6

Republic of Korea

KEUN LEE AND HOCHUL* SHIN

6.1 Introduction

With the arrival of the knowledge-based economy, universities and public research institutes have emerged as key components of the national innovation system (NIS). According to Freeman (1987), the NIS is "a network of institutions in the public and private sectors whose activities and interactions initiate, import, modify, and diffuse new technologies." In the NIS literature, one role of universities and public research institutes is to channel their knowledge into firms. Universities also diffuse knowledge by producing quality students and interacting with firms through cooperative programs.

One of the most important characteristics of the Republic of Korea's NIS is the "twin dominance" (Eom and Lee 2010) of big businesses (*chaebol*s) and the government. This implies a relatively weak role for universities and small and medium-sized enterprises (SMEs) (Kim 1993; Lim 2006; Cho et al. 2007). For instance, universities and industry employ around 70 percent and 20 percent, respectively, of all doctorates in the Republic of Korea and yet, paradoxically, universities conduct only 10 percent of research activities in the country, while industry conducts 77 percent (OECD 2008). Additionally, as of 2005, 39.7 percent of researchers and 52.2 percent of PhD researchers were employed by the top twenty firms (Eom and Lee 2010).

While big business groups have dominated the Republic of Korea's NIS through their large in-house R&D since the mid-1980s, the government and public research institutes and universities initially led the country's NIS during its early takeoff period in the 1960s and 1970s. In the 1970s, the Republic of Korea was in transition from light to heavy and chemical industries, but its national R&D base was weak. The government developed its national R&D capacity by setting up public research institutes and universities. Several were established based on the Special Research Institute Promotion Law of 1973 in the fields of machinery, shipbuilding, chemical engineering, marine science, and electronics. From the mid-1970s, chaebol firms started to grow rapidly and enter heavy and chemical industry. Afterward, the government played a significant role by providing a selected number of big firms with privileges such as concessional bank loans and exclusive access to foreign exchange. Even in the 1980s and 1990s, big business groups were aided by government-led public–private research consortia in achieving key R&D goals, with examples such as the development of TDX (a system of telephone switches), memory chips, and digital TV projects (Lee and Lim 2001; Lee et al. 2005). According to a study by the OECD (2003), the Republic of Korea is the only country in which public research institutes play a more important role in national R&D than do the universities themselves.

In contrast to public research institutes, universities have played a minor role in boosting the R&D performance of the private sector in the Republic of Korea. Big private firms relied more on foreign knowledge sources than local sources and universities, as they wanted to hire quality scientists and engineers from abroad or acquire technology in collaboration with foreign partners. Kim (1993) argues that the lack of interaction between university and industry, due to the teaching-oriented nature of Korean universities, is one of the greatest weaknesses of the country's NIS. Research has received increasing priority in universities in the Republic of Korea only since the 1990s. For example, while Korea ranked nineteenth overall in terms of the number of Science Citation Index (SCI) papers in 1996, universities accounted for 83.0 percent of contributions (Lee 1998).

From the late 1990s, the policy agenda shifted to encourage the entrepreneurial role of universities in expanding national technological capability. The Technology Transfer Promotion Act 2000 symbolizes this growing interest in knowledge transfer from public science. The Act stipulates that public universities should establish units or institutions, such as knowledge transfer offices (KTOs), charged with knowledge transfer and training specialists. Promotion of university–industry cooperation gained further momentum with the Act on the Promotion of Industrial Education and Industry–University Collaboration 2003. While there were only seventeen KTOs in 2003, their number increased rapidly after that, especially in 2004, when 263 more were created

(KRF 2016). By 2014, 356 universities – about 84 percent of the country's total – had established KTOs.

The main aim of this research is to explore the progress of the knowledge transfer system following these policy initiatives. Early assessments, such as that of Eom and Lee (2010), found that knowledge industrialization in the Republic of Korea remained at an early stage compared to advanced countries. Specifically, while government initiatives had had some nominal success (e.g., in generating more patents), such generated knowledge had not been successfully commercialized. Our research suggests that the situation has barely improved from the situation described in Eom and Lee (2010). Further, we argue that one source of the problem is the Republic of Korea's legacy of success with the twin dominance of big businesses and government dominating the process of economic catch-up, which has meant that both the manner and extent of knowledge commercialization have not fully accommodated or embraced the needs and specificities of SMEs and universities. Thus, SMEs tend to complain that organizations and university technologies are unsuitable for their conditions. Conversely, university KTO offices are very weak in terms of financial and human resources, leading to underutilization or under-commercialization of relatively good quality research outcomes from university professors.

The rest of this chapter is organized as follows. Section 6.2 reviews the policy changes since 2000 that were designed to improve knowledge transfer from public research institutes. Section 6.3 focuses on the overall performance of knowledge transfer activities in public research institutes. Section 6.4 identifies the important knowledge transfer channels in the Republic of Korea and presents some examples of them. Section 6.5 reviews the challenges that government policy and public research institutes face in achieving successful knowledge transfer. Section 6.6 provides conclusions.

6.2 New Policies to Improve Knowledge Transfer from the Public Research Base

The Technology Transfer Promotion Act 2000 was the first law to encourage knowledge transfer from the public sector research base. It required public research institutes and public universities to establish KTOs and allowed the government to financially support university KTOs. The Act specified that public research institutes and university researchers were eligible to obtain a portion of the income from

https://doi.org/10.1017/9781108904230.015 Published online by Cambridge University Press

knowledge transfer, providing researchers with an incentive for knowledge transfer and commercialization. This became possible because, as with the Bayh-Dole Act in the United States of America (U.S.), it allowed universities to retain ownership of IP from government-funded research.

In addition, Korea Technology Exchange was founded by the 2000 Act to manage the knowledge transfer market and mediate knowledge transfer. It also provided various services such as technology evaluation and support for technology transfer agents. The 2000 Act created a system of technology transfer agents: a person who satisfies standard qualifications, such as an experienced lawyer or a government official, can be authorized as a technology transfer agent by the government if he or she completes a specific curriculum.

The Act on the Promotion of Industrial Education and Industry–University Collaboration 2003 deemed that most universities should have KTOs and could establish and run a for-profit "university company" using technology that they had developed, thus enabling direct commercialization.

The Technology Transfer and Commercialization Promotion Act 2006 focused more on commercialization than knowledge transfer. It required the government to include a budget for commercialization in R&D funding. Previous laws had provided that R&D funding was to be mainly used for technology development rather than commercialization; the new Act changed that. Accordingly, part of the expenses of KTOs were to be provided by the government, equating to 29 percent in 2014. Public research institutes received more government funding than did universities: 38 percent of the expenses of public research institute KTOs came from government while the figure for universities amounted to only 14 percent.

The 2006 Act allowed public research institutes to establish technology holding companies if they developed cutting-edge technology. These holding companies were allowed, in turn, to establish subsidiaries using their technology; such subsidiaries include incubating, business consulting, and funding to improve technology commercialization. Researchers or staff could take leave to work at the technology holding companies.[1]

The law also specified that KTOs should receive more than 10 percent of total license income. Public research institutes were allowed to invest in forms of technology if authorized institutes such as the Korea Institute

[1] Conversely, it is not easy for Korean researchers to take leave to work at spinoffs or startups.

https://doi.org/10.1017/9781108904230.015 Published online by Cambridge University Press

for Advancement of Technology (KIAT) appraised and established the value of the technology. The government also promoted the securitization of technology assets by using technology as collateral for loans; this was designed to help SMEs borrow money using their technology.

To increase knowledge transfer from universities, the government also provided money through several initiatives. First, 150 billion Won (KRW) was spent on the Connect Korea project between 2006 and 2010, the main goal being to invigorate the regional economy by improving KTOs' ability to support knowledge transfer and commercialization. Second, the Hub University for Industrial Collaboration (HUNIC) project from 2004 to 2011 saw a budget of KRW 31 billion per year split among seventeen to twenty-three universities and colleges chosen by the government, with each receiving between KRW 0.8 and 4 billion per year. Third, the Leaders in Industry–University Cooperation (LINC) project, from 2012 to 2016 increased the number of supported universities and colleges to eighty, while the project budget increased to approximately KRW 250 billion per year.

