. So in long term, cultivating internal engineers can lead the firm to have long term development.

The researcher: In your view, how do hired individuals influence other employees (technician, engineers) in terms of their technology capability?

Interviewee A: Learn specific project they do and after one project has been done means they learnt…

The researcher: How does the firm measure whether they (novice workers) learned from hired experts?

Interviewee A: If they upgrade the module they have given, means they learnt that specific technology

The researcher: What are the main barriers faced to induce these experts from leading firms (both inside and outside of China) to your firm?

Interviewee A: A non-compete agreement that engineers are not allowed to work for competitor firms.

The researcher: What are the main barriers faced by hired experts (foreign experts) in your firm?

Interviewee A: There is no language barrier, as technical terms are English so no communication barrier, of course, there is a personal problem.

(Continue…)

2. Interview B

The researcher: Can you tell me about your background including your country of origin, nationality, working experience, etc.?

Interviewee B: --------------------

The researcher: What was your last position in your previous firm?

Interviewee B: --------------------

The researcher: What made you want to leave your last job from a previous firm?

Interviewee B: --------------------

The researcher: What was your main role (position, working domain) when you were hired?

Interviewee B: --------------------

The researcher: What is your main role (Position, working domain) now? Can you explain all of them?

Interviewee B: --------------------

The researcher: In your view, how is your main role in the current firm different compare to your previous firm?

Interviewee B: When a firm hire engineer there is a political factor, the firm does not want to change the current engineer with a new one. I did my expertise related thing after few years I came here.

Sometimes the firm hires when there is lacking a specific person, so the firm will directly hire that person. Also when the firm has to develop new technology, the firm will hire to fill the position. I used to do A technology before, now also do A technology (this is out of dated technology, it is about a war of time) if they ask me to do a new thing I think I can do it, but they will not give you this opportunity, … it is impossible to be comprehensive. If you are in the field of engineering, you can only improve in this field and solve problems. I do things that I have never done before such as managing cost, calculating production capacity, how many machines should be purchased…, I will have to look for indicators, the cost for the materials of machines, etc. If I don't understand then I will ask, before I didn't understand the operation of the factory because I was in R&D before, but these years I start to know it. At least I have the concept, so I will consider more about cost when I do my own expertise and think of how it affects the cost or not.

The researcher: What is your main expertise in terms of knowledge area?

Interviewee B: --------------------

The researcher: In your view, in your current firm do you feel you are more likely to do projects you are specialised in or projects which are not your specialised knowledge domain?

Interviewee B: ---------------------

The researcher: In your view, in terms of your main knowledge area, do you find you are more likely to re-use (repeat) what you did in the previous firm, or more likely to develop (upgrade) new knowledge?

Interviewee B: I used to do A technology (certain technology) before, now also do A technology, if they ask me to do a new thing I think I can do it, but they will not give you this opportunity, you do not know when, but if I go to the old factory, then I would not worry, but if I am asked to work in a new factory then it will cause the problem. A technology here is new so I will not worry too much.

It is about methodology, the firm can ask me to do new generation but it needs longer than 2 years because I have to learn too. When engineers have experience in this, they will know how to do it, probably they can develop in half-year, it will be faster and less possibility to go winding road, winding road consumes not only time but also money. The firm would not let engineers who used to do A technology do B technology (new technology).

The researcher: Could you please explain what major influence you brought to your firm's technology capability (based on the main project you are working on)?

Interviewee B: It is impossible to be comprehensive. If you are in the field of engineering, you can only improve in this field and solve problems. X(person) knows how to operate, and operate the whole process as a whole, giving him power then he can promote as a whole.

The researcher: Could you please explain how you influenced your team colleague's technology capability?

Interviewee B: Usually juniors will train others, I don't train them directly, but I train seniors

The researcher: In your view, do you think they learn your technology (knowledge) capability?

