4 Coevolution of Firms with Sectoral, Regional, and National Systems

4.1 INTRODUCTION

The overarching theme of this book is alternative pathways for latecomers in catching-up development. This chapter addresses this question at the level of firms, whereas Chapter 2 does so at the level of nations. Overall, the book looks at the interaction of national and sectoral dimensions of innovation; sectoral and regional dimensions; and the interaction of corporate innovation systems with sectoral, regional, and national innovation systems. This chapter examines these interactions to derive the importance of firms, particularly big businesses, as the ultimate carrier of catching-up growth in the latecomer context.

Regarding the issue of alternative pathways, one way to raise this question at the firm level is to ask whether latecomers catch up and finally forge ahead by using "similar or different" technologies from those of the forerunning incumbent firms. Using similar technologies implies that the latecomer simply attempts to imitate, whereas using different technologies indicates the pursuit of creating new technologies and taking a different technological path or trajectory from the incumbents.

This contrast between similar and different technologies is interesting in terms of the literature on technological catch-up. Traditional or early studies, such as those of Lall (2000), Kim (1980), Westphal et al.(1985), and Hobday (1995a, 1995b), have observed that the latecomers attempted to catch up with advanced countries by assimilating and adapting the incumbents' more-or-less obsolete technology. A contrasting view has been expressed by Lee and Lim (2001) and Lee (2019) that the latecomer does not simply follow the

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advanced countries' path of technological development; instead, they sometimes skip certain stages or even create their own path that is different from those of the forerunners.

Accordingly, this chapter begins in the next section by exploring the issue of the path of latecomer firms in their effort and achievement in catching up with incumbent firms. Specifically, Section 4.2 addresses the question of whether latecomer firms will catch up with and eventually overtake the incumbent by merely imitating them, or by going beyond imitation but initiating their own technological innovation different from those of the incumbent. The answer will be sought by looking at and comparing the overtaking experiences in three pairs of latecomer and incumbent firms. We draw on the quantitative analyses of Joo and Lee (2010), Oh and Joo (2015), and Joo et al. (2016), which have each analyzed a latecomer vs. an incumbent pair, such as Samsung vs. Sony, Hyundai Motors vs. Mitsubishi Motors, and Huawei vs. Ericsson, respectively.

Section 4.3 then deals with the coevolution of firms and surrounding institutions in the context of post-reform China where firms with diverse ownership have emerged, forming an ideal setting to examine the different interactions of firm ownership and institution. Specifically, relying on my own study (Lee and Lee, 2022), we may compare privately owned local enterprises (POLEs) with foreign-owned enterprises (FOEs) or state-owned enterprises (SOEs) to show how POLEs catch up with other ownership firms by exploiting more effectively the surrounding institutional development. While the initial productivity of POLEs was lower than that of FOEs at the low levels of institutional development, POLEs are shown to eventually catch up with FOEs because institutions develop further over time to be better exploited by POLEs than FOEs. Hence, any policy design should consider this coevolving nature of institutions and firm ownership; whereas private firms cannot prosper without sound institutions, institutional development may be useless unless there are private firms that can benefit from this institutional development.

Section 4.4 will elaborate, relying on Wong and Lee (2021), the case of one region, Hsinchu City in Taiwan, to show that its long-term trajectory of upgrading and centralization is driven by the rise of a leading big business, namely TSMC, a world-class semiconductor foundry, although the region was initially characterized as the Marshallian industrial district with more equal distribution of differently sized firms and diverse sectors. However, with the growth of the leading firm of TSMC, the region has steadily become similar to a hub-and-spoke (HaS) type of industrial district with increasing centralization in the distribution of firms, particularly the increasing dominance by a single firm, TSMC.

This tendency of increasing centralization driven by the rise of leading firms is consistent with the national-level detour of increasing concentration of NIS at the catching-up stage, followed by the eventual decentralization at a later stage (see Figure 2.3D) discussed in Chapter 2. There, the imbalanced catching-up NISs are at relatively low levels of decentralization or high levels of centralization as economies with such NIS have shown a tendency toward increasing concentration of innovation during the last two decades of the 1990s and 2000s, only to turn around in the 2010s toward decentralization. This turnaround is clearer if we look at the graph of an individual economy, such as that of South Korea, for the recent period (Figure 1 of Lee & Lee, 2021a). This U-shaped curve means that these catching-up economies experienced an increasing concentration of innovation into a small number of big inventors or big businesses during the rapid catching-up period and then some decentralization only recently after they matured or entered a post-catching-up period.

Finally, Section 4.5 discusses, relying on Im and Lee (2021), a match between the micro and macro dimension of innovations by referring to the changes in the corporate innovation system of Korean firms. The behavior of Korean firms earlier corresponded with that of typical catching-up firms (e.g., prioritizing growth over profitability, borrowing and investing more, and specializing in short-cycle technologies) but currently show radical changes in

their behavioral pattern to show signs of convergence toward the behavior of mature firms in the advanced economies, such as the United States; they now care more for profitability and dividend payment over sales growth and re-investment, and for moving into long CTT-based sectors such as biomedicals. Such change or a phenomenon of shift from catching up to convergence at the firm level is an exact match with the macro-level convergence of South Korea with respect to the Anglo-American economic systems in terms of the slowing down of growth and employment and rising inequality (Lee & Shin, 2021). Such changes in the firms are driven by the post-1997 crisis reform imposed by the IMF as a condition for emergency loans, which had forced the Korean firms to adopt the corporate governance measures found in the shareholder capitalism in the United Stares or United Kingdom.

This chapter deals with each of the above-discussed themes in sequence. Section 4.2 discusses the roles of similar or different technologies in catching-up. Section 4.3 deals with the coevolution of firms and surrounding institutions in the context of post-reform China. Section 4.4 discusses region-level concentration by the rise of a big business, and Section 4.5 discusses convergence of Korean firms toward the Anglo-American system. Lastly, Section 4.6 summarizes the findings and provides the concluding remarks.

4.2 CATCHING UP BY SIMILAR OR DIFFERENT TECHNOLOGIES

This section digs into the question of whether latecomers catch up using "similar or different" technologies from those of the forerunning firms, and it will look at the three pair-cases of overtaking of incumbents by latecomers. The section draws on the research of Joo and Lee (2010), Oh and Joo (2015), and Joo et al. (2016), which has analyzed each pair of a latecomer vs. an incumbent, such as Samsung vs. Sony, Hyundai Motors vs. Mitsubishi Motors, and Huawei vs. Ericsson, respectively. In the three pairs of cases, one common pattern is that a latecomer firm overtook the incumbent in market shares.

In other words, our selection of the above pairs of companies is not arbitrary, because our objective is to compare an incumbent company and a latecomer firm which eventually overtook the incumbent company. This section focuses on these cases where overtaking in terms of market share is completed to determine the necessary conditions of a successfully completed catch-up, namely overtaking.

Such cases of finished catch-up or overtaking are quite rare around the world, and these cases may be considered the universe of the sample. Thus, the results of the analyses may be generalizable as important necessary conditions for overtaking. Other cases of latecomer firms that are also increasing market shares at diverse speed may exist, but they are not the target of our comparison.

The section will thus focus on the hypothesis that latecomers' consistent accumulation of technological capability rather than its cost advantage has been the crucial factor in its successful overtaking. Furthermore, latecomers' overtaking is hypothesized to be a result of its eventual success in creating its own technological trajectory, although it started by imitating the forerunner by integrating the same or similar technologies in the early stages. The empirical method to verify this hypothesis is quantitative analysis using patent and patent citation data. The focus is on the three specific criteria, namely, quantity and quality of patents with the latter measured by impacts (forward citations received) of patents, technological independence measured by self-citations, and technological dependence on each other measured by mutual citations, which will be further explained in the subsequent sub-sections.

4.2.1 Three Cases of Market Catch-Up by Technological Catch-Up

The three cases of overtaking introduced above are all noteworthy cases as they may represent both market and technological catch-up in different sectors and countries, namely, South Korea and China.

