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Mobility and productivity: brain circulation and sustainability of the Korean academic system

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Abstract The purpose of this study is to examine the unique characteristics of the Korean academic system with regard to brain circulation, with a specific emphasis on the influence of overseas-trained academics on research activities within the Korean academic system. We have analyzed the statistical data on individual characteristics and performances of 48,499 Korean academics in science and engineering. We have examined the results at both the system and individual levels within the broader context of the macro characteristics of the Korean academic system. Our analysis reveals that the total number of domestically-trained academics exceeds the number of overseas-trained academics. However, in terms of research funding, overseas-trained academics tend to receive more funding than domestically-trained academics. Furthermore, after controlling other factors such as funding, personal attributes, and environmental factors, our analysis demonstrates that overseas training has a significant and favorable impact on the publication of internationally renowned journals. As such, the presence of overseas returnees has been essential for the effective functioning of the Korean academic system in the global research network and for conducting high-quality academic research. Therefore, the advantages of dependence on scientific core countries such as the US for overseas training have persisted. Nevertheless, upon scrutinizing the group of recently appointed 5,806 academics exclusively, we have discovered that junior academics who received their education domestically exhibit sufficient academic proficiency compared to their colleagues educated overseas. This observation highlights the potential for the Korean academic system to evolve into a self-sustaining system.

Keywords Researcher mobility, Brain circulation, Scientific productivity, Academic system, University research

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I. Introduction

The catch-up countries such as Korea and Taiwan have achieved remarkable economic growth during the last half-century. This is arguably due to the massive increase in human resources, particularly in the field of science and engineering, based on a rapidly increasing enrolment rate in higher education from the early catch-up stage (Kwon, 2015; Mazzoleni and Nelson, 2007; Mazzoleni, 2003; Kim, 1997; Hobday, 1993). In this process, the overseas trained and highly qualified scientists and their return home have been important for upgrading the technological capabilities to absorb international technical knowledge (Albuquerque, 2001).

In contrast, from the early period of economic development, universities in Latin America have focused on educating a small number of 'professional elite' (particularly outside the field directly applicable to industry and agriculture) (Bernasconi, 2008; Ribeiro, 1969). The key difference between the East Asian, including Korean, and Latin American cases is the scale of provision of domestically-trained engineers during the industrialization (Kwon, 2015).

Recently, we have noticed the research quality of new domestically-trained entrants to Korean universities shows a remarkable improvement compared to returnees from the US or other industrialized countries. According to recent empirical evidence, academics trained in domestic institutions show significantly better performance in terms of academic publications than overseas-trained academics (Shin et al., 2014; Lee and Jang, 2013; Um et al., 2012). This means possibly that the Korean academic system has closely reached a sustainable or independent academic system training highly qualified domestic researchers based on its own training system like Japanese universities.

Those studies raise the need to study one step further in order to understand the role of overseas education of highly qualified scientists and engineers in the formation of the Korean science system. However, it is not so intensively addressed who has been hired in Korean universities and how they have contributed to the Korean academic system during the half-century. Moreover, the structural characteristics of the Korean academic system are still relatively unexplored research areas. Specifically, our research focus is on the systemic difference between overseas and domestically-trained academics such as group, size, personal characteristics, resources, academic performances, and their relations. By exploring these issues, we can understand the brain circulation and the development of an academic system in a rapidly industrialized country.

Based on our research background above, we put forward a few research questions as follows.

- Who has been hired in Korean universities in Korean universities during the last half-century? In particular, what kind of demographic characteristics can we identify in the current academic system?
- Compared to domestically-trained academics, are the returnees with foreign degrees get more research resources? Have domestically-trained researchers shown better performance than overseas returnees?

The structure of this paper is as follows. In Section 2, we have carried out a literature review on brain circulation, the labor market for foreign degree holders, and the growth of the science system in home countries. Section 3 briefly introduces the development of the Korean academic system with regard to the role of overseas-trained doctorates. Next, a research methodology such as the statistical model we adopt here and data collection on Korean academics are provided in Section 4. Section 5 presents discussions on descriptive statistics and the results of statistical analysis. The final section provides some conclusions based on the analysis and puts forward several policy implications.