Interviewee B: --------------------

The researcher: What are the main challenges working in China? (Family, Language, Culture)

Interviewee B: I tell them what to do, does not mean they will do as you supervised, I give them 1,2,3,4,5 thing, but they only do 1,2,3, their learning attitude is not that good. The way how they work is not detail, the self-requirement is not high. They don't care about quality. What they did is different from what I said, sometimes it is the problem of the firm's culture, sometimes is the problem of the person.

The researcher: Is there a policy to integrate hired experts into firm（with other workers）?

Interviewee B: No, the firm would not that much emphasize this thing, the number of engineers (advanced) will be less and less, they are not really outstanding, the firm's operation is ok now, your value is not that big, this means they would not give you more care, the firm now only need engineers with state-of-the-art knowledge. hiring advanced engineers need to be introduced. it is hard to hire from abroad because of the salary, their family and so on, the cost will be really high. So when the firm hires, they will hire really important engineers. the importance of engineers is great in the initial development stage, but it will become less and less important.

(Continue….)

Appendix F: Data analysis table (Technological distance)

Concept	Codes/categories	Condensed meaning unites (close to the text)	Example quotations
Distant knowledge and exploratory innovation	Hire unavailable knowledge and set new team to develop the new technological field	• In charge of the back-end process • Find someone to set up this part themselves	"The part I am in charge of is very special, it is the back-end part. The back-end production process and equipment processing. At the time, it was too expensive to find a factory to do this part for us, so the firm hoped to find someone to set up a team and do this part themselves. So I came here for this reason." (B1)
		• Used to making MP3, and developed technology based on android and now technology relating camera • Increase the engineer and team in making new technology	"We used to make MP3, and then develop technology based on android, and then making technology relating to camera, when changing from music player to camera, increased the number of engineers or management team to make new technology." (H2)
		• Recruit an individual with unavailable knowledge • Start a business	"Our company will recruit an individual who possesses knowledge that is not available in the company and start a business." (A4)
	Hiring engineers whose knowledge is unavailable to develop new technology	• Already done in the previous firm • New for the firm • Hiring to develop new technology • Upgrade this into new technology	"Hired engineers do what they did in their previous firm, but this is new for our firm… when hiring from a leading firm, we mainly focus on exploitation rather than exploration as hired engineers already have done in the previous firm … this is why we use hiring to make us develop new technology and then upgrade this into new technology." (A5)
		• I was developing NROM Memory related elements • The current firm was hiring in similar technology • The firm had no such technology • I develop in this part of the technology	"When I was in the previous firm, I was developing NROM Memory related element, I moved to the current firm because the current firm was hiring engineers who were doing similar technology, so I came here. At the time, this firm had no such technology, so I did contribution to develop in this part of technology." (A3)
		• In the same domain • Some experience, the background is there • Doing a different thing, the foundation is the same	"I don't do what I used to do in the previous firm, from the design perspective, the domain has no change, but in detail, it is completely different from what I did before. It is in the same domain. The things I did in the previous firm, it is something we don't have in this firm. so different from what I did. Some experience, the background is there, but doing a different thing, the foundation is the same." (G1)
	Unavailable knowledge and filling in engineers for new technology	• Do a firm's new things • The firm does not have experience in new technology • Find people to fill in	"There is no one who can do a firm's new things, so we find people to fill in, the other case is a new technology, the firm doesn't have an experience like 40nm immersion lithography, 28nm metal gate. So it depends on what field we don't have." (A2)