First, Samsung's catch-up with Sony is a symbol of Korean catching up with Japan, as Samsung Electronics has been a leading

IT firm in South Korea, whereas Sony previously represented the IT business of Japan. Samsung Electronics, which is the focal company in the section, is the leading affiliate of the Samsung business group, which is now the biggest business group in Korea. Although the early businesses of the Samsung group were textiles and refined sugar, it entered consumer electronics in the early 1970s by establishing Samsung Electronics as a new affiliate. In its early days, Samsung Electronics learned from the Japanese companies such as Sanyo. In the TV or display segment area, Sony was a paramount leader in the global market and had been the target of bench marking and imitation by Samsung Electronics (hereafter Samsung). Even by the early 1990s, Samsung's sales were less than half those of Sony. However, by the mid-2000s, Samsung's sales and firm values in the stock market overtook those of Sony. Thus, the question is, how was that phenomenon possible and, specifically, what was the role of technological capabilities in this overtaking?

The second comparison pair is Hyundai Motors and Mitsubishi Motors. Hyundai Motors represents Korea's auto industry as the leading company. The Hyundai business group earlier focused on the construction business and entered the auto business as late as 1967 or practically in the1970s. Thus, Hyundai was a latecomer and had to start as an OEM assembly maker to Ford. However, Hyundai soon separated from Ford as it wanted to sell its own brand cars and thus had a technology transfer/licensing contract with Mitsubishi in 1973. Since then, Mitsubishi had been a major source of technology for Hyundai, which almost fully relied on Mitsubishi for its engine, transmission, and exhaust systems (Oh & Joo, 2015). In 1982, Hyundai even had to give 10% equity share to Mitsubishi in return for the guaranteed supplies of key parts and components.

Mitsubishi is one of the top four business groups in Japan, with its long history dating back to 1917, when it began production of the Mitsubishi Model A, Japan's first mass produced car. Mitsubishi established its authority as an innovator in automotive technology, developing Japan's first diesel engine in 1931,

Japan's first four-wheel drive passenger car in 1934, and the world's first "Silent Shaft" technology in 1975. Only in 1970, Mitsubishi Motors was split off as an independent firm from Mitsubishi Heavy Industries (Oh & Joo, 2015).

Both companies were doing well in the 1990s, and their revenues kept increasing. However, both companies suffered seriously during the period of the Asian financial crisis in 1997. Nonetheless, since 1998 onwards, only Hyundai had rapidly increased its sales volume in both the US and Korean markets owing to improved productivity during the 1990s led by its own development and production of engines and transmission (Lee & Lim, 2001). Consequently, Hyundai's sales grew bigger than those of Mitsubishi after 2001, as the latter's sales had staggered in the 2000s and thereafter.

The third pair for our comparison is Huawei from China versus Ericsson from Sweden. Huawei was established in 1987 by Ren Zhengfei, a former People's Liberation Army officer. The firm was formerly a telecommunication equipment distributor with a barn on a Shenzhen farm as an office, from which the founders sold telephone switches imported from Hong Kong (Xu & Girling, 2004). In 1990, Huawei decided to risk transforming itself into a telecommunication equipment manufacturer by using in-house research and development, which was the strategy of typical Chinese manufacturers at that time. By using reverse engineering on an imported switching device and networking equipment, Huawei developed the HJD48 (a 512-line analog telephone switch) in 1991 (Mu & Lee, 2005). Huawei's cost advantage allowed it to gain access to the rural Chinese market, a market that was neglected by multinational firms. Eventually, by successfully developing a large capacity digital switch, Huawei increased its market share rapidly to become the largest digital switch supplier in China in 1998 (Mu & Lee, 2005). In the 2000s, Huawei began to reach out to the international market, starting from Hong Kong and extending to emerging and developing countries and regions. Huawei's international market revenues were sluggish during the first few years but surged from the late 1990s.

The telecommunication system industry has long been dominated by several Western firms. In particular, the industry has been led by the Swedish telecommunication giant, Ericsson, followed by Siemens, Nokia, Motorola, Alcatel, Nortel, and Lucent. In the early 2000s, the industry faced a drastic decline in market demand because of the IT bubble burst. Although many incumbents suffered, Huawei had accelerated its market shares since the mid-2000s. In 2012, it finally overtook the longstanding industry leader, Ericsson, in terms of annual revenue.

The impressive story of catch-up and overtaking by latecomers in market sales begs the question of how this became possible, and particularly whether the latecomers achieved such catch-up by cost advantages or technological capabilities. Our focus is on the latter aspect, exploring the hypothesis that gradual catch-up in the market would be possible merely by cost edges. However, sustained catch-up or eventual overtaking by latecomers would not be possible without technological catch-up. Thus, we have to measure the degree of technological capability and address the question of how the technological development path of latecomers is different from or similar to that of incumbents.

4.2.2 Empirical Method

For this purpose, let us first discuss a method to assess whether the technological path of the latecomers is the same or different from that of the forerunners. Three criteria are used to assess the same or different technologies or broad aspect of technological capabilities.

First, the quality of the two firms' patents, measured by the average number of received citations, is examined to determine if the latecomer's patent quality catches up with or even surpasses that of the forerunner. Second, the firms' degree of self-citation, which can measure their self-reliance on their own knowledge base, is examined (Lee, 2013c, Chapter 5). This study focuses on the latecomer's degree of self-citation to assess the extent to which it becomes independent of external knowledge sources and self-reliant on its own

knowledge base. Third, the mutual citations between the two rival firms' patents are examined to establish the extent through which they rely on each other as their source of knowledge. For instance, if Huawei's patents cite many Ericsson patents, then, Huawei is imitating and relying on Ericsson.

The catching-up process has a dynamic nature. Hence, this study's grand hypothesis is that the latecomer firm may imitate the forerunner by incorporating the same or similar technologies in its early stages but should be able to create new or different technologies from the forerunner firm to achieve an overtaking. The logic behind this idea is simple. If a latecomer continues to follow the same path as its forerunner, the latecomer would always remain behind the forerunning company, unless it runs much faster than its target, which is not easy. Thus, an alternative for a latecomer is to explore a short cut or a different path. Lee (2019, p. xxi) referred to this idea as the so-called, "catch-up paradox," that is, you cannot catch up if you only keep catching up. This paradox implies that "just trying to emulate or replicate the practices of the forerunning economies is not enough, and catch up realizes only if you take a different path."

This section also addresses the question of whether latecomers rely more on recent or old technologies than the incumbents by examining the latters' citation lags, and whether the former relies more on scientific knowledge than the latter in terms of their patents' citation in scientific literature. These two aspects have already been verified by an analysis using a large sample of firms in Park and Lee (2015), and this study does a similar job for the case of these two comparable firms. A possible hypothesis is that the latecomer would rely more on scientific literature because science literature is not protected by any IPR forms and is freely available for use. Thus, the latecomer has a reason to explore fully useful knowledge from scientific commons in their catch-up efforts.

The latecomer may also attempt to rely less on old technologies protected by patents, which indicates a continued reliance on the incumbents. Such an attitude also makes sense in terms of

the need to avoid any possible patent dispute with the incumbents. The latecomers therefore have a reason to explore a technological trajectory that is less connected to existing technologies. Thus, their citation pattern will be geared more toward recent patents. Therefore, the average cycle time of their patent portfolio would be shorter than those of the incumbents. This hypothesis is interesting given that some studies (Park & Lee, 2006; Lee, 2013c) have found that the latecomer countries tend to specialize in short-cycle technology-based sectors. These studies are concerned with across-sector specialization, whereas the present section explores a twisted question of whether a latecomer firm's patent portfolio would show a shorter average cycle time than those of the incumbents in the same sector.