Yoon (2013) estimates that from 2004 to 2012, the government provided 473 university companies with KRW 119 billion in total. Accordingly, the number of university technology transfer contracts increased from 1,615 in 2010 to 3,247 in 2014. Universities' income from licensing also increased from KRW 37.6 billion in 2010 to KRW 57.6 billion in 2014. The ratio of license income to R&D expenditure at universities increased from 0.94 percent in 2010 to 1.23 percent in 2014 (KRF 2016).

A new Market-Driven IP and Technology Transfer Promotion Plan, announced in April 2015, emphasized the maximization of market value from knowledge transfer. First, protection of intellectual property rights was strengthened. Previously, a specialized patent dispute court had been available only for first-instance legal disputes; this was extended to cover second-round disputes, meaning rulings at both levels would be based on more specialized expertise. The Plan also contemplated increasing the maximum punitive damages limit to three times the estimated damage amount, as was the case in US practice (Presidential Council on Intellectual Property 2015).

Second, the government relaxed some regulations that had resulted in low efficiency of knowledge transfer. To encourage patent quality in terms of commercialization, it changed the major performance evaluation yardstick to efficiency of knowledge transfer (calculated as license income divided by the cost of R&D). However, the outcome of this change remains to be seen. Previously, knowledge transfer had focused exclusively on domestic SMEs, but this restriction has been relaxed to include large or foreign firms, which may now also benefit from obtaining technologies from public research institutes (Presidential Council on Intellectual Property 2015). Restrictions regarding exclusive licensing were also relaxed, and public research institutes were given greater autonomy in choosing between exclusive and nonexclusive licensing. Regarding co-owned patents, the Plan allowed third parties to practice such patents if firms with co-ownership were not practicing them.

The Plan encouraged technology transfer agents or KTOs to identify firms' technology needs, then help firms to connect with public research institutes capable of developing the required technology. It also encouraged KTO staff to participate in R&D from the beginning so that R&D projects reflected firms' needs. To improve KTOs' capabilities, the government started to allow several public research institutes and universities to share one joint KTO, especially where a public research institute or university was unable to afford its own independent KTO. The government also gradually increased spending on KTOs as a share of total R&D expenditure from 1.3 percent in 2010 to 3.3 percent in 2015. It provided fifty KTOs with KRW 9 billion per year between 2011 and 2015 (Presidential Council on Intellectual Property 2015). However, as we discuss later, the expected results of this have yet to be realized.

6.3 The Extent of Knowledge Transfer from Public Research in the Republic of Korea

Public R&D expenditure increased from KRW 3.8 trillion (USD 3.37 billion) in 2000 to KRW 15.28 trillion (USD 14.5 billion) in 2014. The ratio of public R&D expenditure to GDP also increased, from 0.63 percent in 2000 to 1.03 percent in 2014. The number of public research institutes rose by 80 percent between 2000 and 2014. Table 6.1 shows the trend of public R&D expenditure and the number of public research institutes and universities from 2000 to 2014. The R&D activities of both universities and public research institutes are funded by the government – in 2014, 91.2 percent of public research institutes' R&D expenditure and 86.6 percent of universities' R&D expenditure was government funded.[2] R&D expenditure and the number of research institutes has increased, as has R&D output activity. Thus, the share of

[2] KIAT surveys.

Table 6.1 *Public R&D expenditure and number of Korean public research institutes and universities, 2000–14*

Year	Public R&D expenditure (KRW million)	Public R&D expenditure (USD million)	Public R&D expenditure as a share of GDP (%)	Number of public research institutes	Number of universities
2000	3,816,850	3,375	0.63	164	368
2001	4,361,534	3,378	0.67	152	357
2002	4,739,957	3,789	0.66	141	389
2003	4,876,225	4,091	0.64	154	398
2004	5,446,050	4,756	0.66	159	403
2005	5,877,167	5,739	0.68	150	332
2006	6,632,101	6,945	0.73	151	294
2007	8,177,479	8,802	0.84	193	361
2008	9,249,253	8,393	0.9	202	376
2009	10,888,944	8,527	1.02	236	391
2010	12,270,228	10,614	1.05	237	385
2011	13,003,277	11,736	1.05	237	385
2012	13,822,078	12,275	1.09	245	378
2013	14,241,744	13,006	1.00	269	414
2014	15,275,007	14,506	1.03	296	411

Source: Ministry of Science, ICT, and Future Planning, Survey of Research and Development in Korea, 2001–15

* R&D expenditure includes expenditure on all subjects, including social sciences and humanities. It also includes expenditure on administrative support staff.

Korean-authored science and technology papers among world SCI papers increased from 1.74 percent in 2000 to 3.64 percent in 2013 while the Republic of Korea's share of granted patents among total US utility patents grew from 2.1 percent in 2000 to 6.01 percent in 2015 (USPTO).

The enactment of the Technology Transfer Promotion Act in 2000 encouraged IP commercialization and as a result, 54.6 percent of public research institutes and universities had KTOs by 2014. The rate of knowledge transfer reached 31.7 percent in 2014, which is similar to the rates in Europe (33.5 percent in 2008) and the U.S. (25.6 percent in 2008) (KIAT 2012).[3] As shown in Table 6.2, there was a steep rise in the number of domestic patent applications by public research institutes, which increased thirteen-fold between 2000 and 2015. The number of domestic patent applications by universities increased even faster, by thirty-two times, during the same period.

Table 6.3 shows that other outputs of R&D activity from universities and public research institutes also increased from 2007.[4] The average number of newly developed technologies per institute increased from 70.4 in 2007 to 107.1 in 2014. The average number of transferred technologies per institute rose from 13.4 in 2007 to 30.2 in 2014.

However, the efficiency of commercialization of research output from public research institutes and universities did not improve, even though outputs from R&D activity increased. The ratio of license income to R&D expenditure in public research institutes and universities was 1.38 percent in 2009; it remained at 1.35 percent in 2014. Korean public research institutes and universities had over 190,000 technologies in 2012, but 154,000 of these were not commercialized (Lee and Kim 2015). One explanation could be the short history of IP commercialization by licensing. Korean public research institutes and universities previously provided the country's firms with many free new technologies and KTOs were only established after 2000. Thus, the KTOs of Korean public research institutes and universities have not acquired enough experience in, or developed enough capacity for, IP commercialization. The average number of KTO staff per institute was only 2.7 full-time equivalent in

[3] The rate of technology transfer is defined as the ratio of the number of transferred technologies to the number of newly developed technologies.

[4] Relevant data are available since 2007, when the government of the Republic of Korea started conducting a survey of knowledge transfer by public research institutes and universities.

Table 6.2 *Number of domestic patent applications by public research institutes and universities 2000–15*

	Total			Public research institutes			Universities		
Year	Number	Per 1,000 researchers	Per USD 1 m R&D expenditure	Number	Per 1,000 researchers	Per USD 1 m R&D expenditure	Number	Per 1,000 researchers	Per USD 1 m R&D expenditure
2000	2,302	35.1	0.72	1,675	120.4	0.93	627	12.1	0.45
2001	2,735	40.4	0.92	2,024	145.4	1.21	711	13.2	0.55
2002	3,613	50.4	1.04	2,656	188.4	1.30	957	16.6	0.67
2003	4,877	64.4	1.28	3,185	202.6	1.45	1,692	28.2	1.04
2004	5,441	71.9	1.21	3,479	221.3	1.34	1,962	32.7	1.02
2005	6,862	85.4	1.26	4,292	276.9	1.38	2,570	39.6	1.10
2006	11,612	140.4	1.78	6,051	360.8	1.65	5,561	84.4	1.95
2007	14,936	145.0	1.87	6,857	327.3	1.55	8,079	98.4	2.25
2008	16,704	162.1	2.17	6,892	329.0	1.63	9,812	119.5	2.81
2009	19,490	172.7	2.55	8,334	342.7	1.91	11,156	126.0	3.39
2010	21,057	175.9	2.20	9,109	347.2	1.67	11,948	127.8	2.91
2011	23,781	190.9	2.25	10,220	354.9	1.70	13,561	141.6	2.98
2012	25,906	206.0	2.39	11,211	389.0	1.82	14,695	151.6	3.14
2013	27,395	213.3	2.35	11,356	364.7	1.71	16,039	164.8	3.20
2014	28,408	214.2	2.16	10,398	312.0	1.35	18,010	181.3	3.29
2015	29,991	221.5	2.38	10,078	283.5	1.38	19,913	199.4	3.75

Source: Korean Intellectual Property Office (KIPO), White Papers on Korean Intellectual Property, 2006, 2011, 2016

* Domestic patent applications count unique patents applications at the Korean Intellectual Property Office.