II. Brain circulation and scientific system in home countries

We have observed a brain drain and circulation in the global science system. In other words, the core countries such as the US, the European countries dominate R&D resources such as research funds, and R&D labor forces, whereas the peripheral countries in Africa and Latin America do not. Therefore, some catch-up countries have been inclined to train their scientists and engineers in overseas institutions in advanced countries (Li and Zhang, 2011; Altbach, 2002). Moreover, young and talented students in the industrializing countries are willing to go to industrialized countries in order to find better careers including an enhanced research environment and an academic job with a higher salary level. Consequently, the US and Europe had been the main areas for producing doctoral recipients, particularly in science and engineering fields before the 1990s (Stephan, 2010).

In particular, during the last decade, China, India, and Korea have been the top 3 countries regarding overseas nationalities earned doctorates in US universities (NSF, 2019). Brain linkages to the core countries are regarded to be critical for the development of science systems in peripheral areas. For example, the Korean academic system has been heavily dependent on the US during the last half-century. Korean and Taiwanese doctorate recipients trained in the US are more likely to return to their home countries than those from other countries such as India and China (Finn, 2007). This is because income levels in academic jobs in these countries are higher than that of other countries (Stephan, 2012). Furthermore, rapid expansion and pressure for academic performance tend to encourage the university systems in those countries to hire overseas PhDs (Shin and Kehm, 2013). This may result in the fact that the academic system in the home country consists of a high proportion of overseas-trained academics. For example, in 2016, out of 1,599 Korean academics in the tenure track in economics, more than half of academics (i.e., 840, 52.5%) have been trained in the US (MOE et al., 2019).

Usually known as brain drain, the mobility of researchers is widely known to be advantageous to the receiving country, as they provide skillful knowledge to the host communities. Reversely, the mobility of scientists is also beneficial to the sending country, which is conceptualized as brain circulation (Mahroum, 2000; Jonson and Regets, 1998). In other words, by sending researchers to the scientific core countries, peripheral countries have a chance to connect to global knowledge flows or networks, and scientific mobility contributes to the advancement of scientific communities in the home country by exploiting expertise in advanced countries. Agrawal et al. (2011) maintain that the Indian collaboration between home and host countries enhanced important innovation in home countries as measured by patent citations. Furthermore, Zucker and Darby (2007) find that the academic group with a higher citation shows greater mobility whether they move from one to other places or return to their home places.

The mobility of researchers or overseas training is closely related to success in the scientific labor market (Hargens and Farr, 1973). In research on the scientific labor market, this personal attribute (i.e., mobility of researchers) has been widely addressed with other social and environmental factors. Leslie and Oaxaca (1993) have extensively investigated the factors on graduate supply such as salary, and demand factors such as R&D expenditure. Forecasting the scientific labor market is difficult in reality, although the age structure of academics and the size of cohort students were considered predictors (Stephan, 2010). Regarding the labor market for returning scientists, idiosyncratic characteristics of their home country are critical for their decision to come back. Lee and Kim (2010) suggest that non-economic attributes including cultural background, family duties, and scientific networks, as well as economic elements such as income levels in the home country, are critical for hiring foreign degree holders. For example, except in Japanese cases, universities in Asian countries tend to prefer to hire foreign degree holders based on the belief that they get high-quality education and advanced level of research capabilities (Horta et al., 2011; Finn, 2007; Cummings, 1994).

Research productivity is an important element in the area of the scientific labor market. Moreover, massive studies have carried out on the other personal and environmental factors influencing academics' productivities. On the one hand, regarding personal factors, psychological motivation (i.e., puzzle solving, reputation, and pecuniary incentives), age, gender, and discipline are significantly related to academic productivity (e.g., Stephan and Levin, 1992; Baser and Pema, 2004; Zukerman et al., 1991). On the other hand, environmental factors such as the size of an organization, cultural factors, and the size of funding influence the researchers' academic performances (e.g., Von Tunzelmann et al., 2003; Lee, 1992; David, 2000).

In particular, doctoral training at the early stage of a career is a strong predictor for later academic performances (Enders, 2005). We have found several empirical researches addressing the relationship between various personal characteristics of academics such as overseas training and scientific productivity of academics (Kwon et al., 2015; Shin et al., 2014; Jung, 2014; Lee and Jang, 2013; Um et al., 2012). Kwon et al. (2015) find that the overseas doctorates in science and engineering among 38,149 Korean academics publish significantly more papers in international journals than doctorates, while fewer papers in domestic journals. In a similar vein, Lee and Jang (2013) and Um et al. (2012) also shows that foreign degree holders significantly produce more papers than domestic degree holders empirically based on a large size sample of 14,306 academics in medicine and pharmaceuticals and 48,409 academics respectively.