4.2.3 Common Patterns in Overtaking in Technologies

Table 4.1 summarizes the patterns of catching up by the three latecomers of Samsung, Hyundai, and Huawei against the corresponding incumbents of Sony, Mitsubishi, and Ericsson. The first row shows the year that the latecomers overtook the incumbent in terms of sales volume or the years that market catch-up is completed to realize overtaking. Then, the remaining rows show diverse aspects of technological catch-up, such as quantity and quality of patents, self-citations, and mutual citations, among others.

First, the hypothesis that technological catch-up precedes market catch-up or that market catch-up tends to realize owing to technological catch-up, is mostly supported when we consider technological catch-up in terms of the number of patents only. While Samsung overtook Sony in 2005 in terms of sales volume, its number of US patents grew bigger than that of Sony in 1995 or nearly ten years before the sales catch-up. Whereas Hyundai overtook Mitsubishi in 2001 in sales, it filed more patents than Mitsubishi as early as 1998. Whereas Huawei overtook Ericsson in 2012 in sales, it filed more patents than Ericsson from 2007 onwards. In other words, the three latecomers all succeeded in filing more patents than the

incumbent (which means technological catch-up) before they caught up with the incumbents in markets in terms of sales (which means market catch-up).

Now, the question of catching up by similar or different technologies can find answers by looking at three variables of patent quality, self-citations, and mutual citations. The answer seems to be that the latecomers have all developed their own technologies in the sense that their technologies tend to be of equal or higher quality, and that they have all become independent in terms of increasing self-citations and reducing citations to the incumbents.

Table 4.1 shows that Samsung's patents have enhanced quality to a higher level than that of Sony from 1992 or more than ten years before it overtook Sony in market sales. Similarly, Huawei's patents boasted a much higher quality than those by Ericsson from its early days or since the 1990s or more than ten years before it overtook Ericsson in market sales. Only Hyundai showed a slower catch-up in patent quality as its quality became similar to that of Mitsubishi as late as 2005 or several years later than its market catch-up in 2001. Such slower catch-up in automobile than in IT sectors is expected and makes sense, given that automobiles corresponds to more tacit knowledge and longer cycle time of technologies than IT and thus slow speed in learning and copying incumbents' knowledge by latecomers.

Next, the values of self-citations reflecting the degree of technological independence in Table 4.1 show that the latecomers have all overtaken the incumbents in this regard or several years before overtaking them in market sales. Samsung's self-citations increased to the level of Sony's in 2002 or two years before their market overtaking in 2004. Hyundai's self-citations have also kept increasing to become higher than those of Mitsubishi in 1998 or three years before market overtaking. Huawei's self-citations have also caught up with those of Ericsson in 2008 or four years before the market overtaking.

The final indicator of similar or different technologies is the degree of mutual citations. In this aspect, all the latecomers have

reduced their reliance on or citations to the technologies owned by the incumbents (Table 4.1). In comparison, the citations from incumbent to latecomers indicating the degree of dependency on latecomers' technologies were increasing, although somewhat slowly. This pattern of asymmetry in mutual citations between the latecomer and incumbents is expected and is a part of the continuation of technological catch-up by the latecomers.

An emerging summary of the above would be that when the latecomers have succeeded in overtaking incumbents in markets (sales), they have also succeeded in technological overtaking in terms of quantity and quality of patents as well as self-citations and mutual citations. This analysis confirms the hypothesis that technological

Table 4.1 *Catching up by similar or different technologies: comparison between a latecomer (L) vs. incumbent (I)*

	Samsung vs. Sony	Hyundai vs. Mitsubishi	Huawei vs. Ericsson
Sales revenues, overtaking when? (year)	L > I (2004)	L > I (2001)	L > I (2012)
Patent quantity	L > I (1995)	L > I (1998)	L > I (2007)
Patent quality	L > I (1992)	from L < I to L = I (2005)	L > I from the beginning
Self-citation	increasing L to L > I (2002)	increasing L to L = I (1998)	increasing L to L = I (2008)
Mutual citations			
1) From L to I	decreasing	decreasing	decreasing
2) From I to L	increasing slowly	increasing slowly	increasing slowly
Short or long CTT	from L > I to L < I	from L > I to L < I	L < I from the beginning
Relying on science	L < I	L < I	L > I

Source: Author using the information from Joo et al. (2016), Oh and Joo (2015), and Joo and Lee (2010)

catch-up tends to be a basis for market catch-up, which sounds very similar to Schumpeterian theory.

Finally, Table 4.1 further provides information on the cycle time of technologies and the reliance on science. The literature, such as that of Park and Lee (2015), earlier discovered that the average CTT of latecomers' patents would be shorter than that of incumbents, particularly in the short-cycle sectors. Table 4.1 provides some evidence of this. Huawei's patents show a shorter CTT than that of Ericsson from the beginning or the 1990s. The average CTT of Samsung or Hyundai was previously longer than its corresponding incumbent and has eventually become shorter at a later stage of catch-up. These patterns are consistent with theoretical observation, in that the latecomers have all ended up having shorter CTT than the incumbents, as they all managed to finish the process of market catch-up or overtaking. The pattern also implies that the latecomers attempt to avoid reliance on existing or old technologies occupied by the incumbent during the process of catching up.

In terms of the degree to which patents cite scientific articles or technological innovation relies on scientific knowledge, only Huawei shows a consistently higher degree than that of the incumbents. By contrast, the patents by Samsung or Hyundai rely less on science than those of Sony or Mitsubishi, respectively. Huawei's strong reliance on science may be understood through its having to go through more patent disputes with incumbents such as Cisco from its early days.

4.3 LOCAL VS. FOREIGN FIRMS IN THEIR COEVOLUTION WITH SURROUNDING INSTITUTIONS IN CHINA

4.3.1 Theoretical Perspectives

Economic institutions refer to the rules and standards that make up all the business transactions of a region (Wan & Hoskisson, 2003). Subnational regions within a country may have different levels of institutions (Meyer & Nguyen, 2005; Porter, 1998). In particular,

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subnational regions in developing countries exhibit a high level of heterogeneity in the development of their products, capital, and intermediate markets (He, 2003). Some regions are more troubled by institutional voids than others (Khanna & Palepu, 1997; Ma et al., 2013; Wei et al., 1999). As a result, firms in less developed subnational regions face greater difficulty and uncertainty in doing business than those in developed regions because market transactions in subnational regions are not highly efficient (Ma et al., 2013). A subnational government can improve institutional conditions by developing market institutions and formulating formal rules of transactions in the region (Ma & Delios, 2010; Wan & Hoskisson, 2003). These rules can improve firm performance (Lee and Lee 2022).

Subnational regions within a country can also be dissimilar in terms of the abundance level of various forms of capital, such as infrastructure, human, and knowledge capital (Cantwell, 2009; Meyer & Nguyen, 2005). The level of capital in a region is highly related to the nature of firm production (Wan & Hoskisson, 2003). Therefore, local government investments in physical infrastructure, education institutions, and innovation systems can contribute to the productivity growth of firms (Driffield et al., 2002). For example, a highly educated workforce may help foster the absorptive capacity of a firm with regard to the generation of new product ideas and the acquisition of new knowledge, thereby contributing to firm productivity (Lee and Lee 2022).

In sum, subnational regions within an economy tend to be heterogeneous in terms of institutional factors. Such heterogeneity provides firms with differential opportunities and constraints that shape the cost and return potential of their business activities and ultimately lead to performance differences. In the meantime, as Schumpeterian theory (Nelson, 1991; Winter, 2006) suggests, business firms tend to be heterogeneous, with their heterogeneity often persisting due to the limitation in learning and benchmarking. One source and dimension of firm heterogeneity has to do with their ownership, such as locally or foreign-owned firms. Given that

owners can also decide on how firms allocate resources in the process of production, the ownership types of firms should affect and alter their performance (Cuervo & Villalonga, 2000). Firms of different ownership types, namely, state, private, and foreign, may have different business goals and face different constraints. Such differences may result in different economic behaviors, particularly in the way institutions are exploited. Therefore, different ownership types can lead to different economic outcomes even though they face the same institutions (Lee and Lee 2022).