* The figure for "researchers" includes those in all disciplines including social sciences and humanities. It also includes PhD students at universities.

Table 6.3 *Output of R&D activities by Korean public research institutes and universities – new technologies and knowledge transfer, 2007–14*

Year	Number of new technologies			Number of transferred technologies		
	Per institute	Per 1,000 researchers	Per USD 1 m R&D expenditure	Per institute	Per 1,000 researchers	Per USD 1 m R&D expenditure
2007	70.4	139.89	n.a.	13.4	38.38	n.a.
2008	59.8	152.12	n.a.	12.4	33.62	n.a.
2009	80.7	140.78	2.65	14.0	32.02	0.60
2010	88.2	180.48	2.54	16.8	41.69	0.59
2011	81.3	155.08	2.32	20.6	40.28	0.60
2012	94.9	205.21	2.47	25.5	55.55	0.67
2013	88.4	258.83	2.65	27.6	80.64	0.83
2014	107.1	256.97	2.72	30.2	81.51	0.86

Source: Korea Institute for Advancement of Technology (KIAT), Survey of knowledge transfer by public research institutes and universities

2014 with an average work experience within the KTO of just 2.6 years (KIAT 2016).[5]

These average figures mask very different performance between the best and worst public research institutes and universities. Licensing incomes are highly concentrated among a small number of top public research institutes, but less concentrated in the case of universities. The five leading public research institutes received 64 percent of total public research institute license income in 2014, whereas the top five universities obtained 27.9 percent of total university license income in 2014. The leading public research institutes[6] had a ratio of license income to R&D expenditure of 2.11 percent in 2014. In contrast, university knowledge transfer was less efficient, with a ratio of license income to R&D expenditure of 1.16 percent. Leading universities performed much worse than the average – the ratio of license income to R&D expenditure of the five leading universities was only 0.93 percent. As Ok and Kim (2009) note, Korean universities focused on education rather than research until the

[5] Other possible reasons for this low efficiency are dealt with in Section 6.5.

[6] The top twenty-five public research institutes include ETRI and the Korea Institute of Science and Technology (KIST).

1980s, so their research capability and commercialization ability was even lower than that of public research institutes.

The emphasis on knowledge transfer since 2000 has led public research institutes and universities to develop more transferrable technologies at the expense of technology quality. Further, universities and public research institutes may have split technologies into many small patents to help maximize their scores in performance evaluation. There are several indicators of this. The share of transferred technology among the total number of valid knowledge transfer contracts that resulted in increased sales was 14.1 percent in 2009, but had fallen to 12.4 percent in 2014. License-based incomes per institute from knowledge transfer did not increase. The average license income per institute was KRW 625.2 million (USD 0.67 million) in 2007, falling to KRW 561.3 million (USD 0.53 million) in 2014. Since the average number of transferred technologies per institute has increased since 2007 (see Table 6.3), we can infer that the average license income per transferred new technology has fallen. Average license income per transferred technology was KRW 40 million (USD 36,300) in 2008, but KRW 18 million (USD 16,440) in 2013. Table 6.4 presents these statistics.

If we compare leading Korean and US universities, the number of transferred technologies (license agreements) is similar. The total knowledge transfers per year by the Seoul National University (SNU) is seventy-nine, and the figure for Stanford University is 101. However, average license income per transferred technology shows a huge gap. Average license income per transferred technology for the SNU is KRW 58 million, but for Stanford it is KRW 734 million. One of the main reasons is that Stanford has several patents, such as a Google-licensed search patent, which earn lots of money. Three important patents earned 75 percent of Stanford's license income from 2000 to 2010.

Another possible reason for this low efficiency is that the focus of knowledge transfer in public research institutes in the Republic of Korea switched from big businesses to SMEs. SMEs cannot usually pay high license fees due to their limited financial resources. Large firms and foreign firms can pay higher license fees, but the government of the Republic of Korea made the country's public research institutes prioritize knowledge transfer to domestic SMEs over large or foreign firms in an attempt to reduce the huge productivity gap between large firms and SMEs. Fully 90.7 percent of knowledge transfer contracts from public research institutes were concluded with SMEs in 2014. License income

Table 6.4 *Output of R&D activities by Korean public research institutes and universities – license income, 2007–14*

Year	License income				
	Per institute (USD million)	Per 1,000 researchers (USD million)	Per transferred technology (USD thousand)	License income as a share of R&D expenditure (%)	Knowledge transfers resulting in sales as a share of the total number of valid knowledge transfer contracts (%)
2007	0.67	1.24	n.a.	n.a.	n.a.
2008	0.45	1.22	36.30	n.a.	n.a.
2009	0.33	0.74	22.71	1.38	14.1
2010	0.49	1.05	25.09	1.48	18.3
2011	0.59	0.88	21.66	1.32	23.6
2012	0.74	1.22	22.20	1.47	33.6
2013	0.45	1.33	16.44	1.36	15.9
2014	0.53	1.27	n.a.	1.35	12.4

Source: KIAT, Survey of knowledge transfer by public research institutes and universities, 2008–15

* License incomes include both lump-sum payments and running royalties.

per transferred technology was KRW 15.39 million from SMEs and KRW 52.51 million from large firms in 2014.

As regards the sectoral distribution of transfer activity from universities, Kwon et al. (2014) analyzed 5,249 knowledge transfer contracts between universities and firms from 2011 to 2013 to identify the number of contracts by industry. Table 6.5 shows the top seven industries by the number of knowledge transfer contracts. The electronic parts, video, sound, and communication equipment industry accounted for the largest share in terms of both the number of knowledge transfer contracts and license income, which is reasonable given that this is the major industry in the Republic of Korea. The IT services and software industry also had a large number of knowledge transfer contracts. The textile and food industries had a relatively large number of contracts, but their license income was small. Thus, the size of knowledge transfer contracts is small in these industries.

The Science and Technology Policy Institute (STEPI) conducts a survey every two or three years to reveal the sources of innovation for Korean firms' innovation activities. In this survey, STEPI asks firms about the major sources of information/knowledge for their R&D activities. In their answers, firms identify universities, research institutes (public or private) or other sources such as in-house, suppliers and customers as their main source of information. Table 6.6 summarizes the main findings in this regard.

Research institutes are used more in the electronic and chemical industries, perhaps because these have been the major industries in the Republic of Korea since the 1970s and have a long history of collaboration with public research institutes. Universities are used more in the other machinery and medical and optical instruments industries. The medical and optical instruments industry is science-based and depends more on universities than other industries. The food and textiles industries depend on both universities and research institutes.

Korean universities interact with both local and foreign firms, but the share of foreign firms is small. According to Kwon et al. (2014), only 1.4 percent of knowledge transfer contracts from Korean universities in 2012 were with foreign firms and they accounted for only 0.68 percent of total license income. Most of the interaction occurs between universities and local firms.

6.4 Knowledge Transfer Channels in the Republic of Korea

There are various knowledge transfer channels from public research institutes to the private sector, including reading papers, attending

Table 6.5 *University knowledge transfer contracts by industry, 2011–13*

Industry	Number of knowledge transfer contracts	Share of knowledge transfer contracts (%)	License income (KRW million)	Share of license income (%)
Electronic parts, video, sound, and communication equipment	526	13	12,748	13
IT services and software	397	10	7,291	7
Other machinery and equipment	376	9	7,765	8
Chemicals and chemical products	290	7	12,731	13
Textiles (excluding clothing)	274	7	969	1
Medical and optical instruments and watches	261	6	12,654	13
Food and beverages	232	6	2,319	2

Source: Kwon et al. (2014)

Table 6.6 *Firms reporting universities or research institutes as sources of innovation information, 2011–13*

Industry	Source of information for innovation activity: Universities or other higher education institutions (%)	Source of information for innovation activity: Public or private research institutes (%)
Electronic parts, video, sound, and communication equipment	15.4	20.0
IT services and software	n.a.	n.a.
Other machinery and equipment	14.8	10.8
Chemicals and chemical products	21.9	27.0
Textiles (excluding clothing)	14.4	15.6
Medical and optical instruments and watches	15.9	8.8
Food and beverages	24.4	22.8

Source: Science and Technology Policy Institute (STEPI), Korean Innovation Survey, 2014

conferences, IP licensing, employing researchers and graduate students, startups, consulting by researchers, using public research institutes' research facilities, collaborative R&D, and informal discussion between firms and public research institutes. These can be classified into formal and informal transfer channels, with formal channels being those based on contracts.