		• When developing new technology we don't have, hire people who specialising or having experiences • Faster to carry new technology development	"When developing new technology, we don't have that technology, so we hire people who are specialising it or who have experience in it, … as long as that person has done it before, it will be faster for us to carry on new development on new technology…. It is always better than starting from zero… as it can save time and faster." (H1)
Familiar knowledge and exploitative innovation	Same technological area and refining existing technology	• Engineers doing my area in the current firm • Did not bring anything new • Reinforcing this area • Refinement on design flow and methodology	"When I came, there were engineers doing my area (what I was doing), I did not bring anything new that the firm did not have, but what I brought is reinforce this area. my influence is on refinement on design flow, design methodology, and in this respect, my previous firm is a bit stronger." (F1)
		• Working in different factories within a firm • Keep doing the same thing • Did 8inches in the previous firm and the hiring firm did 8 inches at the time	"When I was newly hired I was doing what I had done in the previous firm, … they also sent me to different factory keep doing the same thing, when I was in the previous firm I did 8 inches after I came here, they do 8 inches, which this firm just initiated 8inch at the time. When I just came they did 40 and 28nm." (A2)
	The same knowledge and problem-solving	• Hiring to solve a specific problem • Overcome the existing problem	"Hiring can bring advanced knowledge, but it is not a full set of technology, usually hiring experienced engineers is to solve the specific problem and overcome the existing problem." (A1, A2)
		• Did A nanometres before and now do A technology • Improve and solve problems	"I used to do A technology (name of technology) before, now also do A technology, if they ask me to do a new thing I think I can do it, but they will not give you this opportunity, … it is impossible to be comprehensive. If you are in the field of engineering, you can only improve in this field and solve problems. " (A1)
		• Solving the engineering problem • We did the same or similar knowledge before • Aware of know-how, knowledge, and methodology	"Fab manufacturer is about to solve the engineering problem, based on our experience because we did the same or similar thing before, we know how to do or knowledge and methodology."(D1, B1)
	Solving the problem, efficiency improvement, Cost down in accordance with existing technology	• Doing the same technological field • Solving system related problem • Efficiency improvement • Cost reduction • Refinement in the process • Not designing new technology	"I used to work at Alpha firm (leading firm) before I moved here, doing the same technological field, CMP (Chemical Mechanical Polishing) in manufacturing. In terms of technology, I basically solve the problem in the process (systematic improvement) also help to produce manufacturing process cost reduction, or projects that need efficiency improvement (reduce the time). So, from this point of view, we are not designing new technology, but do some refinement in the process." (C2)

			"When I was just hired back that time, they spent 13 to 14 hours per day to complete work, and supplement emergency, but after I lead the team for one and two years, solved some problem in terms of system related problem, and the working time has reduced, and then based on efficiency improvement, the working time reduced to 8 to 9 hours to complete work." (C2)
		• Some problem with cost • Find new and cheap material • The problem for R&D • Give the various specification of the formats • Figure out how to modify his recipe • Cost down	"A firm hired us to solve the problem… the solving problem means that the factory has abnormal product every day, you have to find out the reason for this, the symptoms may not be the same, and there is a problem with the yield test, and when the problem occurs in the final stage then you have to chase back to see where the production process has problems. …Also, there are some problems with cost, for instance, how much does it cost per step, the firm has requirements that you need to cost down 10% every year, so you have to do experimentation, find new and cheap material to do it, so the problem for the R&D is that he is going to give the various specifications of the formats, he is going to figure out how to modify his recipe. " Also, there are some problems with cost, for instance, how much does it cost per step, the firm has requirements that you need to cost down 10% every year." (A1)
	Increase the understanding	• Difficult problem solving • Know-how to mix • How to do, how to correct • Provide specialised technical needs • Fill in the weak part of a technology	"Some specifically difficult problem needs to be solved through hiring engineers who have experience. Sometimes it is not clear if the engineer really understands, some technological things, he just needs to know how to do it, just like making coffee, it is enough knowing the proportion of coffee, whether the person really know or not it is not important as long as firms get what they want. Sometimes hired engineers do not need to really know this technology as long as you have seen then it is alright. Some engineers you need to get into it, and know-how to mix (配), and then how to do, how to correct, this is to provide specialised technical needs. Otherwise, you will have to find engineers with experience if your department does not have enough capability. Poaching is used when there is a weak part so fill in with engineers." (A2)
		• Did not now understand too well • Implement those technologies and methodology • Yield improvement • Suitable manager for my field • Not new for a firm	"In my case, my expertise is line monitor (inspection & metrology), the firm didn't understand too well and details, how to implement those technologies and methodology to do yield improvement well. The technology is not new for firm, they didn't have a suitable manager for my field..." (C2)