In contrast, we found different research shows contrasting results to those of Kwon et al. (2015), Lee and Jang (2013), and Um et al. (2012). Based on the sample consisting of 1,663 academics from Korea (868), Hong Kong (417), and Malaysia (378), Shin et al. (2014) show that domestic doctorates publish more than foreign doctorates in Korea. Moreover, Lee and Jung (2018) maintain that Korean academics with recent domestic degrees produce significantly more international publications than those with overseas degrees. In a similar vein, Jung (2014) analyses the research productivity of 894 Korean academics according to career stages. In the statistical test, academics in the early career stage with domestic degrees show high performance in domestic journals significantly.

However, those studies are based on the smaller size of samples. In this study, we attempt to resolve this conflict based on a recent and larger sample of academics considering changing academic environments. Specifically, we collect data on the individual characteristics and performances of 48,499 academics in 2017. In this vein, the statistical results at the individual level are needed to be discussed in the context of macro characteristics of the Korean academic system.

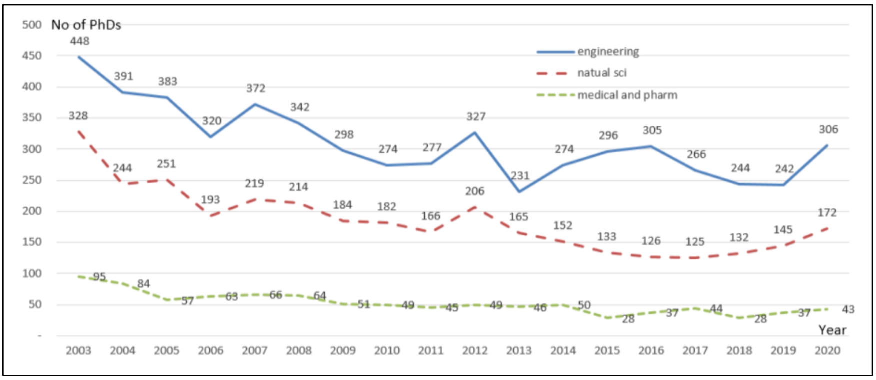
III. Brief history of brain circulation and the Korean academic system

1. Brain circulation in Korea

Lee (2004) maintains that in terms of the higher education system, the US influence on the Korean system after the Korean War (1950-1953) is more significant than in the period between 1945 and 1948 during the reconstruction of the country. The US spent more than 19 million dollars from 1953 to 1967, with a great number of aid programs for the reconstruction of Korea (Dodge, 1971: 199-201). The biggest program in terms of the level of expenditure was the 'Minnesota Project' between 1954 and 1958. Based on this project, three hundred academic faculty members (particularly in the fields of agriculture, engineering and medical sciences) at Seoul National University were invited to be trained as PhD students at the University of Minnesota in the US (Dodge, 1971: 199-210), and the facilities and equipment of Seoul National University were enhanced to an international level (McGinn et al., 1980: 91).

Moreover, the quality of the working condition (e.g., three times higher salary than for professors) of these public institutes attracted a large number of highly qualified scientists and engineers trained in industrialized countries throughout the '70s, the '80s and the '90s in a process known as the 'reverse brain drain' or 'brain gain' (Moon, 2004). The US-trained scholars at Korean universities played a leading role in the development of the Korean higher education system (Lee, 2004). However, these programs created inequality issues in the Korean university system between the public and the private and between the different regions, and a strong preference was established for overseas training, particularly in US institutions (Umakoshi, 1997).

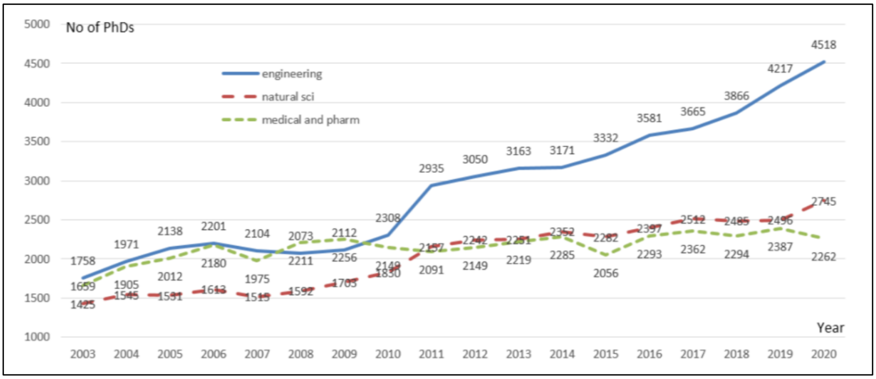
According to the data archive of the Survey of Earned Doctorates in the US (NSF, 2021), the number of Korean PhDs in the areas of science and engineering trained in the US amounted to 325 in 1985, then steadily increased to 1149 in 1994. After a steady decrease between 1994 and 2000, the number restored from 695 in 2000 to 1167 in 2006. After this peak, the number decreased to 822 in 2019. This recent decade's fall can be confirmed in other statistics on the number of overseas PhDs reporting services provided by NRF in Korea. As shown in the below figure, the number of overseas PhDs in science and engineering has steadily decreased since the early 2000s.