Cho et al. (2007) surveyed 600 Korean firms to study how they cooperate with public research organizations to transfer knowledge. Table 6.7 summarizes their main results. The most common channel of knowledge transfer in the Republic of Korea is collaborative R&D commissioned by firms. About 60 percent of the firms that cooperate with public research organizations used this channel as the primary cooperation type. Cho et al. (2009) argue that this is because government

https://doi.org/10.1017/9781108904230.015 Published online by Cambridge University Press

Table 6.7 *Primary types of cooperation with public research organizations among surveyed firms*

Type of cooperation \ Object of cooperation	University (percentage share of each type of cooperation)	Public research institute (percentage share of each type of cooperation)
Collaborative R&D or commissioned research by firms	62.9	58.0
IP licensing	2.9	4.8
Using public research facilities	16.1	22.7
Dispatch of staff between firms and public research organizations	3.4	1.2
Startup or joint venture between firms and public research organizations	0.3	2.7
Commissioned education of firms' staff	2.1	0.0
Consulting or lectures by public research organization researchers	8.8	8.2
Activities of public research organization researchers as official consultants for firms	3.6	2.4

Source: Cho et al. (2007)

supports collaboration between industry and public research organizations in the Republic of Korea. The second most common channel in their survey was use of public research facilities. Twenty percent of firms reported this channel as their primary method. There is no similar category in the equivalent US survey (the 1994 Carnegie Mellon Survey), so direct comparison between the U.S. and the Republic of Korea is difficult, but it is clear that using research facilities are more important to Korean firms than IP licensing or establishing startups. About 10 percent of Korean firms reported consulting and lectures by researchers in public research institutes as the primary channel, which makes it less important than consulting in the US survey. Other types of transfer, such as hiring, licensing, education of staff members, and start-ups are not very significant in the Republic of Korea.

Table 6.7 also shows some differences between public research institutes and universities in the Republic of Korea. Interaction between universities and firms is mostly consulting and training-based while that between public research institutes and firms tends to involve IP licensing, joint ventures, and laboratory infrastructure, seemingly reflecting the fact that universities are education-oriented whereas public research institutes have better research capabilities and facilities.

6.4.1 Formal Channels in Public Research Institute and University Knowledge Transfer Contracts

Drawing on the results of the various KIAT surveys of public research organizations in the Republic of Korea (see Appendix for details), Table 6.8 shows the total number of knowledge transfer contracts in public research organizations and the share of each knowledge transfer channel. IP licensing is a more common (formal) knowledge transfer practice than sales of technologies. The share of license contracts among the total number of knowledge transfer contracts was 68.5 percent in 2014 whereas the share of technology sales was only 12 percent. However, free-of-charge licensing also accounts for a significant share of knowledge transfer contracts – 10.7 percent in 2014 – because one of the main goals of Korean public research institutes and universities is to support SMEs by providing them with free technology. As there is a large technology gap between large firms and SMEs, the government has used public research institutes and universities to improve the technological competitiveness of SMEs.

Within IP licensing, lump-sum payment dominates. While there are presently no statistics to prove this, most of the respondents in this study confirm it anecdotally. In contrast, most IP licensing in leading US universities involves running royalties. The low efficiency of the knowledge transfer market involving public research organizations in the Republic of Korea, in the sense that there is a low level of trust on both sides, makes negotiating long-term contracts involving running royalties difficult. This is bad for research organizations as running royalties, proportional to increased sales, may generate a more stable income.

Table 6.8 *Knowledge transfer contracts and share of different types of knowledge transfer, 2007–14*

Year	Number of knowledge transfer contracts	Share of technology sales (%)	Share of licensing (%)	Share of free licensing (%)
2007	2,593	22.6	65.0	6.7
2008	2,641	10.8	74.2	10.0
2009	2,918	7.7	75.7	14.8
2010	2,940	5.9	86.3	6.1
2011	3,420	9.6	80.7	5.2
2012	4,312	8.9	82.5	6.5
2013	4,358	12.3	79.3	6.0
2014	5,981	12.0	68.5	10.7

Source: KIAT, Survey of technology transfer by public research institutes and universities, 2008–15

Conversely, no firm was willing to pay a large lump sum because of the uncertain sales potential of the transferred technology.

The total number of startups in 2014 created using technologies from public research institutes and universities was 136; the number of startups by staff (spinoffs) was 108; the number of startups by other people using public research IP was twenty-eight; and the average number of startups per institute was 0.54, which is relatively small compared to rates in the U.S. and other countries. However, several leading public research institutes created more startups: twenty-four leading public research institutes under the auspices of the National Research Council of Science & Technology (NST) created forty-one startups, and the average number per institute was 1.7 (KIAT 2016).

One special type of startup from public research institutes is the "laboratory company," which is defined in the Special R&D Zone Promotion Act 2005. If a startup from a public research institute is located in a special R&D zone and the institute invests more than 20 percent of the capital, then it can be authorized as a laboratory company and exempt from tax for three to seven years. The technology of public research institutes can be regarded as the startup's

Table 6.9 *Laboratory companies – sales and employment, 2009–15*

Year	Sales (KRW billion)	Employment
2009	28.3	237
2010	43.0	272
2011	72.4	310
2012	120.8	524
2013	164.3	639
2014	236.5	850
2015	288.1	1,194

Source: INNOPOLIS Foundation (www.innopolis.or.kr/sub0303)

capital, so it is not difficult for such startups to be authorized as laboratory companies.

In 2016, there were 219 laboratory companies in the five special R&D zones (Daedeok, Daegu, Busan, Gwangju, and Jeonubuk). Due to government support and advanced technologies from public research organizations, their sales increased tenfold and their employment increased fivefold between 2009 and 2015, as shown in Table 6.9. The five-year survival rate of laboratory companies was about 64.9 percent, more than double the survival rate of normal startups (29.6 percent) (Ministry of Science, ICT, and Future Planning 2014).

6.4.2 *Qualitative Evidence of Successful Knowledge Transfer*

IP licensing by ETRI represents a case study of successful licensing. ETRI is the largest public research institute in terms of both R&D expenditure and license income. It earned KRW 34.6 billion from licensing in 2014 – about a quarter (24.7 percent) of the total license income of all Korean public research organizations. Its ratio of license income to total R&D expenditure is 8.4 percent – the highest ratio among Korean public research organizations.

One example of successful IP licensing at ETRI involved a company called Initech, an IT security system company that started in 1997 with two employees. Its core technology is a user authentication solution based on public-key infrastructure (PKI) which ETRI transferred to it through IP licensing in December 1999. In the late 1990s, the number of users of Internet and e-commerce increased rapidly, and so IT security in e-commerce became important. ETRI started research into authentication servers and systems in 1995, as a project for the Korean Ministry of Information and Communication. At an early stage of R&D, ETRI identified potential users of the technology, such as public financial institutions (e.g., the Korea Financial Telecommunications & Clearing Institute). Within four years, ETRI had developed an "authentication processing protocol and verification technology," and transferred this technology to Initech.

Public-key infrastructure is the system relating to the generation, authentication, distribution and management of public-key encryption, a method of data encryption that uses different keys for encryption and decryption. It is a more secure method than its predecessor, secret-key encryption, and became widely adopted as demand from e-commerce and Internet banking increased. Even after knowledge transfer, researchers in ETRI frequently helped Initech to further develop its own system and service.

Apart from the favorable demand conditions, government policy also contributed to the success of Initech. The government recognized the PKI-based technology as the industry standard in 1999, encouraging more domestic users to adopt it. In turn, this helped the rapid growth of Internet banking and e-commerce.

Although several hundreds of *technology startups* existed in 2014, most remained small and did not develop a stable growth path. One of the most successful cases of a startup from a public research institute comes from the Korea Atomic Energy Research Institute (KAERI). KAERI is the third-largest public research institute in the Republic of Korea. It started to develop health-promoting functional foods focusing on boosting immunity in 1997. Researchers at KAERI recombined medicinal herbs such as *dong quai*, cnidium, and white woodland peony using radiation technology. It took six years to develop the original technology[7] and cost KRW 1.2 billion in R&D. Researchers at KAERI were confident of the quality of their product and decided to establish a company, reaching an agreement with a private company, Kolmar Korea, in 2001. KAERI had transferred other technologies to Kolmar Korea before 2001, and so Kolmar Korea was interested in its new technology.