First, FOEs or affiliates of MNCs can access, and therefore share, technical and managerial knowledge of their parent companies located in their home or developed countries (Javorcik, 2004). According to the resource-based view of firm growth (Penrose, 1959), parent corporations in advanced economies have access to diverse resources within the firm, or they can easily acquire these resources from other firms, compared to firms in emerging economies (Mathews, 2002a). Thus, FOEs can bring a large portion of advanced resources from their parent companies to the production process in emerging economies, and this could be a source for their out-performance (Lee and Lee 2022).

However, FOEs have no strong desire to invest in regional resources transacted in local markets (Graham & Wada, 2001). Furthermore, MNCs, which are the parent companies of FOEs, invest and maximize profit on a global basis. Thus, MNCs tend to be more cautious with regard to huge long-term investments in a specific region than privately owned local enterprises (POLEs), which have roots in the area. On the one hand, MNCs can repatriate profits without expanding investment over time once they have successfully settled in their host countries (Seabra & Flach, 2005). On the other hand, MNCs tend to decrease their investment in a specific region in the long run if they lose location advantage because of rising wage rates or the lack of tax breaks (Dunning, 1998). FOEs may depend less on the subnational region in terms of acquiring the resources they need. For example, FOEs may not need to hire local human capital if they can bring in talented workforce from their parent companies.

Therefore, regional innovation systems and institutional development has minimal or less effect on FOE performance. The development of institutional factors in a region may also contribute to the performance improvement of FOEs (Lee and Lee 2022).

In comparison, POLEs, especially those in latecomer or emerging economies, tend to be lacking in diverse resources and competences for business (Mathews, 2002a). Thus, the main goal of firms in developing economies is to acquire these resources and to improve the availability of such resources over the course of firm operations. Therefore, profit is sought mainly to facilitate further the expansion of these resources (Lee & Temesgen, 2009). This type of backwardness is more serious for private firms than for SOEs and FOEs, which may have access to resources as a result of their networks with the state or parent corporations in their home countries. By contrast, POLEs must strive to fully exploit any available external resources (institutions) in a region because of the lack of support from the government or foreign parents (Xia & Walker, 2015). POLEs in China may have a high propensity to rely on the supply of resources from a subnational region (Nachum, 2000). Subsequently, the development of regional institutions and innovation systems may lead directly to the performance change of POLEs. For example, the evolution of market institutions allows POLEs to pay for the minimal costs associated with market transactions, which could have possible effects on the improvement of productivity over time (Lee and Lee 2022).

In summary, although the development of regional institutional factors is beneficial to all firms in the region regardless of ownership, POLEs are desperate and are likely to obtain more benefits because of their strong predilection for investing to acquire and benefit from regional resources in local markets. Thus, the effect of institutional development on a firm may vary depending on the type of firm ownership, because each type involves different incentives and business goals. So, my own study (Lee and Lee 2022) explore the hypothesis that institutional development is positively related to firm productivity and that the extent of the effect is larger in POLEs than in FOEs.

4.3.2 *Exploring the Hypothesis in the Context of China*

The subnational regions in China exhibit significant heterogeneity in institutional development (He, 2003). China comprises thirty-one subnational regions (twenty-two provinces, four municipalities, and five autonomous regions). Each region has its own market institution within which firms operate; meanwhile, each local government plays an important role in shaping the infrastructure, education, and innovation systems, as well as other public services in the region to stimulate regional economic development. Therefore, these regions tend to differ from one another in terms of the levels of institutional development, which exerts varying levels of influence on firms. Further, China has a unique industrial structure in which state-owned, private, and foreign-invested companies constitute a substantial portion of its economy in the twenty-first century (Bai et al., 2009; Sachs & Woo, 2001). Hence, testing the influence of such heterogeneity on firm productivity according to ownership type can be interesting and effective in the Chinese context. However, few solid empirical analyses of the effect of subnational institutions on performance of different ownership in China exist.[1] One notable exception is my own study, Lee and Lee (2022), and thus we present the main results of that paper in a summary form.

Lee and Lee (2022) use the Chinese Industrial Enterprises Database of the National Bureau of Statistics (NBS) of China, covering the period of 1998–2009, and include all industrial enterprises with annual sales of 5 million yuan or higher. Their descriptive table shows that in terms of labor productivity, the FOEs significantly outperformed the other types of firms on average, but the productivity gaps decreased continuously over time due to rapid catching up by privately owned local firms. The sales per worker of the POLEs in the sample increased from 202.1 Yuan RMB in 1998 to 568.8 in

[1] For instance, important works like Dollar et al. (2005), Chan et al. (2010), and Ma et al. (2013) have not dealt with the possibility of institutional effects varying according to ownership.

2009, whereas those of FOEs increased from 312.7 to 630.9 during the same period. The productivity gap decreased from 115.6 to 61.2. One reason behind the fast catching up by POLEs can be their different coevolution with surrounding institutions.

In Lee and Lee (2022), several dimensions of institutions are considered. The first set of institutional variables are about transportation (physical capital), high education (human capital), and invention patents (knowledge capital).[2] The second set is about market institutions, measured by the marketization index developed by the National Economic Research Institute (NERI) (Fan et al., 2011). The NERI index is a comprehensive catalog that captures regional market development in the following aspects: (1) the relationship between the government and the market, (2) the development of the nonstate sector in the economy, (3) the development of the product market, (4) the development of the factor markets, and (5) the development of market intermediaries and legal environment (Li et al., 2009). Measured at each province, three major regions of eastern, western, and central regions, as well as those for the entire country, all the average of these values exhibit an increasing trend over time, reflecting the rapid development of institutions in China.

4.3.3 Institutions Supporting Out-Performance of Local Firms over Foreign Firms

In Lee and Lee (2022), a robust econometric analysis is conducted to reveal the reason behind the differences in the relative performance of firms with different ownership types. The key interests are the effects of interaction between institutions and ownership, in addition to their separate effects. First, the benchmark results without

[2] First, we measure the development of physical capital through the expansion of public transportation, such as railways and highways. Our measure for each province is defined as the ratio of the total length of railway and highway to the gross area of the province. Second, this study determines the development of human capital through the number of college graduates per 10,000 population in each province. Third, the number of invention patents registered per 10,000 population in each province is used to represent the development of knowledge capital.

the interaction terms suggest that the coefficient of foreign ownership is positive and significant, indicating that foreign ownership alone has a bigger positive effect on firm performance as compared with private ownership. Second, the effects of the three institutional factors, namely, market development, human capital development, and physical infrastructure development, are all positive and significant as expected.

Finally, and most importantly, the results with the interaction terms of ownership dummies and institutional variables show that private ownership enjoys larger positive benefits from regional institutional development in comparison with the other types of ownership. For instance, the three institutional factors (human capital, knowledge capital, and physical infrastructure) are positive and significant for foreign ownership but these coefficients are all smaller than those for POLEs. Therefore, we can infer that POLEs tend to derive and enjoy larger benefits from the same institutional development in comparison with FOEs.

Figure 4.1 illustrates the dynamic effect of the interaction of ownership and institutional development on labor productivity. The graph shows the different sizes of the effects of institutional development by ownership type of firms, and the differences are shown by the different slopes of the two curves. The intercept term, referring to the initial level of productivity, is lowest for the POLEs but the slope is the steepest in POLEs, which reflects the larger effect over time of institutional development on POLEs than on FOEs or SOEs. In other words, the sizes of the curve slopes correspond to the capability of firms of diverse ownership to exploit the institutions.

Figure 4.1 also reflects well the coevolution of firms and surrounding institutions. That is, the productivity of the POLEs lags behind that of the FOEs or SOEs when the institutions are at low levels or in their early stages of development. However, POLEs gradually catch up with FOEs or SOEs as institutions develop over time because the POLEs have stronger capabilities to use and exploit the institutions than FOEs or SOEs; hence, POLEs eventually overtake FOEs or SOEs.