Knowledge integration & Collaboration	Combining new method and material	• Hire different areas to develop new technology • Add a new process, a new material that firms doesn't have	"When we hire a different technological area, that means we need to develop new technology. For us, to upgrade the technology you need to add a completely new process, new materials that our firm doesn't have, so it is new for us." (A2) "We hire engineers who can bring knowledge that our firm does not possess. For instance, the firm didn't have EUV (Extreme ultraviolet lithography**),** so in order to develop EUV, which is the technology required in lithography (we have), … hire from B (also competitor, even though that firm is not specialising in EUV). But this person is at least aware of how to develop EUV, he can supervise in the firm for rapid development… save much time." (A2)
	Collaboration between hired and incumbent engineers	• Solve one part of the problem • Require a team to be able to support or cooperate, hired engineer	"Hiring a person like me can solve one part of the problem, you want to solve the whole problem, and do you think that is possible? Not possible. … even hiring a star engineer, if he has no team, then you have to make the team for him, and he has a request for a team, they should be able to do this, know to do this, they have to co-operate. This team has to have a certain capability." (C1)
		• When incumbent engineers cannot support him • We will replace them by hiring new people	"We hire engineers whose capability is high, let him lead the team, but when incumbent engineers cannot support him, then we will replace them by hiring new people, or train junior engineers." (A2)
		• Hiring team can be more effective • Hire one expert to make a new team • Team members are trained to support hired engineers	"Hiring the whole team from the leading firm can be more effective, but it is not possible hiring the whole team, so usually we hire one expert and make a new team for him … but team members are not much capable of supporting him…training them takes time… so basically the team cannot immediately get into work." (A1)
		• Poaching one or two may not be that helpful • Poaching the whole team is helpful	"The semiconductor is different from other industries. Some you can learn his knowledge but in semiconductor poaching, one or two people may not be that helpful, it will be helpful when you poaching the whole team, hiring one or two then his ability may be helpful but his previous thing (knowledge) cannot directly bring in and use it, because every factory, every process has more than 400 steps so each factory can be different." (C2)
		• When no one collaborates with them • Work independently but weak effect	"In the case when no one can collaborate with him, then, the firm will let him work independently but the effect will be weak." (A5)
	Similar knowledge makes easy collaboration	• Similar knowledge would not be difficult in working together	"People, in general, share a similar knowledge base, so they would not have difficulty in working together."(B1, E1)
		• In the same area • Knowledge is common • Knowledge and technical skill can be shared	"Now I do a similar thing as before, in the same area. It is not completely the same, but the knowledge is common, knowledge and technical skill can mostly be shared." (C1, E1)

	Technological languages	• Communication problems are not big • Using English, so this is not a problem	“The industry is very special, communication problems are not big, South Korea, Japan, Taiwanese, the industry's professional words are all in English because semiconductor is invented by the U.S., so this is not a problem.” (C1)
		• Similar words and sentence • No many problems when working	“In terms of language in work, we use similar words and sentences so not many problems when working.” (E1)
		• Using English and number so no problem	“We use English and number so there is no problem, but communication will have trouble, but for technology, there is data so no problem.” (A2)
		• No language, English, and communication problem • No technological problem • Has a personal problem	“We have no language problem, English has no problem, communication has no problem, from technological perspective there is no problem, of course, there is a personal problem.” (A4)
	An issue relating to mind-set	• Engineers are half-hearted • Do not comply with specifications and follow the standard procedures • This leads to a problem in the production line	“There are thousands of steps in the manufacturing process of semiconductors, and even small differences in key processes will affect yield. During the R&D stage or production process, engineers are often half-hearted, do not comply with specifications, and follow the standard procedures, leads to many problems on the production line without causes, this is the most considerable difference from leading firms.” (A1)
		• Learning attitude • Self-requirement is not high • Don’t care about quality	“I tell them what to do, does not mean they will do as you supervised, I give them 1,2,3,4,5 things, but they only do 1,2,3, their learning attitude is not that good. The way how they work is not detail, the self-requirement is not high. They don’t care about quality.” (A1)
		• Problem in mindset • When local engineers cannot change the mindset, they do the wrong direction	“The other important thing is the mindset, if the local engineers cannot change their mindset when they meet a new problem, they still don’t know how to do it or the wrong direction. A mindset like accountability, honesty, what you say is what you do, data, not guess. When we work together, I can see their attitude and what they think, most people don’t pursue excellence, part of the truth to cover the mistake.” (A2)