Source: Foreign Doctor's Degree Registration Service, National Research Foundation.

Figure 1. The number of Overseas PhDs reported

In contrast, the provision of domestically-trained PhDs in science and engineering has strengthened since the early 2000s. The figure below shows the increase in the number of domestic PhD in the field of science and engineering. Governmental support for domestic postgraduate programs has encouraged students to stay in domestic institutions rather than go abroad. Furthermore, research universities such as KAIST and GIST offer highly qualified programs and conduct cutting-edge research on a global scale.



Source: Korean Educational Statistics Service

Figure 2. The number of Domestic PhDs

According to statistics on the recent academic system (NRF, 2020), in the year of 2020, out of 73,762 Korean academics, 64% of academics are domestic degree holders, while 36% are foreign. This proportion has slowly increased in the last decades. However, considering the size of domestic degree holders are seven or eight times greater than that of foreign degree holders, new entrants foreign degree holders might be enjoying advantages. Regarding academic performances, in 2016, among the top 20% of journals including Korean authors, academics with domestic degrees published more than 60% of papers. Moreover, the SCI publications of domestic degree holders steadily increased in the period between 2012 and 2016 (JoongAng Daily, 2017).

2. Development of the Korean academic system in science and engineering

We have retrieved a dataset from the “Survey on Korean University Researcher’s Activities” carried out by the Nation Research Foundation of Korea. This includes Korean academics’ personal details such as age, gender, and affiliation, as well as their performances like the number of papers and patents. In this section, based on the personal details of 48,499 Korean academics in the fields of science and engineering at the end of the year 2017, we explore the structural characteristics of the Korean academic system during the last half-century.

Firstly, as of the end of 2017, about 26 % (12,621) of Korean academics have studied overseas, and of those, 74 % (9,038) have received education in US universities. Next, 15 % (1,883) of those have done in Japanese universities. This illustrates how Korean universities continue to depend on foreign institutions to produce top-tier scientists. However, the proportion of domestically-trained scientists recruited in Korean universities has recently begun to rise, while the number of newly recruited academics trained in overseas institutions has remained stable, as shown in the figure below.

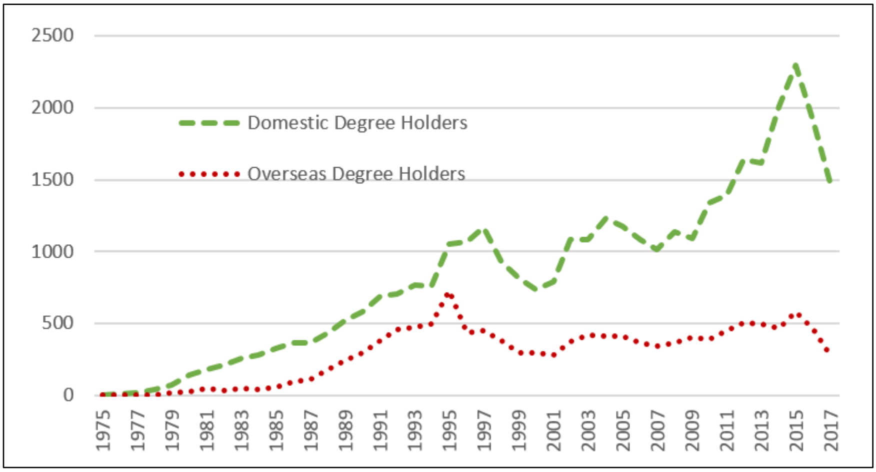


Figure 3. The number of academics trained domestically and overseas

Secondly, in terms of gender, the proportion of female academics has steadily increased from 10% to 30% over the last half-century. Furthermore, as shown in the figure below, the proportion of female domestically-trained academics has been significantly higher than that of female overseas-trained academics throughout the period. By the end of 2017, there were two times as many women with domestic training (23.7%) as there were with international training (12.5%). This indicates that the gender balance in the Korean academic system has improved, especially with regard to academics who have received domestic training.