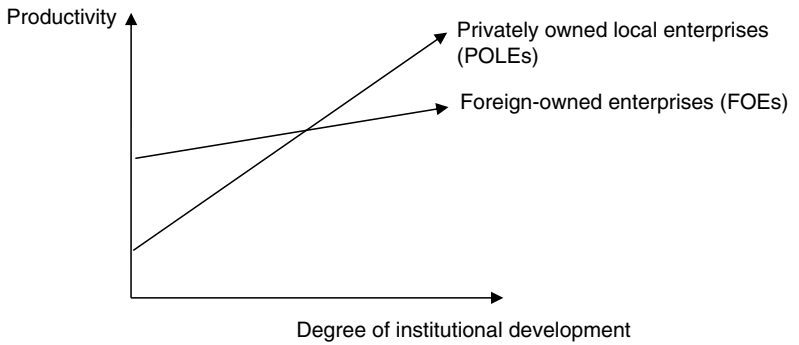

FIGURE 4.1 Productivity catch-up by interaction of firm ownership and surrounding institutions
Notes: adaptation of a Figure in Lee and Lee (2022).

The aforementioned results are consistent with the reasoning that POLEs tend to utilize the development of institutions more effectively and seize new business opportunities well. Local ownership translates into stronger incentives and capabilities to exploit regional institutions than other types of ownership. This capability comes from the strong incentive of local private ownership to exploit regional resources for profit and growth. FOEs have less need to exploit local institutions in comparison with POLEs because the former can rely on their parent companies abroad when seeking a large portion of productive resources; thus, they are not deeply rooted in the local economy. In comparison, SOEs are typically under government protection and network with bureaucrats; thus, they have fewer reasons to try to exploit the institutional development in their locality.

The results suggest that the influence of institutional factors on firm performance depends not only on the ownership type of a firm but also its interaction with institutions. In this light, these results may have some policy implications. Any one-sided promotion of institutional development or private entrepreneurship (start-ups) cannot be effective in fostering economic growth because these two elements tend to evolve together. On the one hand, private firms cannot prosper without sound institutions. On the other hand, institutional development is useless unless there exist private firms

that can benefit from this development. Also, the results imply that POLEs may outperform FOEs in the long run as long as there is sound and steady development of diverse institutions including innovation systems, and thus they can be relied upon as a long-term determinant of economic growth.

4.4 CORE FIRM LEADING THE GROWTH OF A REGION: TSMC IN HSINCHU

National-level analysis in Chapter 2 discusses the idea of detour in two dimensions. One is a detour of first specializing in short TT sectors before going into long-CTT sectors at a later stage, and the other is that of becoming more centralized during the catching-up stage as innovation tends to be led by big businesses rather than a large number of SMEs. Thus, an important element of an imbalanced pathway of catching up is the nonlinear pattern of transitional specialization into short CTT sectors led by big businesses. A necessity for big businesses was to find a vehicle to circumvent entry barriers to high-end and value-added segments by seeking niches and mobilizing resources and competences. This section explores this issue further, now at the level of a region, exemplifying the growth of Hsinchu City led by the emergence of a core firm, TSMC.[3]

4.4.1 Innovation Systems of Industrial Districts

Centered on the question of why innovation activities and economic development are unevenly distributed over space (Asheim et al., 2019, p. 1), many studies have investigated industrial districts and RIS. Markusen (1996) and Park (1996) are two noteworthy classic works on the typologies of the industrial district. They focus on the interfirm network in the governing productive activities in a region. Markusen (1996) presented several industrial network structures, such as Marshallian, HaS, and satellite platform

[3] This section is a summarized account of the case of TSMC using the detailed information in a study by Wong and Lee (2021).

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districts. The Marshallian district demonstrates high resiliency in sustaining the dynamics of productive activities because it primarily consists of small firms that often engage in cooperative competition (Markusen, 2003). By contrast, HaS districts, such as Toyota City in Japan, are led by a small number of large firms as the magnet for smaller firms that want to utilize proximity to resourceful anchored tenants. The satellite platform district consists of SMEs that supply diverse MNCs clustered in a region. The key players of the three structures comprise many firms, a few large firms, and firms supplying to MNCs, respectively.

Given our interests in the characteristics of the RIS of Hsinchu, a catching-up region in emerging economies, we combine the district typologies with the analyses of the innovation systems to identify the innovation-related counterparts that differentiate the dynamics of the industrial districts. In this sense, we are not only interested in the features of a Marshallian or HaS industrial district but rather in Marshallian or HaS innovation systems, specifically the patterns of knowledge creation and diffusion among firms and their concentration or decentralization. Such focus is justifiable because the firms in catching-up Asia have emerged not only as producers or suppliers but also as innovators that offer state-of-the-art technologies.

Given that Hsinchu is populated by SMEs, we may say that Hsinchu resembles a Marshallian network. Actually, Hsinchu shows a high degree of cooperation/linkages among local firms. An intriguing question then regards dynamic transformation and the possibility of convergence, namely, whether a tendency exists toward a gradual convergence to a HaS type of RIS, and to what extent it is associated with an increasing dominance by the core firm (TSMC) or ever higher levels of concentration in tems of innovator distribution. As the core firms continue to grow to reach the technological frontier, they tend to become responsible for a dominant share of innovation activities in the region while increasing the degree of self-citations and strengthening the linkages with nonfirm actors (e.g., universities or scientists). Such a possibility of eventually changing types

of industrial districts is consistent with the early observation by Park (1996) on the emergence of the "advanced HaS" type from the Marshallian type.

4.4.2 Evolution of Hsinchu toward Centralization by a Leading Firm

The establishment of Hsinchu as a high-tech region originated from the plan of the National Science Council of Taiwan to construct the Hsinchu Science and Industrial Park (HSIP) in 1980, which envisions a tripartite collaboration between industry, academia, and government research institutes, such as the ITRI (Wong et al., 2015). Since its construction in 1980, HSIP has witnessed how six industrial sectors, namely, ICs, personal computers (PCs) and peripherals, telecommunications, optoelectronics, precision machinery, and biotechnology, formed a self-sufficient and closely integrated value chain from R&D to mass production (Hu, 2011). This origin can serve as a basis to propose that Hsinchu resembles the Marshallian district more than the HaS one. However, the semiconductor sector (IC chips) has replaced the PC and peripheral sectors since the 1990s as the core sector. The former has eventually become the focal sector of HSIP, dominating in terms of the number of employees and sales since the 2000s (Hu, 2011).

The rise of the semiconductor sector in Hsinchu is not simply a natural progression but was rather caused by the targeted promotion of this industry at the national level in the early 2000s under the "Two Trillion and Twin Star Project." In 1970, the government and pragmatic technocrats and entrepreneurs envisioned that the established semiconductor companies abroad would promote a fabless[4] business structure because globalization and offshoring movement were then gaining momentum. Therefore, they aspired to make Hsinchu the foundry hub for global fabless firms in

[4] Fabless manufacturing is the design and sales of hardware devices and chips while outsourcing their fabrication (fab) to a specialized manufacturer called a foundry.

the semiconductor production value chain. The government allocated ample resources to ITRI and two other research universities in Hsinchu to develop such capabilities and niches. In the 1980s, the segmentation detaching foundries from integrated device manufacturers was realized, and the firms that invested in foundry businesses in HSIP were then contracted to supply fabrication services to foreign firms in advanced countries.