Appendix G: Data analysis table (Status distance)

Example quotations	Condensed meaning units (close to the text)	Revising codes/categories	Concepts
"Unlike other industries, the semiconductor industry has to integrate with many departments and the sales and technical communication are important so the firm provides fair support for this… in order to maximise the performance for an individual engineer… we are given the authority to derive or control other departments." (A3)	• The firm provides fair support to maximise the performance of the engineers • We are given the authority to derive or control other departments	Technological contribution of hired engineers	**Knowledge flows**
"They would not isolate me, when I just came I was an assistant, when I just came there were no one with me, but after 3 months, we had around 10 to 12 engineers, so the team was established. After setting up a team, I direct the work slowly, training slowly, doing technological tasks slowly." (C1)	• The team was established when I came • I direct the work, training them and doing the technological task		
"Within the firm, hired engineers are often to be rotated, so the standard operating procedure (SOP) has to be made as a recipe when one goes from A team to B team, he has to bring SOP together. The technology has to be shared between teams, the firm will make hired engineers sufficiently share their knowledge, I have four teams under me, for example, A team make the most advanced technology, the hired engineer from A team will be sent to the B team to setup technology, share their knowledge, so more teams can conduct same technology." "Firm hire engineers for a reason, hired engineers do what they used to do, or he will train other engineers, and there is a possibility he may continue to develop the next generation of technology. Usually, the purpose of hiring is to absorb advanced knowledge so he will be asked to do what he had done before and then develop new technology, but if he is not able to develop the next generation, if he still has value, he will train other engineers to diffuse the knowledge to more engineers so that more engineers can do the same technology." (A4)	• Hired engineers are often rotated to set up technology • Sharing knowledge between teams • Hired engineers will train other engineers • He will do what he has to do or develop new technology • When hired engineers are not able to develop the next generation • If he still has value he will train other engineers to diffuse the knowledge to more engineers		
"You find an expert, and he belongs to our department, he will be same as other workers, but the role of hired experts will be more important, many times giving the consultant about his idea if there is a problem then ask, and see if there is the point of conflict if there is something engineers find it different then look for the correct one. Sometimes what they do is right and sometimes what we do is right." (A2)	• Same as other workers but the role is more important • Giving the consultant about his idea • If there is a problem, then ask and find the correct one		
"When experienced one is hired, the firm will create a team, they will have to lead the team to build the foundation, running cycles, the process building foundation is	• Create a team for a hired engineer • Ask them if we have some problem		