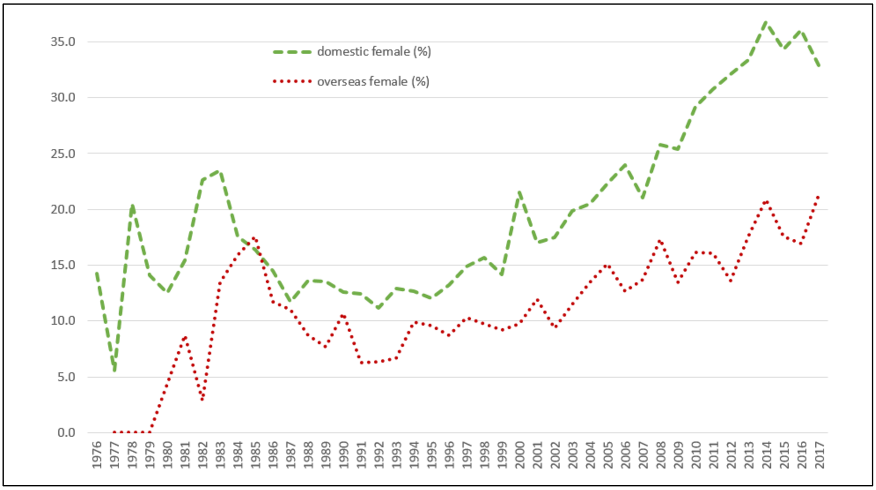


Figure 4. The proportion of female academics trained domestically and overseas

Thirdly, the figure below depicts the age structure of the Korean academic system as of the end of 2017. The average and median values for overseas-trained academics are 52.6 and 54.0, respectively, while those for domestically-trained academics are 50.1 and 50.0. This implies that the overseas-trained group is three or four years older than the domestically-trained group.

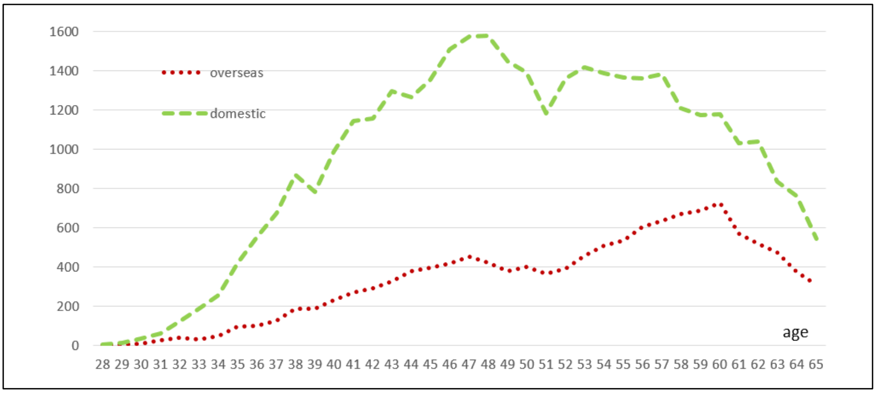


Figure 5. The age distribution of academics trained domestically and overseas

Fourthly, the figure below depicts the six different disciplines based on the academics' recruited years. Until the late 1990s, engineering was the largest of the six disciplines. However, following the 2000s, medical and pharmaceutical disciplines were the most popular destinations for domestic degree holders, while engineering was the most popular degree for academics trained abroad. Other disciplines such as natural sciences and agricultural and maritime science follows.