Taiwan used its networking assets and mobilized its social capital to commit to specialized assets (i.e., sources of finances and technical skill) to develop a "pure-play" foundry[5] (Yeung, 2016, p. 138) and encouraged associated industries to realize an active ecosystem. These efforts led to the founding of TSMC as a spin-off in 1986 from ITRI as a joint venture with Philips as well as other fabless firms that provide designs and chips for telecommunication and multimedia products. As the firms gained sufficient capabilities to upgrade and mature, ITRI evolved as a platform that coordinates collaborative research and establishes R&D consortiums for new industries. Actually, laboratories of ITRI had acted as the prime vehicle for leveraging and modifying advanced technologies from abroad, and these technologies were effectively diffused among various Taiwanese firms including TSMC (Amsden & Chu, 2003, Mathews, 2002b). Thus, a patent citation analysis for the 1990s shows a high citation tendency of TSMC and United Microelectronics Corporation (UMC) to the patents held by ITRI (Lee & Yoon, 2010).

However, the rise of TSMC to global prominence occurred ten or fifteen years after its spin-off from the ITRI, which could be attributed to the firm-specific innovation effort beyond the initial government promotion in the 1980s (Yeung, 2016, p. 140). Specifically, between the two dominant firms, TSMC and UMC, TSMC eventually significantly outperformed UMC in revenue and technology capabilities after the mid-2000s. Such performance is attributable

[5] Pure-play foundry means a company that does not design but operates fabrication plants for other companies.

to the technological breakthrough TSMC made in 2005, unveiling its manufacturing capability in commanding 90-nm node process technology in 12-inch semiconductor wafer production. By contrast, other competing firms in Taiwan and abroad were operating via 0.5-micrometer (μm) to 110 nm process technology.[6] In sum, such development of the IC sector, which is led by TSMC, has been the driving force for Hsinchu to evolve toward a HaS structure.

Increasing dominance of TSMC in the region can also be captured by looking at the distribution of patents in the region. Except in the early years, the share of TSMC in the total number of US patents filed by the region was flat at 7% for most of the 2000s, when it faced regional competitors, such as UMC. TSMC eventually emerged as the frontrunner after the global financial crisis in 2008 and dominated the region, owning approximately 30% of the total patents in Hsinchu in 2017. Such a tendency toward centralization in innovation is consistent with the hypothesis that Hsinchu is shifting toward the HaS structure despite being a close Marshallian type prior to the 2000s or before the rise of the semiconductor sector as the main industry in the region (Hu, 2011). We can also discuss this observation in terms of the value of HHI (Herfindahl–Hirschman Index), which is a conventional measure of concentration used in analyzing NIS or RIS. Initially, the HHI level of Hsinchu is comparable to San Jose in the Silicon Valley area or 0.02 in 2018 (Wong et al., 2021). Later, Hsinchu showed a trend of increasing concentration, reflecting the increasing dominance of the core firms. For instance, the value of HHI hit the bottom at less than 0.05 in the late 2000s; then, it kept increasing in the 2010s and approached 0.20, which is a big jump.

4.4.3 Doubling Upgrading of the RIS Led by a Core Firm

Such a trend of centralization does not need to be considered bad, because it is accompanied by the upgrade of Hsinchu from a peripheral to a catching-up RIS at both the dimension of the leading firm

[6] See Wong and Lee (2021).

and the region excluding the core firm. First of all, as shown in Table 4.2, the number of US patents increased a couple of times from the early 2000s to the early mid-2010s in both the region and the region excluding the core firms; from 2,431 to 5,063 in the region excluding TSMC, and from 901 to 3,838 by TSMC.

Most importantly, in view of the literature on the peripheral RIS with a low level of regional embeddedness, upgrading or catching up of RIS in Hsinchu has been explained in terms of the reduction of reliance on external knowledge or increasing localization of knowledge creation and diffusion, which is further accompanied by increasing reliance on new sources of knowledge, such as scientific articles (science-based-ness) and universities (university–industry linkages). Specifically, in terms of upgrading in knowledge sourcing, not only the core firm but also the region excluding the core firm has realized increases in all the three dimensions of localization (over the 1990s to the 2000s period), university–industry linkages, and science-based-ness.

For instance, the degree of localization (share of local citation in total citations) in "Hsinchu without TSMC" has increased from an average of 5.3% in the 1995–1997 period to an average of 9.3% in the 2000–2002 period, whereas it remained around that level (or 8.3%) in the 2016–2018 period (Table 4.2). The corresponding numbers for TSMC are 3.6% in the 1995–1997 period, 7.8% in the 2009–2012 period, and 6.4% in the 2016–2018 period. In terms of science-based-ness measured by the share of patents citing one or more scientific article, the degree in the region excluding TSMC has increased from an average of 13.6% in the 2000–2002 period to 39.0% in the 2016–2018 period. In the case of TSMC alone, the increase was from 14.8% in the 2002–2002 period to 40.6% in the 2016–2018 periods.

Technological diversification has also increased at both levels of the core firm and the region excluding the core firm. The numbers indicating diversification have increased from an average of 0.26 in the 2000–2002 period to an average of 0.32 in the 2016–2018 period

Table 4.2 *Comparison of the core firms and the regions without the core firms, 2000–2002 and 2016–2018*

	Hsinchu	Hsinchu without TSMC	TSMC	Suwon	Suwon without Samsung	Samsung
1. Patent counts (filed in the United States)						
Total count: 2000–2002	4,846	2,431	901	1,772	116	1,581
Total count: 2016–2018	13,286	5,063	3,838	11,465	1,036	9,260
2. Localization of knowledge creation and diffusion						
Average of 1995–1997	0.036	0.053	0.036	0.00	0.00	0.01
Average of 2000–2002	0.075	0.093	0.078	0.001	0.003	0.032
Average of 2016–2018	0.060	0.083	0.064	0.032	0.046	0.042
3. Concentration of innovations (assignees): HHI						
Average of 2000–2002	0.09	0.096	–	0.826	0.336	–
Average of 2016–2018	0.13	0.02	–	0.67	0.15	–
4. University–industry linkage (share of patents with both firms and universities as co-assignees)						
Average of 2000–2002	0.00	0.00	0.00	0.00	0.00	0.00
Average of 2016–2018	0.007	0.003	0.003	0.022	0.006	0.016

5. Science-based-ness (share of citations with more than one citation to scientific articles)						
Average of 2000–2002	0.147	0.136	0.148	0.126	0.16	0.127
Average of 2016–2018	0.405	0.39	0.406	0.493	0.453	0.500
6. Cycle time of technologies (backward citations lags in years)						
Average of 2000–2002	5.15	5.92	4.77	6.52	8.16	5.65
Average of 2016–2018	7.98	10.04	7.19	7.94	11.963	6.51
7. Technological diversification (no. of classes a region has filed patents divided by the total number of 3-digit patent classes)						
Average of 2000–2002	0.316	0.256	0.07	0.22	0.056	0.186
Average of 2012–2014	0.343	0.32	0.073	0.316	0.153	0.246

Notes: The concentration (HHI) for Suwon considers Samsung Group as one of the top five assignees.
Source: Adaptation of Table 4 in Wong and Lee (2021)

at the level of the region without the core firm. In the case of the core firm, TSMC, the degree of technological diversification has increased from 0.070 to 0.073 during the same period.

If upgrading happens only at the core firms, it may not be called a proper upgrading. However, in Hsinchu, both the surrounding regions and the SMEs have experienced upgrading. Notably, Hsinchu without its core firm, TSMC, displays higher specializations in long-cycle technologies (associated with parts and components), distinct from the core firm specializing in short-cycle technologies (developing, assembling, and producing IC chips). Such growth of SME suppliers to the core firm with a different technological specialization from the core firm seems to have been possible because ITRI provided them with various technical services, consultancy, licensing, and workforce training; it also played an important role in fostering domestic industrial competencies by linking SMEs with large foreign corporations (Fuller, 2005; Mathews & Cho, 2000, pp. 258–259; Wong et al., 2015).