the process of growth and improvement. In the process of self-improvement, if we have some problem, then we will ask them. they will give you a comprehensive direction of guidance. I learnt how to solve the problem in technology… if we have a problem then we ask them, solving the problem is the process of learning, it will not be the problem when we have a new problem next time." (A8)	• They will give a comprehensive direction of guidance • I learn how to solve the problem in technology • Solving problems together to learn		
"There were 18-19 engineers within my team at the time, by now I trained 4 engineers to become managers to support other factories, of course, some of them got promoted or gain new project (duty)" (C2)	• Trained 4 engineers to become a manager to support other factories • Some got promoted or gain new project		
"There is a one who has 15 years experience in our team, they usually lead us to enter and master (technology) and provide the direction like a supervisor." …"They help us to enter the field, later they will help us develop us depending on which direction we want to develop in the field, I can learn much, and if we encounter a problem we cannot solve then we will ask them, sometimes I will be given the working task what they did if there is a problem then ask them first because they know it well as they did before." (H3)	• Lead us to enter the field and master technology • Help us develop depending on which direction we want to develop • When encounter problems then we will ask them • Given the project, they did and ask them about the problem		
"I also train other workers, and if there is a problem, I will tell them why the problem is like this. The person who got trained can work more effectively." (G1)	• Train engineers • Give the reason why the problem is like this • Training to enhance work efficiency		
"Instead of saying training them, I would say since I have more experience than other engineers, so during the technological task, I will maximise the efficiency when there is a chance, or tell them the technology they did not recognise like seniors tell juniors." (A3)	• Maximise the efficiency • Tell them the technology they did not recognise like seniors tell juniors		
"In this firm, for the last 9 years, I trained 100 engineers, they got a better job after being trained, their working quality has been improved."(A2)	• I trained 100 engineers • They got a better job after being trained • Working quality has been improved		
"Training them is to increase their experience, some technology if you do not transfer, and they do not experience themselves, they are likely to make mistakes, this is one thing. On the other hand, they may have no the same way of analysis of the problem, they will look at this thing very simply but experts will tell you that from a larger scope of analysing things. So this will be helpful for them. When they conduct the same thing by themselves, the first time I have to do it, and if we have the same technological task they can do it independently, or I will help them to find the problem they cannot find when analysing, then they will learn it. So I improve their experience and capability." (G2)	• Training engineers and transfer to help them build experience • Experts will tell you from a larger scope of analysing things • Trained engineers will do the technological task themselves after I do first • Help them to find the problem they cannot find • Improving their experience and capability		

“In the previous firm, I was just an engineer, but here they treat me as an expert, so for me, the working environment is much better here than in the previous firm… the most technological task is cooperative work so harmony is important, in terms of work, we are harmonised. ”(E1)	• Treated as an expert • The working environment is much better than the previous firm • We are harmonised when doing cooperative work	High dependency on newly hired engineers	
“ My position was right below manager before being hired by the current firm when I came here, I got promoted, and the salary has increased to … when we work we do not have a problem, because…, our authority is higher so we have relatively less problem in working. ” (A2)	• Got promoted and my salary has increased • Do not have a problem when we work because our authority is higher		
“When experts were hired, everyone shows respect, no one arise conflict with them, you must admire him, his authority is higher than yours… when they are hired, integration into a firm has no problem because when they are initially hired, they will be given a certain level of authority, so no problem to get adapted in the firm. ” (H1)	• Everyone shows respect to hired experts • No one arises in conflict with them • Must admire them as his authority is higher • No problem in integration when they are initially hired • They are given certain authority • No problem to get adapted in the firm		
“I got certain authority, so it is not so difficult to work in the new firm.” (A1)	• Certain authority • No difficulty in the new firm		
“They are given a higher position when they are hired, so the integration with other engineers will be easier.” (G2, H3)	• Higher position when they are hired • The integration will be easier		
“There will be conflicts, knowledge gap, which will not affect the work. Because of matrix management, the authority given by the firm to the program manager (hired) is relatively high” (L1)	• The conflict and knowledge gap will not affect the work • Matrix management • Given high authority to a hired manager		
“I also do the task that is not in my expertise, it belongs to “Zashi”, relating to safety, it has somehow had a relation with my expertise, but the relation is not absolute. Not really, but it is what I have to think about… What I said that I have never done before means I do manage the cost or to calculate the production capacity, how many machines we need to buy to produce, then I have to find the indicators, the cost of machine and material and so on. I don’t know how to do then I learn and ask. I did not know about the operation of the factory at R&D before, but for these few years I learned concept, so when I went back to my original expertise (profession), I will consider these, for instance, the cost down, I will consider if what I am doing is affect the cost or will it help.” (C1)	• Doing things not related to expertise but chores • Manage the cost or calculate the production capacity • I learn and ask if I do not know	Maximising knowledge transfer	