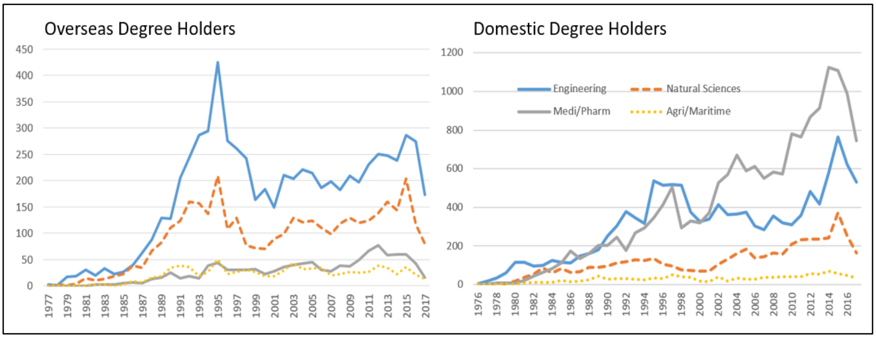


Figure 6. Disciplines of academics according to the recruited years

Fifthly, for a long time, geographical proximity to the capital (i.e., Seoul, Incheon, and Kyunggi) has been an important factor for job seekers in South Korea. This is also true for the academic labor market. Academics trained abroad are typically regarded as highly qualified scientists and thus are more likely to be hired in universities in the capital area with abundant academic resources such as reputation, graduate student, and funding. As of the end of 2017, 49.1% of those trained overseas were in the capital area, while 33.7% of those trained domestically were in non-capital areas. As shown in the figure below, the proportion of those trained overseas in the capital area consistently outnumbers those trained domestically after the 1980s.

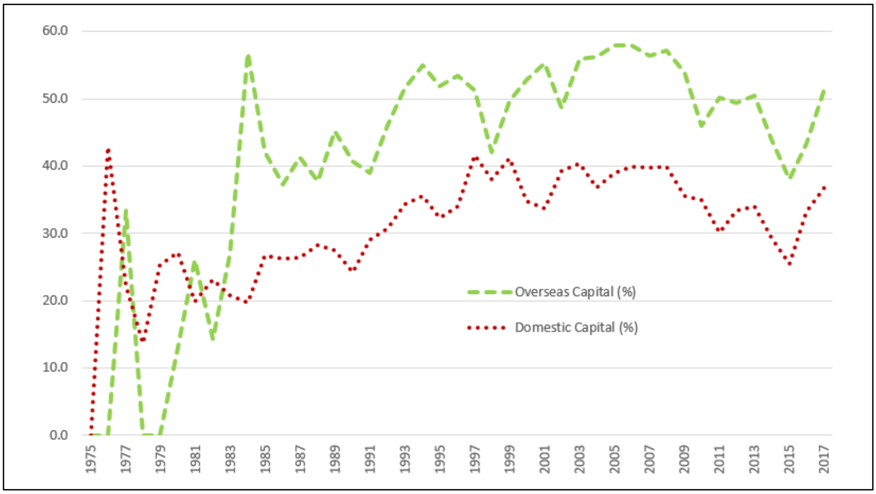


Figure 7. The proportion of academics located in the capital trained domestically and overseas

Sixthly, the Korean academic capability, whether they hold PhD degrees or not, has rapidly improved in the Korean academic system. The figure below shows the time lag between years of degree earned and recruited. Prior to the 1990s, universities typically hired non-PhD researchers as tenure-track professors. However, for newly hired academics, it takes approximately seven years after PhD completion. This means that the labor market for academics has become more competitive than it was a few decades ago. Overseas degree holders, in particular, have two or three years more experience than domestic degree holders.

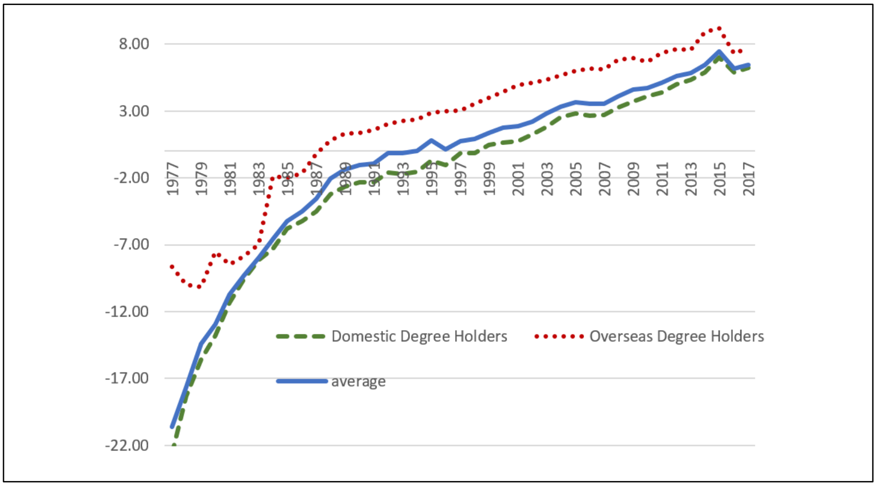


Figure 8. Time lag between degree-earned year and recruited year during the last half-century

IV. Data and Methodology

We use a statistical model to investigate the relationship between scientific productivity and overseas training, which includes independent and control variables such as academics' age and gender, as well as a dependent variable such as scientific productivity as measured by the number of publications. Scholars in the areas of the institutional sociology of science and the economics of science have conducted a large number of studies based on these productivity models (Hess, 1997; Stephan, 1996). We chose abroad training as an independent variable and research production as a dependent variable in this article. Additionally, we incorporate a variety of control factors such as personal characteristics (e.g., age and gender), contextual conditions such as the location and legal status of affiliated universities, and the amount of research funding.