Given that such upgrading of the whole region has accompanied the region's centralization over the distribution of innovators, this mode of the RIS may not be called a mature RIS which is characterized by a more even or dispersed distribution of innovation but can be called a catching-up RIS along an imbalanced development path discussed in Chapter 2. Such conceptualization of an imbalanced mode of catching-up RIS is consistent with the idea of the two alternatives: balanced and imbalanced modes of catching-up NIS discussed in Chapter 2, which revived the classic debate on imbalanced development (Hirschman, 1958), in contrast to the balanced development of Nurkse (1953). In this sense, this study has identified at least one viable path of upgrading RIS in emerging economies. In such a mode of imbalanced RIS, upgrading may happen not necessarily through globalization associated with foreign direct investments or MNCs but through the emergence of large indigenous firms, although they have learned from MNCs at their early stage.

4.5 FIRM-LEVEL CONVERGENCE MATCHING THE MACRO-LEVEL CONVERGENCE: KOREAN FIRMS

4.5.1 How to Measure and Analyze the Firm-Level Innovation Systems

While the literature on innovation systems tends to focus on the national or sectoral level, one can also conceptualize and analyze corporate innovation systems (Granstrand, 2000). For instance, we can use the same variables measured at the level of a nation to analyze the firm-level innovation system as has been done in Lee (2013c, Chapter 5). Such extension is consistent with Schumpeterian theory of firms discussed in the research of Winter (2006) and Nelson (1991, 2008a, 2008b), which emphasizes the heterogeneity of firms and considers knowledge and imperfect learning as sources of interfirm heterogeneity. Given such emphasis on the knowledge base or innovation systems of firms, this section looks at several quantitative expressions of various aspects of the knowledge base of firms so that they may reveal the changing behavior and performance of South Korean firms. These knowledge-related variables are indicators of the nature of the knowledge pool each firm utilizes for its innovation and other activities. The property of the knowledge base thus relates to the firm-level innovation system underpinning the innovative activities of a firm.

Given our focus on catching-up firms, we address the aspects of knowledge that are shown to be markedly different between advanced and catching-up firms. Following Lee (2013c, Chapter 5), key variables are the CTT, self-citation (intra-firm creation and diffusion of knowledge), technological diversification, and originality. These variables are used to investigate their relationship with firm behavior and performance. Among them, we are particularly interested in the following two variables.

The first focal variable is CTT, which is about the speed of change in the knowledge base of technologies, and a short cycle time means a quick speed of change and thus means the underlying knowledge tends to be quickly outdated or becomes obsolete over

time. The average CTT of a firm can be measured as the average time difference between the application year of the cited patent and of the citing patents which are owned by a firm (Jaffe & Trajtenberg, 2002). A sector-level analysis by Park and Lee (2006) found that technological catch-up tends to occur in sectors with a shorter cycle time, whereas advanced countries tend to be dominant in sectors based on long-cycle technologies (Lee, 2013c, Chapter 3). The firm-level analysis in Lee (2013c, Chapter 5) found that catching-up (Korean) firms tend to specialize in short-cycle technologies, which also lead to higher profitability. This is because short CTT on average means that such firms rely less on average on the old stocks of knowledge of which the patent rights are owned and dominated by the incumbent. Accordingly, the latecomers may avoid direct competition, or IPR disputes, with incumbents, and may find a niche, thus avoiding competing in the same markets. In other words, it makes more sense for the latecomer firms to conduct innovation relying on more recent technologies than the old technologies occupied by the incumbents.

Specifically, for the Korean and US companies in the 1990s, short CTT specialization had a significantly positive effect on Korean firms' performance but not on those of the United States, because US firms or advanced firms need not identify a niche in such short CTT but tend to be more diverse in their patent portfolio. Thus, if Korean firms became similar in the 2000s or 2010 to US firms and commanded a more diverse patent portfolio in diverse sectors, their profitability would also have been less affected by CTT as in the case of US firms.

The second focal variable is that of self-citations in Korean firms. The ratio of self-citation at the sector level represents appropriability, namely, the capability to protect one's innovations from being copied by others and thus monopolize profits from the innovation (Trajtenberg et al., 1997). By contrast, self-citation at the firm level is the degree to which the innovation of a firm builds upon its accumulated knowledge pool. In general, the literature

finds that the more advanced or older the firm, the higher its patent self-citation ratio, or its self-citation can be a measure of technological capabilities, which is confirmed by comparing Samsung with Sony (Joo & Lee, 2010) and Huawei with Ericsson (Joo et al., 2016). In fact, Lee (2013c) found that self-citation ratios are much higher in US firms than in Korean firms, and they tend to have a significantly positive effect on firm performance (firm values) in US firms; conversely, such is not the case for Korean companies with a very low ratio in the 1990s. Then, if Korean firms have become similar to, or technologically as strong as, US firms over time, we may hypothesize that the self-citation ratio must have increased in Korean firms and should have a significant impact on firm performance, particularly firm values.

In summary, if Korean firms had entered the convergence phase in the 2000s or 2010s, the effect of CTT on corporate performance should be positive or insignificant. By contrast, it was negative in the 1990s. Next, whereas the self-citation ratio was insignificant to the performance of Korean companies in the 1990s, it is expected to be positive and significant for firm values from the 2000s onwards.

4.5.2 The Trend of CTT and Self-Citations and Their Effect on Firm Performance

If we investigate the trend of key innovation system variables of Korean firms since the 1990s and later, we can notice a clear-cut trend of continued catching up and even convergence, which is well presented in Im and Lee (2021). First, the average number of patents filed by each firm has shown a substantial increase since the 1990s, from less than 50 per firm in the early 1990s to more than 150 per firm in the 2000s and 2010. Second, the average ratio of self-citations has also notably increased about four times, from less than 2% in the early 1990s to approximately 8% by the mid-2010s. As discussed in Lee (2013c, Chapter 5) and Joo et al. (2016), high self-citation represents one aspect of strong technological capabilities. In fact, the level of 8% in the 2010s is somewhat close to the average level

(12%) of US firms in the 1990s according to the information in Lee (2013c, Chapter 5). Thus, this increasing number of patents per firm and increasing trend of self-citations reflect the increasing levels of technological capabilities of Korean firms over time.

Third, the trend of the average CTT of Korean firms has increased from six or seven years in the early 1990s to nearly twelve years in the 2010s, although some changes have occurred in recent years. Overall, this finding indicates that Korean firms have substantially reduced the degree of former specialization into short CTT-based sectors. The nearly double increase over a period of time can be considered a big change, although it might also reflect, to a certain extent, the increasing trend of CTT over time and over the nationality of firms as analyzed in Lee and Lee (2021b).

Table 4.3 presents the average values of key innovation variables of firms and their change over time in the three sub-periods of the 1990s, 2000s, and 2010s. The statistically significant changes over time are confirmed with regard to the two focal variables of self-citations and CTT. The subsequent regression analyses also showed that these two variables are the main drivers of change affecting the performance and behavior of Korean firms and their innovations.

We can discuss the regression results as reported in Im and Lee (2021) on the impacts of the CTT and self-citations on the two measures of firm profitability (return on assets and return on sales). The variable of the CTT is noteworthy and important. The CTT is shown to be negative and significant in the 1990s but insignificant in the 2010s. That is, the results for the 1990s are identical to the results for the Korean firms in Lee (2013c), but the results for the 2010s have become similar to those for the US firms in the 1990s as reported in Lee (2013c). An interpretation is that Korean firms have discontinued their earlier strategy of focusing just on short CTT for niche areas but are now more diversified in the 2010s. This find is consistent with what we hypothesized as one aspect of convergence of the Korean firms toward US firms.

Table 4.3 *Trends of innovation variables of the Korean firms over the three periods*

Variables	Mean value			T-test of the gap between periods: mean difference	
	sub-period 1: 1990–1996	sub-period 2: 2001–2006	sub-period 3: 2010–2015	Period 2 - period 1	Period 3 - period 1
Technological specialization (inverse of diversification)	0.601	0.483	0.516	–0.118**	–0.085*
Originality	0.333	0.343	0.268	0.01	–0.065**
Self-citation ratio	0.026	0.058	0.070	0.032**	0.045**
Cycle time (years)	8.815	9.797	13.385	0.982*	4.570**

** $p < 0.01$, * $p < 0.05$, + $p < 0.1$.

Note: Technological specialization is HHI over technological classes of the patents filed by firms and therefore an inverse of technological diversity of firms' patent portfolios.