[7] The *Korean Economic Daily*, "10 Billion Won in Royalties for Research," May 23, 2015, www.hankyung.com/news/app/newsview.php?aid=2015032265091.

However, KAERI faced a difficulty as government-appointed directors on its board opposed the agreement, arguing that public research institutes should not engage in income-generating businesses and that there was no precedent for a public research institute providing funds to establish a company.[8] This is interesting because the government of the Republic of Korea had already enacted the Technology Transfer Promotion Act 2000 and mandated public research institutes to establish KTOs.

No company was established for three years. However, finally KAERI changed its strategy and chose technology investment, which meant that the value of KAERI's technology was regarded as capital and so it did not have to invest any cash. This plan persuaded the government, so KAERI and Kolmar Korea co-established a company, Sunbiotech, in 2004. Sunbiotech can be classified as a joint venture, as the value of KAERI's technology was approved as KRW 378 million and Kolmar Korea invested KRW 622 million as capital.

Sunbiotech's sales were poor at first because the product did not obtain approval from the government as a functional health food. The company achieved total sales of between KRW 0.8 and 1.2 billion between 2004 and 2006. Finally, in 2006, it obtained approval for the product as a functional food from the Ministry of Food and Drug Safety. This was one of the first approvals in the Republic of Korea for a functional food that improves immunity. It also obtained authorization from the government as the first laboratory company under the Special R&D Zone Promotion Act 2006. Using that governmental authorization, it was able to sell its products as health-promoting, functional foods that improve immunity. It grew rapidly, with sales increasing from KRW 3.8 billion in 2007 to KRW 9.9 billion in 2008 and KRW 20.1 billion in 2009 (Ham 2015). By 2013, sales reached KRW 121.5 billion and the company's name was changed to Kolmar BNH. It was floated on the KOSDAQ stock market in 2015.

The sales and operating profit of Kolmar BNH reached KRW 236.2 billion and KRW 34.4 billion respectively in 2015, by which time the company had 156 employees. By July 2016, its market value stood at around KRW 1 trillion. KAERI held 16.1 percent of Kolmar BNH's stock at the time of the IPO, and earned over USD 100 million, a sum greater than the total license income of all Korean public research institutes in 2014. The case of Kolmar BNH thus shows the potential of startups and

[8] In-soon Jang (former president of KAERI), *EconomyTalk* (Korean Press), September 2015, www.econotalking.kr/news/articleView.html?idxno=129290.

joint ventures in knowledge transfer and commercialization. Following the success of Kolmar BNH, the government of the Republic of Korea changed its attitude and started to actively support public research organization startups.

The KAERI KTO played an important role in the success of Kolmar BNH as it started to apply for Korean and international patents on the core ingredients of the product between 2000 and 2003, just three years after the start of its R&D activities. It applied for the trademark "HEMOHIM" in relation to its products in 2002.

Another factor in Kolmar BNH's success was reputation. KAERI has a fifty-year history and is well known as the third-largest Korean public research institute, so Korean consumers trusted the product more than products from other startups. The stability and safety of the product are very important factors to consumers in the functional health food market, so the reputation of KAERI helped Kolmar BNH to survive in its early stages.

As in the case of Initech, demand also helped Kolmar BNH to succeed. As income levels in the Republic of Korea rose, people started to pay more attention to their health and the market size for functional health foods increased rapidly. Production of functional health foods in the Republic of Korea increased from KRW 700.8 billion in 2006 to KRW 1.48 trillion in 2013, and the annual growth rate was 11.5 percent during this period (Ham 2015).

A further factor explaining the company's success was the management skill available from a private firm. A typical problem in public research organization startups is the lack of sound management skills. However, Kolmar BNH was a joint venture with the private sector, and the managers and employees of Kolmar BNH had the benefit of the management knowhow of Kolmar Korea.

6.4.3 Informal Knowledge Transfer Channels

As seen in Table 6.7, the proportion of firms that actually use formal channels is small. To detail other knowledge transfer channels, Cho et al. (2009) cite examples that do not use IP licensing or startups. We summarize those examples here.

Company S[9] is a leading Korean ICT firm that actively cooperates with public research organizations, but it does not use IP licensing or startup

[9] The discussion here is based on Cho et al. (2009).

channels to transfer knowledge from them. Instead, its main knowledge transfer channel is the participation of its staff in seminars or education programs provided by public research organizations. For example, it began research into optical materials in the early 2000s, attracted by the thriving optical industry, but since it lacked basic knowledge about optical materials, it sent researchers to participate in relevant university seminars.

It also uses researchers from public research organizations as consultants. Company S has built a network of specialists, and consults them about technology trends and information in their specialized fields. To do this, it undertakes an annual program of twenty–thirty technology seminars with them. In addition, the CEO of the company holds periodic meetings with key experts. It usually consults researchers in public research organizations about the market or technology situation for emerging technology. For instance, it consulted researchers at the Korea Institute of Energy Research about the market prospects and technology when solid oxide fuel cell technology was regarded as promising.

A third knowledge transfer channel is collaborative R&D. As technological convergence/fusion has deepened, Company S has needed collaborative R&D because it does not have research capability in some technology fields. For example, it needed film-coloring technology for PDP (plasma display panel) filters, but did not have research capability in that field. It therefore collaborated with SNU to develop the technology. It obtained basic knowledge about the technology through a year of collaborative research.

However, Company S has not used IP licensing for knowledge transfer. There has been no case of licensing or joint venture with public research institutes. It has previously concluded license contracts with firms in an advanced country, but has not licensed technology from domestic public research organizations. The main reason seems to be that as Company S has recently become a leading ICT firm in the global market, it needs world-class technology to compete, but domestic public research organizations do not offer research capability at a sufficiently high level.

Using research facilities is the second most used knowledge transfer channel in the Republic of Korea, as shown in Table 6.7. However, Company S has not used research facilities in public research organizations, presumably because it is a big firm and has most of the research facilities that public research organizations have and so does not need to use external facilities.

Company S has barely used basic research outputs from public research organizations such as reports, papers, and patents because basic research is not relevant to the company's technology roadmap.

In sum, leading companies such as Company S primarily use public research organizations as consultants, trainers of their staff, and partners in collaborative research. However, they barely use research outputs such as papers, patents, and technologies produced by public research organizations, which might reflect the relatively low level of research capability of such organizations.

Another example of knowledge transfer channels that shows the importance of informal channels is ViroMed Inc. ViroMed was established by Professor Sun-Young Kim from SNU in 1996. Its main products include DNA, protein, and cell-based biotherapeutics that can treat incurable diseases such as diabetic peripheral neuropathy, peripheral artery disease, amyotrophic lateral sclerosis (Lou Gehrig's disease), and thrombocytopenia.

Professor Kim received KRW 150 million in government funding as part of a leading technology development project in 1994. It was a joint project with a firm. Professor Kim's team achieved positive results concerning DNA-based biotherapeutics in 1996. They published their results in *Science* in 1996 and applied for patents in 1997. After these results, Professor Kim suggested that a firm participating in the project invest and commercialize the product, but the firm refused due to the high risk in the biotherapeutics sector. Following a presentation by Professor Kim at an international conference, a UK venture capital company indicated its intention to invest in his research. Using that investment, Professor Kim established ViroMed in 1996.

ViroMed agreed to a technology export contract with Oxford Biomedica, a UK firm, in 1997, and Takara Shuzo, a Japanese firm, in 1999. On the basis of this export agreement, ViroMed was able to attract both domestic and foreign investment. It was floated on the KOSDAQ stock market in 2005. Its market value reached KRW 1.64 trillion in October 2016, following sales of KRW 7.7 billion and operating income of KRW 1.1 billion in 2015. Its market value is high compared to its sales and operating income because clinical trials of its major products have yet to be completed, even though those products are regarded as high quality. As of October 2017, some of its biotherapeutics are in phase III clinical trials (the final step before coming to market) and some are in phase II in the U.S., China, and the Republic of Korea.

Informal channels of knowledge transfer are important, as shown in the ViroMed case, which was established because a UK venture capital firm was interested in its work after learning about it at an international conference.

Another important informal channel is the use of research facilities at public research organizations. The initial capital of ViroMed was only KRW 200 million and, as such, it did not have enough money to buy research facilities. To solve this problem, SNU allowed Professor Kim and ViroMed to use its research facilities. Without such support, ViroMed would not have been able to continue its research.