Afterward, we gathered a distinct dataset comprising the personal information of over 33,505 Korean scholars. In the previous section, we investigated the unique traits of the Korean academic system in science and engineering using this dataset. In this section, we merged the personal data as of the end of 2017 with information on their research funding and academic performance over a 3-year period from 2014 to 2016, including their number of SCI and KCI publications. We have obtained all of the information from the "Survey on Korean University Researchers' Activities," which is conducted annually by the National Research Foundation of Korea.

The table below depicts variables included in the statistical analysis. Firstly, in terms of dependent variables, we established two types of performance indicators: KCI- and SCI-level research outcomes as measured by the number of publications. SCI papers are publications in journals listed in Clarivate Plc's Science Citation Index, whereas KCI papers are from the National Research Foundation of Korea's KCI journals. Papers published in SCI journals are typically of higher quality than those published in KCI journals. As shown in the table below, the average value of KCI-level research outcomes is 0.275 papers, while that of SCI-level research outcomes is 0.772 papers with a bigger standard deviation. Secondly, we set a dummy variable of the country trained as an independent variable. If academics are trained overseas, the value of the variable is one; otherwise zero. The value of the independent variable in the table below is 0.309, which implies that 30.9% of academics in the dataset are overseas-trained.

Thirdly, several control variables are set, as shown in the table. The research funding for those academics comes from various sources, including central and local governments, private organizations, the university itself, and overseas institutions. As indicated in the table, the average amount of funding from these four sources is 116.9, 22.2, 7.6, and 0.6 million won, respectively. In addition, we include other control variables such as age, gender, discipline,legal status, and the location of the university affiliated. Among those variables, country trained, gender, four disciplines of academics and legal status of the university affiliated are included as dummy variables. Age was calculated for researchers' personal variables by adding squared terms, in agreement with prior results that researchers' careers have a quadratic function shape with negative values related to increasing age. (Baser and Pema 2004; Oster and Hamermesh 1998). The average age of academics is 53.4. 82% of academics are male. 33% of academics belong to public universities, and 44% of academics are located in capital areas such as Seoul, Incheon, and Gyung-gi.

Table 1. Description of Variables

Category	Index	Definition and Measurement	Average (standard deviation)
Dependent Variable	Pub_1	KCI-Level Research Outcomes	0.275 (0.588)
	Pub_2	SCI-Level Research Outcomes	0.772 (1.149)
Independent Variable	Country	A dummy of Country Trained (Overseas = 1/ Domestic = 0)	0.309 (0.462)
Control Variable	Fund _gov	Natural Logarithm of the amount of Governments' funding	116.857 (376.434)
	Fund _pri	Natural Logarithm of the amount of private funding	22.221 (108.947)
	Fund _internal	Natural Logarithm of the amount of internal funding	7.596 (38.905)
	Fund _overseas	Natural Logarithm of the amount of overseas funding	0.569 (10.766)
	Age	Age	53.361 (8.047)
	Age2	Age Squared	2912.176 (857.631)
	Gender	Dummy of Females	0.823 (0.382)
	Disp	Dummy of disciplines	0.25 (0.433)
	NU	A dummy of a National/Public Univ.	0.336 (0.472)
	Region	Regional Dummy Variable	0.44 (0.496)

V. Results and Discussion: The effect of trained countries on the productivity

1. Descriptive statistics and t-test for the productivity of the two groups

Table 2 shows the number of academics domestically and overseas trained by disciplines. According to the table, out of the total number of academics in science and engineering in Korea, 23,267, or 69%, have received their degrees from domestic institutions, while 10,338, or 31%, are from overseas institutions. Among the four different disciplines, natural sciences have the highest percentage of academics who have received overseas training, followed by agricultural and maritime sciences, engineering, and medical and pharmaceutical sciences. However, when it comes to the total number of academics, engineering and medical and pharmaceutical sciences have the largest groups of overseas-trained and domestically-trained academics, respectively.