Source: Adaptation of Table 7 in Im and Lee (2021)

The regression results for the determinants of firm values measured by Tobin's Q are also interesting with regard to the key innovation variable of self-citation. The variable of the self-citation ratio is now shown to be positive and significant in the 2010s whereas it was insignificant in the 1990s or 2000s. The results for the 2000s are a continuation of the results for the 1990s reported in Lee (2013c), whereas the latter part for the 2010s is consistent with the results for the 1990s US firms reported in Lee (2013c). The fact that the self-citation ratio now shows a positive effect on Korean firm value in the 2010s is indicative of the convergence of behavior of Korean firms toward US firms in terms of their level of technological capabilities and their importance in firm values. The results that the variables of self-citations are insignificant as a determinant of firm growth are also consistent with the US firm results reported in Lee (2013c).

4.5.3 A Partial Convergence?

The overall picture emerging from the preceding part is a thesis of ongoing convergence of Korean firms toward US firms. With a marked increase in self-citations and CTT occurring over time in Korean firms, the relationship between innovation variables and profitability and firm values in Korea has now become similar to that in the United States in the 1990s. In other words, we find some important evidence of convergence, such as no significant relationship between (short or long) CTT and firm profitability and a significant relationship between higher self-citation and firm values. This new pattern is exactly the same pattern found in US firms for the 1990s by Lee (2013c), which is a reflection of an increasing level of technological capabilities of Korean firms and is indicative of convergence in the innovation system of Korean firms. This aspect of convergence is also a deviation from the typical pattern of catching-up firms in the 1990s discussed in Lee (2013c, Chapter 5) when Korean firms sought niche-based strategies for profitability by specializing in short CTT, and their technological capability represented by self-citation is too low to significantly affect firm values. The unfinished part comes

from the finding that although Korean firms are shown to be diversifying into non-short CTT-based sectors, their growth mechanism is still shown to have not considerably changed, still relying on fixed investment associated with a high capital–labor ratio rather than technological capability associated with self-citations.

The trend of firm-level changes in Korea analyzed in this chapter is consistent with the country-level pattern discussed in Chapter 2. Additionally, the finding of Lee and Lee (2021a) indicates that the economic growth (per capita income) of Korea is now positively associated with long CTT of the country, as it is now moving toward long CTT-based sectors, such as biomedicines and bioproducts and high-tech materials and components. Given that the overall level of CTT in Korea (nine years) remains notably shorter than that of Germany (twelve years) (Figure 1A in Lee & Lee, 2021a), the shift toward long CTT continues to be an ongoing process. Interestingly, this gap between Korea and Germany in average CTT is somewhat similar to their gap in per capita GDP in PPP terms such that per capita GDP of Korea has now reached the 70% level of the United States, whereas that of Germany is approximately 85% of the United States according to the more recent data from the IMF released in 2021.

4.6 SUMMARY AND CONCLUDING REMARKS

This chapter deals with the question of alternative pathways for latecomers' firms in their coevolution with regional or national innovation systems. Thus, it takes up a similar framework from the national level proposed in Chapter 2 and modifies it for the firm-level analysis.

Specifically, the first question at the firm level is about whether latecomer firms use "similar or different" technologies compared with that of incumbents. The discussion in Section 4.2 shows from the cases of latecomers overtaking incumbents in market shares that such market overtaking involved technological overtaking in terms of quantity and quality of patents as well as the level of technological capabilities (proxied by self-citations) and mutual dependency

measured by mutual citations. We also find that the average CTT of latecomers' patents tends to become shorter than that of incumbents, which reflects their strategy of seeking niche areas different than those occupied by incumbents in long-CTT sectors.

Section 4.2 of this chapter deals with the important issue of coevolution of firms and surrounding institutions with an example of the Chinese context. It shows that POLEs tend to exploit the benefit from regional institutions rather than other types of ownership. This capability comes from the strong incentive of private local ownership to exploit regional resources for profit and growth. FOEs have less need to exploit local institutions in comparison with POLEs because the former can rely on their parent companies abroad when seeking a large portion of productive resources; thus, they are not deeply rooted in the local economy. The implication is that any one-sided promotion of institutional development or private entrepreneurship (start-ups) cannot be effective in fostering economic growth because these two elements tend to evolve together, and that POLEs may outperform FOEs in the long run, as long as there is sound development of institutions including regional or sectoral innovation systems.

Section 4.4 of this chapter discusses the role of the leading firms in a region going through the detour of centralization first or during the catching-up stage, probably to be followed by decentralization at a later stage, which is also an important element of an imbalanced pathway of catching up. The focus region is Hsinchu City in Taiwan, led by emergence and eventual dominance of a core firm, TSMC. Rapid development of the IC sector led by TSMC has been the driving force for Hsinchu to evolve from a decentralized Marshallian district in the 1990s toward a more centralized structure or HaS type since the 2000s. Such a trend of centralization does not need to be considered bad, because it is accompanied by the upgrade of the entire Hsinchu City. Specifically, in view of the literature on the peripheral RIS characterized as a low level of regional embeddedness, upgrading or catching up of RIS in Hsinchu has been documented in terms of the reduction of reliance on external knowledge or

increasing localization, which is further accompanied by increasing reliance on new sources of knowledge, such as scientific articles and universities. Given that such upgrading has happened at the expense of increasing the region's centralization over the distribution of innovators, this mode of the RIS may not be called a mature RIS with more even or dispersed distribution of innovation but can be called a catching-up RIS along an imbalanced development path as discussed in Chapter 2.

Such conceptualization of the imbalanced mode of catching-up RIS is consistent with the idea of two alternative, balanced and imbalanced, modes of catching-up NIS discussed in Chapter 2, which revived the classic debate on imbalanced development (Hirschman, 1958), in contrast to the balanced development of Nurkse (1953). In this sense, this study has identified at least one viable path of upgrading RIS in emerging economies. In such a mode of imbalanced RIS, upgrading may happen not necessarily through globalization associated with continued dominance of FDI or MNCs but through the emergence of large indigenous firms, after they have learned from MNCs at their early stage. The role of big businesses in such upgrading can be understood as a vehicle to circumvent entry barriers to high-end and value-added segments by seeking niches and mobilizing resources and competences.

Finally, this chapter in Section 4.5 has dealt with the question of whether behavior and performance of catching-up firms would become similar to those of mature firms in advanced economies as they build up technological capabilities over time. Given that Chapter 2 has discussed the national-level detour or eventual convergence, a remaining issue is the match between the firm- and national-level innovation systems as discussed here. Based on the Schumpeterian theory of firms, Section 4.5 analyzes the innovation systems of Korean firms as a representative of catching-up firms to determine that their behavior has changed from the 1990s to the 2010s, indicating an ongoing process of convergence toward US firms. With a marked increase in average self-citations and CTT

occurring over time in Korean firms, the relationship between innovation variables and profitability and firm values in Korea has now become similar to that in the United States in the 1990s. In other words, we find some important evidence of convergence, such as no significant relationship between (short or long) CTT and firm profitability and a significant relationship between higher self-citation and firm values. This new pattern is exactly the same pattern found in US firms by Lee (2013c).

This change is a reflection of an increasing level of technological capabilities of Korean firms and is indicative of convergence in their innovation systems. This aspect of convergence is also a deviation from the typical behavior of catching-up firms in the 1990s discussed in Lee (2013c, Chapter 5) when Korean firms sought niche-based strategies for profitability by specializing in short CTT, and their technological capability represented by self-citation is too low to significantly affect firm values. The trend of firm-level changes in Korea is consistent with the country-level pattern that the economic growth (per capita income) of Korea is now positively associated with long CTT of the country, as it is now moving toward long CTT-based sectors, such as biomedicines and bioproducts and high-tech materials and components.