"I have a lot of chores (Zashi), for instance, work about the public security, the production safety, there is a management team in charge of production safety, but now I manage the production safety of our department…I have to help, this is not my expertise (profession), so my time is dialled away. …When I was just hired, I was doing my expertise (Huang guan) and training other engineers." (A2) My previous firm is very specialised, but here we have a lot of chores. You cannot focus on what you do, you have to do a lot of things that are not your responsibility, not your speciality, and you should not do. For instance, hiring is what the HR department does, but here we have to do it if they cannot hire. My previous firm is not like this… specialisation is not obvious, while the previous firm makes it really specific and precise, you will not do outside of your speciality, it is acceptable to do a technology-related thing. But here you are asked to do many things not related to technology. a lot of things, if you do not do it then you have a disadvantage, in the previous firm, there were no chores, none-technical things." (A2)	• I have a lot of chores, not technical things • The previous firm is specialised, here have a lot of chores • You cannot focus on what you do		
"The atmosphere is similar, but I have to deal with external things and have many chores (Zashi), More times I deal with things and chores (Zashi) with the outside of the firm, more things to do with management. When I was in the previous firm, I didn't do these things, I only did what I had to do." (G1)	• I have to deal with external things and chores • I do things that I have never done before		
"I do things that I have never done before such as managing cost, calculating production capacity, how many machines should be purchased to produce, I will have to look for indicator, the cost for the materials of machines, etc. If I don't understand then I will ask, before I didn't understand the operation of the factory because I was in R&D before, but these years I know it. at least I have the concept, so I will consider more about cost when I do my own expertise if it affects the cost or not." (A1)			
"Technology of Alpha firm is behind another company when I decided to come here in 2012. Everybody said I was crazy. We gain special incentives for new technology, is it long term? If the local guy can learn does the company keep the special incentive? This is a potential risk for us. Even the local guy still has a gap with us, but it depends on how the firm thinks, it is not controlled by ourselves."(A1)	• Gain special incentives for new technology • A local guy learns then the firm does not keep incentives • The potential risk for us	The potential risk of losing value when sharing knowledge	**The perceived psychological safety**
"To be honest, we came here 2002 and was going to be here until 2006 and going back to Taiwan, we are going to transfer our value and then when we will have no value to be used, so it is how we set our plan at the time but see we are still here now and did not go out. I think we did not go out because we still have value. Why we have value, firstly, it is about cultural difference, they did not learn seriously, a	• We are staying here longer than we initially planned • The local guys did not learn much from us • The firm does not replace us		

lot of people cannot drive things… and secondly, at the time the salary for them is low cause them slow learning. We did not go back between 2002 and 2006 because they did not completely replace us… The firm cannot operate by depending on one or two persons, so we have to remain (since 2002), now they already learn certain level about 8 inches, for the 12 inches, the firm will directly hire experts from other firms, we are also risky because 8inches become a mature technology, they can make themselves without us."(A2) "If he asks me to do something new, I think I can do it too, but you will not have this opportunity, I think I will be replaced, you don't know when. If I want to go to the old factory, then I will not be worried." (A2)	• The firm already learn a certain level of 8 inch • We are risky because 8 inches become a mature technology, they can make without us • I have no opportunity to do new technology • I will be replaced, but don't know when • If I go to the old factory, there are no worries		
"When we were just hired, we were given a high salary and position, but as time goes by, in some cases, the promotion is slower than local engineers, of course for people who are in the higher position than me, they will prefer workers who have no language and cultural barriers…engineers like me will only work in technical parts, so it is hard to be a higher-level position and become important decision-maker within a firm. therefore, it is undervalued compare to my experience and skill." (A3).	• Given a high salary and position when just hired • The promotion is slower than local engineers • They will prefer workers with no language and cultural barriers • Engineers like me are hard to be a higher-level position and become an important decision-maker • My knowledge is undervalued		
"I train them and teach them how to do it, about methodology, but in terms of knowhow once I transfer it then there will be no value for me. We see knowhow as idea… I teach them, but not all" (C1).	• I train and teach them methodology but if I transfer knowhow, no value for me • I teach them but not all		
"I don't think I learn that much by working with mobile engineers, not much has changed for me, I just do my own work, if a project leader teaches team members too much, he will have a risky, my boss will teach us but he does not want to teach all, he does not want to teach you too much." (M1)	• I don't learn much with them • Not much has changed if the leader teaches team members too much, he will have a risky • My boss does not want to teach all		
"A few years ago, Java was popular in the market, now is AI and Big Data, so now we need engineers whose integrating ability is stronger, …when an expert came at the time, there is a possibility his knowledge can be fell behind with when he stops learning… When experts are hired initially, at the time he is useful but he will be obsoleted when the technology is outdated… when he is just hired, he repeated what	• Experts will be obsoleted when the technology is out of date • When he repeats what he did before, cannot make a new thing • His title will be removed	Possibility to lose the advantage	