A third informal knowledge transfer channel involves hiring graduate students. ViroMed started in the form of a "university company," so Professor Kim could work with graduate students in his laboratory at SNU, thus providing ViroMed with high-quality personnel.

One distinctive feature in ViroMed's case is that knowledge transfer to domestic firms is very hard. Unlike Korean ICT firms, Korean pharmaceutical firms have been very reluctant to invest in high-risk projects. They have been used to licensing-in foreign technology. This case shows that domestic industrial capability can affect knowledge transfer from public research organizations. Low industrial capability means that domestic firms have insufficient knowledge and are unable to properly evaluate the potential and risks of new technology. Professor Kim indicated that the most serious problem during the growth process of ViroMed was technology evaluation (Cho et al. 2009).

6.4.4 *The Government-Funded Nonpracticing Entity*

One distinctive feature of knowledge transfer in the Republic of Korea is the existence of a government-funded IP nonpracticing entity (NPE). This approach began in 2010 to protect domestic firms against patent infringement lawsuits by global NPEs or patent trolls. At that time, US private NPEs started buying many Korean patents from public research organizations, sparking public concern that they might use them to file IP lawsuits against domestic firms, taking advantage of the fact that most Korean firms did not seriously consider IP issues at that time. To prevent this possibility, the government decided to set up an entity serving as a pool of patents owned by Korean agents. Thus, the government and big businesses invested about KRW 58 billion and established an IP NPE with the name of Intellectual Discovery (ID), one of the first government-funded IP NPEs in the world; other countries such as Japan, China, and France have since followed suit.

Intellectual Discovery, ranked sixth globally, buys domestic and foreign patents, and had a portfolio of about 5,000 patents by 2016. Its first objective is to protect domestic firms from patent infringement lawsuits. Big firms that funded it initially and have paid license fees can use the patents that it owns. SMEs can obtain membership and license patents by paying a relatively small fee. If foreign firms or NPEs file a lawsuit against domestic member firms, ID provides them with professional help and even some patents which can be used defensively for cross-licensing. If foreign firms or NPEs violate patents that ID holds, ID can charge them with patent infringement and, on behalf of any domestic firm, negotiate for settlement and for legal process.

6.4.5 Important Factors in Knowledge Transfer

The cases cited earlier show the important factors in each type of knowledge transfer channel. The cases of Initech and Kolmar BNH show the importance of follow-on/adaptive R&D by public research institutes after initial knowledge transfer, which is consistent with the results of the qualitative analyses of Kim (2012) and Lee et al. (2015). Furthermore, the case of Kolmar BNH shows the benefits of having a joint venture with existing firms, allowing it to draw on the management skills of the parent companies. Nevertheless, the fact that both were supported by favorable demand conditions suggests it might not be easy to obtain successful results by IP licensing or through a startup if demand conditions are poor.

The cases of Company S and ViroMed show the importance of contract/collaborative research and using facilities in the public sector for knowledge transfer from the public science base. Company S relies on collaborative R&D and consulting, whereas ViroMed relies on using research facilities in public research institutes. The Company S case suggests that the level of research capability of public research institutes may be an important success factor for knowledge transfer, as we argued in Section 6.2. The ViroMed case shows the importance of informal transfer channels such as conferences, even though firm survey data usually rank these as unimportant. It also shows that knowledge transfer from public research institutes can be more difficult in sectors where the country has relatively weak industrial capacity. This may be related to knowledge transfer from ETRI in the ICT sector being more efficient than that of public research institutes in other sectors.

Last, the establishment of ID is an institutional innovation, driven by the government of the Republic of Korea to protect domestic firms against patent infringement by hostile foreign actors.

6.5 Public Policies and Knowledge Transfer Challenges

The government of the Republic of Korea started focusing on knowledge transfer in 2000 and tried to "create" knowledge transfer markets using various policies and projects. In other words, the major player in the knowledge transfer system was the government itself rather than private agents. However, the country's institutional system for knowledge transfer remains immature, and some of the legacy of the developmental state of the past hinders the realization of a knowledge transfer market. This section will discuss important institutional challenges encountered in the Republic of Korea.

6.5.1 Institutional Challenges

One of the first and fundamental challenges is that legal protection of IPR remains weak in the Republic of Korea. Although the country was ranked twenty-ninth among 128 countries for IPR protection in 2016 in the International Property Rights Index (IPRI), actual protection by the courts is weak compared to advanced countries. For example, the probability of the plaintiff winning a patent infringement lawsuit was 20 percent in 2011, far lower than that in the U.S. (60 percent). Furthermore, when the plaintiff did win, average damages from 2009 to 2011 were just KRW 78 million – a mere 0.77 percent of the US figure (Presidential Council on Intellectual Property 2015). The expected payout to the plaintiff was only KRW 15.6 million compared to legal costs of approximately KRW 200 million, severely decreasing the incentive to file a patent infringement lawsuit. In consequence, firms have little incentive to buy licenses or patents from public research institutes if they can obtain technology in other ways, reducing the efficiency of knowledge transfer from public research institutes and depressing the knowledge transfer market.

Weak IPR protection is a legacy of the developmental state during the catch-up period. The major knowledge transfer channel in this period was copying technology from firms in advanced countries. Korean firms did not hesitate to copy good domestic or foreign technology. Furthermore, patent lawsuits were dealt with by the ordinary courts,

https://doi.org/10.1017/9781108904230.015 Published online by Cambridge University Press

where judges lacked the technological expertise to analyze the issues at stake. While dozens of private knowledge transfer agents exist, their IP business is mainly geared to foreign countries; they do not usually file domestic lawsuits for patent infringement even when the IPRs of their domestic clients are violated.

6.5.2 *Immature Capabilities of Government and the SMEs Sector*

A second set of challenges relate to the government's immature policies for knowledge transfer. One of the clearest examples is co-ownership of patents from publicly funded research. It is often difficult for co-owners to reach consensus about whether to license and, if so, to whom, and as a result co-owned patents tend to be underutilized or under-licensed. Thus, while co-owned patents accounted for around 10 percent of total patents in the Republic of Korea in 2013, only 2.8 percent of patent transactions involved co-owned patents. This problem is especially severe when public research institutes and private firms share a patent. As public research institutes do not have production facilities, they cannot make money directly using shared patents.

A second or related problem concerns types of license. The government has tended to encourage nonexclusive licensing to promote more and wider uses of technologies developed by public research institutes. However, this can undermine the interests of licensee firms, which will generally want to use the technology exclusively to increase their potential profits, and it also fails to offer any extra reward to first-licensee firms, which take a bigger commercial risk than follow-on firms in acquiring technology before its value has been proved in the market. Firms have therefore avoided nonexclusive licensing, reducing licensing income for the public research institutes.

The preferred form of licensing payment is a lump sum. This contrasts with the situation in the U.S., where running royalties make up around 70–80 percent of total license income for the leading universities. And even when a running royalty clause is included in the contract, firms do not usually reveal their true sales from the technology to public research institutes – a serious implementation issue and a possible case of market failure.

Other challenges for knowledge transfer in the Republic of Korea stem from the short history of its knowledge transfer system and the primary role of the government in developing that system. The R&D process in public research organizations does not fit the needs of SMEs. Until the

https://doi.org/10.1017/9781108904230.015 Published online by Cambridge University Press

1990s, the major partners of public research institutes included big firms such as Samsung and LG, because their R&D capability remained weak. However, as their R&D capability has improved due to large in-house R&D investment, big firms can conduct their own R&D without the support of public research institutes. As a result, SMEs have become the major partners of public research institutes, accounting for 90.7 percent of knowledge transfer contracts with public research institutes in 2014 (KIAT 2016).

As the R&D capability of SMEs is weak, public research institutes have to develop technology to an advanced stage, until it is ready for commercialization. However, many government-supported R&D projects do not consider this issue. The normal R&D project duration is two to three years, and public research institutes usually have only completed laboratory-stage development within this period. In terms of technology readiness level (TRL),[10] SMEs need at least TRL level 7 technologies (technology demonstrated by prototypes in operational environments), but public research organizations usually tend to provide only TRL level 4 technologies (technology validated in labs). Thus, there is a serious gap in of the technology level demanded and supplied, which hinders effective commercialization of R&D conducted in public laboratories.