he did before, but later if he cannot make a new thing, then his title used to be a manager but now it was removed" (H1)			
"If you are the leader when you are hired, but the engineers you lead are more capable than you, if the leaders cannot give them advice or the direction that you lead is not as good as your team members then they will be obsoleted. This is probably they did not grow themselves, there is no value, you remain the same, and people you lead better than you then you have no value." (C2)	• When your team members you lead are more capable than you • When the leaders cannot give advice or lead to a good direction, they will be obsoleted • Leaders do not grow themselves there is no value		
"In terms of technology there is no problem, but if I do not pay attention then I would not gain new information and news about what is going on within the firm, I think it is caused by language problem, or even though in the same firm, department, project, I am a foreigner so I am treated an outsider, so I feel isolated, which decrease my self-esteem which also affects my working efficiency." (A3)	• If I do not pay attention, I would not gain new information due to a language problem • I'm a foreigner so I am treated as an outsider • I feel isolated which decreased self-esteem • Affects my working efficiency	Personal concern	
"… There is salary requirement, which may be higher than the original salary structure, resulting in an impact on the internal salary system…engineers from other countries face a huge change in language and living condition, challenges associated with team psychological establishment (团队精神的建立), and concern about future localisation, rising living costs including the cost of children's education and obstacles." (A5)	• Require a higher salary • Resulting in an impact on the internal salary system • Challenge in language and living conditions, team psychological establishment • Concern about future • Rising living costs and the children's education		
"Some hired engineers are not good at building a good relationship with people, sometimes it has a destructive effect on a team atmosphere, this will negatively influence their team working capability. It may depend on the power within a team, more power, more influence so can make a great influence on others in terms of technology and integration. For instance, hired engineers have great capability, but tend to do office politics, and cause other engineers to leave, even though the technology gap can be filled but if lack of basic human resource can slow down the development progress." (A5)	• Some experts are not good at building a good relationship • It has a destructive effect on the team atmosphere • Negative influence team working capability • More power more influence to others in technology and integration • Some tend to do office politics • Cause other engineers to leave	Perceive others as competitors	

	• The technological gap may be filled but lack of human resources can slow down the development progress		
" You feel there is something good, you think it should be done, this new thing you suggest your department but they may not agree with you, this is to say, the firm looked for an expert, the firm thinks this expert got a lot of good things, that has to transfer to others, refining the current efficiency and some engineering conditions, but the boss in this team may not accept. Promoting your idea is really challenging. People here are not good at adjusting to each other (Mohe), so the expert has no way to promote these good things. What is the point to hire experts? This is also the reason I want to leave… When the experts come to the firm, they have to integrate or get along (Mohe)with their team members who are in a lower position. But they cannot really get along, they stand opposite for the sake of opposition. Experts see other members as competitors." (A2)	• Hired engineers have to integrate or get along with their team members with a lower position • They cannot get along • Stand opposite for the sake of opposition • See other members as competitors		