SMEs cannot successfully commercialize the transferred technology due to their weak R&D capability. As a result, the technology is not utilized successfully and public research organizations and SMEs tend to blame one another for this failure. It also decreases future private demand for technology from public research organizations. Government therefore needs to provide public research organizations with enough time and funds to complete the technology to a sufficient level. Otherwise, a short-termist reluctance to commit to extra spending decreases the efficiency of public R&D projects. An interviewee from ETRI said that this is a major barrier in knowledge transfer, which is consistent with the findings of several qualitative studies and case studies that emphasize the importance of *follow-on/adaptive* (or after-transfer)

[10] TRL is an indicator of the completeness of technology development. It has nine levels; the higher the level, the readier the technology is to be implemented in factories. The TRL scale was developed by NASA in the 1970s and is widely used in many fields. The European Commission (2014) describes each level as follows: TRL1 – basic principles observed; TRL2 – technology concept formulated; TRL3 – experimental proof of concept; TRL4 – technology validated in laboratory; TRL5 – technology validated in industrially relevant environment; TRL6 – technology demonstrated in relevant industrial environment; TRL7 – system prototype demonstration in operational environment; TRL8 – system complete and qualified; TRL9 – actual system proved in operational environment.

R&D being provided by public research organizations to ensure successful knowledge transfer.

6.5.3 Issues with Public Research Institutes and Universities

One problem is due in part to the specific nature of the project imposed on public research institutes in the Republic of Korea. In the project-based system, the government allocates R&D expenses, including the researchers' salaries and overhead costs for each R&D project. The main goal of the project-based system is to increase the cost efficiency of R&D, but it generates some side effects. Researchers at public research institutes have to undertake as many R&D projects as possible to generate their own income, because the majority of R&D funding is determined by the number of R&D projects executed and the researchers' salaries are part of the acquired R&D budget. Furthermore, given that each public research institute's budgetary resources are proportional to the size of the R&D funding it receives, public research institutes incentivize researchers who obtain more R&D projects. Such a system induces researchers to try to obtain as many public R&D projects as possible. Thus, the average number of R&D projects per researcher per year reached as high as 4.8 in 2011 (Kim and Shim 2013), reducing the amount of time that researchers could spend on each project and diminishing the quality and TRL of R&D results.

Public research organizations also face problems relating to the low capability of KTOs. Despite support from various government laws and projects, KTOs employ small numbers of staff and lack many important skills for successful commercialization. Furthermore, many KTOs implement a staff rotation system, making it difficult for them to accumulate the necessary skills. Incentives for KTO staff to commercialize technologies are weak – 61.8 percent of public research organizations gave no license income to any KTO staff in 2014 even if they played a role in the commercialization of technologies (KIAT 2016). The average share of license income going to KTO staff that played a role in successful commercialization in 2014 was just 3.8 percent, discouraging high-performing staff from working in KTOs. The average annual wage of KTO staff in 2014 was about KRW 34 million (less than USD 30,000), close to the national average wage and clearly insufficient to attract high-quality workers. Only 20 percent of KTOs hire professional staff such as patent lawyers.

Weak incentives for staff at KTOs are related to strong incentives for researchers. The Technology Transfer and Commercialization Promotion Act requires a minimum share of license income for researchers of 50 percent. The actual average share of license income going to researchers across public research institutes was 40.8 percent in 2014 (KIAT 2016), but this is greater than in advanced countries such as the U.S. and Germany. It seems that the government is trying to compensate researchers generously because the system for knowledge transfer remains immature, but one consequence is that little or no license income is available for KTO staff and so they have few incentives to conclude licensing deals.

The problem of weak KTO capability is exacerbated by the fact that few public research organizations are willing to provide the knowledge transfer market with high-quality technologies. Instead they prefer to commercialize their best technologies directly using their KTOs. Nevertheless, the capability of most KTOs at public research organizations is weak, except at ETRI and some leading public research institutes. Thus, public research organizations are not in a good position to fully utilize or commercialize high-quality technologies generated in-house, which decreases the efficiency of the knowledge transfer market. One private knowledge transfer agent identified this as a major problem in the Republic of Korea.[11]

The weak capability of KTOs is mainly due to the Republic of Korea's short history[12] of knowledge transfer and commercialization. The government mandated many public research organizations to establish KTOs in the early 2000s, but it takes time for these KTOs to build capability. During this period, the government should have set up systems whereby private agents could use and commercialize high-quality technologies developed by public research organizations, but these policies are yet to be realized. Thus, this problem is one side effect of the government-driven character of the knowledge transfer system.

Weak KTO capability is related to a third challenge, which concerns the quality of patents. As KTO capability is weak, it is difficult to generate high-quality patents even when high-quality technologies exist. In particular, professionals such as patent lawyers make up only a small

[11] This information is based on interviews conducted for the research project report that preceded this chapter.

[12] Friedman and Silberman (2003) argue that there is a strong relationship between the age of a KTO and its performance in technology transfer because developing a high-quality portfolio of inventions takes time.

proportion of KTO staff, so public research organizations cannot obtain high-quality services during the patent application process. Even when public research organizations sign contracts with external professional staff for patent applications, their budget is very small compared to R&D expenses and, as such, it is difficult to obtain good services. Most interviewees said the budget per patent draft has stagnated – it has remained at about KRW 0.5–1 million (less than USD 1,000) per patent for the last twenty years. This is a very small budget compared to that in the leading global firms, which is about KRW 10 million. One interviewee argued that the budget for drafting each patent application should increase to as much as KRW 5 million – five to ten times the current level.[13]

6.6 Summary and Concluding Remarks

Public research institutes played a significant role in economic catch-up in the Republic of Korea by importing and assimilating foreign technologies and knowledge in the 1970s and early 1980s, and by initiating public–private joint R&D since the late 1980s and 1990s. Universities remained less active in this catch-up process until the 2000s. One of the reasons the Republic of Korea was late in enacting its own version of the Bayh-Dole Act, in comparison to South Africa or Brazil, was the dominance of businesses possessing higher levels of technological capabilities and thus demanding and expecting less from universities. Moreover, these big firms used to collaborate more with government research institutes than with universities.

Since the 2000s, knowledge transfer from universities and public research institutes and its commercialization have become a top policy issue in the Republic of Korea, as the country's technology level converges with that of advanced countries and its economy tries to switch to more science-based or long-cycle-based technology fields (Lee 2013). The Technology Transfer Promotion Act 2000 led to an increase in some quantitative measures of knowledge transfer such as patent applications, and the number of knowledge transfer contracts with public research institutes increased markedly. However, other measures such as the ratio of license income to R&D expenses did not increase, and average license income per transferred technology fell. The government's emphasis, until recently, on quantitative measures such as patent

[13] This point was noted in interviews with private agents.

https://doi.org/10.1017/9781108904230.015 Published online by Cambridge University Press

applications led to a rapid increase in patent applications by public research organizations, but also caused the quality of patents to fall.

The main channels for knowledge transfer in the Republic of Korea still show some differences from those in advanced countries. The major channels are collaborative/contract-based R&D between firms and public research organizations funded by firms, which implies no change from the situation in the 1990s as described in Eom and Lee (2010). Informal channels, IP licensing and startups are all minor channels. Our research identifies as one of the most serious problems the fact that the research outputs of public research organizations do not meet the needs of firms, especially SMEs, which have low levels of absorptive capacity. Furthermore, the typical Korean firm still prefers in-house R&D to licensing from public research organizations. When firms work with public research organizations, they prefer joint/collaborative R&D to IP licensing.

Since 2000, the government has tried to "create" a knowledge transfer market and initiated various polices and projects. The government forced many public research organizations to have their own KTOs in the early 2000s, but their capability remains weak and the incentive system for them is not strong. In particular, the fees paid to patent attorneys for writing and preparing patent application documents have generally been too low at just KRW 0.5–1 million per patent for the last two decades, making it very difficult to produce high-quality patents. This problem means that even high-quality inventions and technologies tend to be either undersold or not sold at all in IP markets. As such, and given the abundance of low-quality patents from universities, the typical perception of private firms is that patents and technologies from universities are of low quality and not easily commercialized. Thus, domestic firms have little interest in obtaining licenses or patents from universities and public research institutes. A low level of domestic IPR protection is another reason for this attitude; damages in IP disputes tend to be far lower than in advanced countries. The knowledge transfer system remains immature and some of the legacies from the early "developmental state regime" hinders further development of the knowledge transfer market.

Government policy mandating all public research organizations to have a KTO had several adverse effects. The KTOs ended up being small and lacking sufficient resources. Although they had initial monopoly rights in the research outcomes of their organization, these were often underutilized. This problem of monopoly and related underutilization is more serious in universities than in research institutes. If the patenting and marketing activities for university research outcomes were more open to capable private agents, rather than being monopolized by university KTOs, there could have been more successful knowledge transfer. Instead, the KTOs' monopoly has depressed the private knowledge transfer market. The government responded by giving higher shares of license-related income to individual researchers, to strengthen their incentives to commercialize their work, but this reduced the incentives available to KTO staff.

In sum, it can be said that the national innovation system in the Republic of Korea has found it difficult to change from the old catch-up mode characterized by the twin dominance of big businesses and the government. Several important factors for successful knowledge transfer from public research organizations, as identified in the literature, are undeveloped in the Republic of Korea: the importance of demand-oriented research, monetary incentives for researchers in terms of license income, sufficient weight on knowledge transfer outcomes in the performance evaluation of researchers, and high-quality personnel for KTOs. These are all areas where the Korean system should try to improve to move beyond the catch-up stage.

Appendix: Data Sources Used in this Chapter

Nature of the Survey

We conducted an email survey of thirty-one KTO managers at public research organizations, thirteen at public research institutes and eighteen at universities (five of which are technical universities). Ten organizations are located in Seoul and seven in Daejeon, the two main innovation centers in Korea. Most leading universities are located in Seoul, while most leading public research institutes are located in Daedeok special R&D zone (part of Daejeon). Other locations include Chungcheong province, Gyeongsang province, Gyeonggi province, Gangwon province, and Jeju island. We divided the thirty-one organizations into fifteen leading and sixteen other organizations according to R&D expenditure in 2014. The average R&D expense was KRW 170,961 million at the leading organizations and KRW 22,117 million at the others in 2014. The average number of full-time researchers was 868 at the leading organizations and 249 at the others. Full details of the responses to our survey are available at www.keunlee.com.

In-Depth Interviews

We also conducted seven interviews between August and October 2016: three with staff from public research organizations, two with government officials, and two with knowledge transfer experts in the private sector. These interviews were used to detail the typical knowledge transfer channels.

KIAT Surveys

Another source of data utilized in this paper is the annual national survey of public research organizations conducted by KIAT (Korea Institute for Advancement of Technology). Most Korean public research organizations are included in the survey, which had a response rate of 94 percent in 2014. The survey was first conducted in 2007 and focuses on a limited number of channels for knowledge transfer (technology contracts, start-ups, and license income), but not the number of research agreements and use of research facilities of public research organizations by firms. In addition, it only covers knowledge transfer to domestic firms.

References

Cho, H.-D., Y.-S. Hwang, W.-D. Kim et al. (2007). *The Evolution of Public Research Systems of Major Countries and Policy Recommendation for Korea*. Sejong: Science and Technology Policy Institute (in Korean).

Cho, H.-D., C.-G. Min, J.-O. Lee et al. (2009). *An Analysis of Impacts and Channels of Public Research on Industrial Innovation in Korea and Policy Recommendations*. Sejong: Science and Technology Policy Institute (in Korean).

Eom, B.-Y. and K. Lee (2010). "Determinants of industry–academy linkages and their impact on firm performance: The case of Korea as a latecomer in knowledge industrialization." *Research Policy*, 39(5): 625–39.

European Commission (2014). *Horizon 2020 Work Programme 2014–15*. (European Commission Decision C (4995 of 22 July, 2014).

Freeman, C. (1987). *Technology Policy and Economic Performance: The Theory and an Application to the Semiconductor Industry*. London: Macmillan.

Friedman, J. and A. Silberman (2003). "University technology transfer: Do incentives, management, and location matter?" *Journal of Technology Transfer*, 28(1): 17–30.

Ham, H.-U. (2015). "A Case Study of Spin-off by a Public Research Institute – Kolmar BNH Co. Ltd." Master's thesis presented to the Department of MOT, Graduate School of Hannam University, Daejon (in Korean).

INNOPOLIS Foundation website: www.innopolis.or.kr/sub0303.

Kim, C.H. (2012). "Case Studies of the Successes and Failures of Commercialization of Technology." Doctoral thesis presented to Hannam University, Daejon (in Korean).

Kim, H.-S. and Y.-B. Shim (2013). "An exploratory study on the interaction model of institutional change of government-funded research institutes: focused on R&D funding systems." *Journal of Digital Policy & Management*, 11(9): 29–43 (in Korean).

Kim, L.-S. (1993). "National system of industrial innovation: dynamics of capability building in Korea." In Nelson, R.R. (ed.), *National Innovation Systems: A Comparative Analysis*. Oxford: Oxford University Press.

KIAT (Korea Institute for Advancement of Technology) (various editions) *Survey of Technology Transfer of PROs and Universities*. Seoul: Korea Institute for Advancement of Technology (in Korean).

KIPO (Korean Intellectual Property Office) (2006, 2011, 2016). *A White Paper on Korean Intellectual Property*. Daejeon, Korean Intellectual Property Office (in Korean).

Korean Council for University Education, Higher Education in Korea website: www.academyinfo.go.kr (in Korean).

KRF (Korea Research Foundation) (2016). *A White Paper on University-Industry Cooperation*. Seoul: Korea Research Foundation (in Korean).

Kwon, K.-S., I.-W. Seo, H.-G. Kim, S.-H. Kim, and T.-S. Park (2014). *The Analysis of Korean Industry-University Collaboration Network*. (KRF Issue Report 2014(3)). Seoul: Korea Research Foundation (in Korean).

Lee, J.-J. (1998). "University research and industry-university cooperation." In Lee, et al. (eds.), *National Innovation System in Korea*. Sejong: Science and Technology Policy Institute.

Lee, K. (2013). *Schumpeterian Analysis of Economic Catch-Up: Knowledge, Path Creation, and the Middle-Income Trap*. Cambridge: Cambridge University Press.

Lee, K. and C. Lim (2001). "Technological regimes, catch-up and leapfrogging: Findings from the Korean industries," *Research Policy*, 30(3): 459–83.

Lee, K., C. Lim, and W. Song (2005). "Emerging digital technology as a window of opportunity and technological leapfrogging: Catch-up in digital TV by the Korean firms." *Industrial Journal of Technology Management*, 29(1/2): 40–63.

Lee, K.-B., K.-W. Kim, and H.-K. Park (2015). "A study of the success factors for start-ups through technology transfer by public research institutes." *Productivity Review*, 29(1): 115–42 (in Korean).

Lee, S.-J. and T.-Y. Kim (2015). "A study of determinants of national R&D projects." *Journal of Korea Technology Innovation Society*, 18(4): 590–620 (in Korean).

Lim, C. (2006). *Research Issues Derived from the Study of National Systems of Innovation (NI) of Small Advanced National*. Sejong: Science and Technology Policy Institute.

Ministry of Science, ICT, and Future Planning (various editions) *Survey of Research and Development in Korea*. Gwacheon: Ministry of Science, ICT, and Future Planning (in Korean).

Ministry of Science, ICT, and Future Planning (2014). *The Performance of INNOPOLIS Research Spin-Offs*. Gwacheon: Ministry of Science, ICT, and Future Planning (in Korean).

Ministry of Strategy and Finance, All Public Information In-one System (ALIO) website: www.alio.go.kr (in Korean).

OECD (2003). *Turning Science into Business: Patenting and Licensing at Public Research Organizations*. Paris: Organisation for Economic Co-operation and Development.

OECD (2008). OECD Review of Korea's Innovation Policy. Interim report presented in Seoul.

Ok, J.-Y. and B.-K. Kim (2009). "Measuring the performance of technology transfer activities of the public research institutes in Korea." *Journal of Technology Innovation*, 17(2): 131–158 (in Korean).

Presidential Council on Intellectual Property (2015). Market-Driven IP and Technology Transfer Promotion Plan (in Korean).

Property Rights Alliance (2016). *The International Property Rights Index 2016*. http://internationalpropertyrightsindex.org/ipri2016.

Science and Technology Policy Institute (various editions). Korean Innovation Survey. Sejong: Science and Technology Policy Institute (in Korean).

Yoon, C.-M. (2013). "A study of the management system of special organizations for university technology transfer and commercialization," *Journal of Korea Technology Innovation Society*, 16(4): 1055–89 (in Korean).