Table 2. Number of academics by disciplines and country trained

Disciplines	Subtotal	Domestically-trained	Overseas-trained
Engineering	12,905 (100%)	7,333 (56%)	5,572 (44%)
Natural Sciences	6,310 (100%)	3,238 (51%)	3,072 (49%)
Medi/Pharm	12,706 (100%)	11,776 (93%)	930 (7%)
Agri/Maritime	1,584 (100%)	820 (52%)	764 (48%)
Total	33,505 (100%)	23,167 (69%)	10,338 (31%)

Table 3 shows the funding amount for academic research categorized by funding sources and the country in which the academics received their training. Based on the table provided, the majority of research funding for academics comes from the government, followed by private sources, internal funding, and overseas sources. When comparing the amount of research funding received per capita between academics with domestic degrees and those with overseas degrees, the latter group receives double the amount of funding. It is worth noting that domestically-trained academics receive twice as much private funding compared to overseas-trained academics, which could be attributed to the stronger relationships they are able to form with domestic companies during their degree programs.

Table 3. The amount of funding earned by sources and country trained

(Unit: million won)

Country trained	Total funding	Government	Private	Internal	Overseas
Domestically-trained	2,608,954	1,985,997	476,593	137,919	8,445
Overseas trained	2,324,401	1,929,290	267,917	116,590	10,604
Total	4,933,355	3,915,287	744,510	254,509	19,049

The table below shows the performances of the academics in four different disciplines based on the number of KCI and SCI papers they published, categorized by the country where they received their training. Academics who obtained their degrees domestically in engineering, agricultural and maritime sciences, and natural sciences tend to produce more KCI papers compared to those who obtained their degrees overseas. Conversely, those with overseas degrees tend to produce more SCI papers in the same fields. This suggests that academics who received their training overseas perform better in internationally recognized academic fields than domestically-trained academics. The academics regard publishing KCI papers as a training opportunity for students by academics. However, in medical and pharmaceutical sciences, academics with overseas degrees tend to perform better in both KCI and SCI publications compared to those with domestic degrees. This may be because this field considers domestic publications as a professional performance in the domestic market, unlike other fields.

Table 4. T-test of academic performances by the country trained

	KCI			SCI		
Disciplines	Group	Obs.	Avg.	Group	Obs.	Avg.
Eng	Overseas	1764.09	0.32	Overseas	4249.45	0.88
	Domestic	3030.51	0.41	Domestic	4933.63	0.67
	Combined	4794.60	0.37	combined	9183.09	0.76
	Diff		-0.09	Diff		0.21
	t-value	-0.097***(0.012)		t-value	0.212***(0.022)	
Agri & mari	Overseas	256.28	0.34	Overseas	693.22	0.91
	Domestic	339.18	0.41	Domestic	477.59	0.58
	Combined	595.46	0.38	combined	1170.81	0.74
	Diff		-0.07	Diff		0.33
	t-value	-0.064*(0.033)		t-value	0.371***(0.073)	
Medi & phar	Overseas	185.00	0.20	Overseas	794.18	0.85
	Domestic	2073.34	0.18	Domestic	8771.73	0.74
	Combined	2258.34	0.18	combined	9565.90	0.75
	Diff		0.02	Diff		0.11
	t-value	0.034**(0.016)		t-value	0.146***(0.034)	
Nat sci	Overseas	652.86	0.21	Overseas	2836.03	0.92
	Domestic	924.17	0.29	Domestic	2484.83	0.77
	Combined	1577.03	0.25	combined	5320.86	0.84
	Diff		-0.08	Diff		0.15
	t-value	-0.073***(0.016)		t-value	0.156***(0.035)	

* Diff = mean(Overseas) – mean(Domestic)

2. Regression Analysis: Zero-Inflated Negative Binomial (ZINB) model

The dependent variables of our model, such as the number of publications, are count variables that can only take on zero or positive integer values. Therefore, for the regression analysis, the Poisson distribution and negative binomial distribution are considered as alternatives. The descriptive statistics presented in Table 1 clearly indicate over-dispersion, where the variance is significantly larger than the mean. This over-dispersion was also found to be statistically significant based on the alpha value. Consequently, the analysis shows that a negative binomial (NB) model is preferable to the Poisson model. Additionally, the results of the Vuong test indicate that a zero-inflated negative binomial (ZINB) model is a better fit for the data than a regular negative binomial (NB) model. Because it is possible that independent variables are linearly related to other variables, we choose to eliminate independent and control variables with VIF (Variance Inflation Factor) values exceeding 10.

Through analyzing the regression outcomes demonstrated in the subsequent table, we have identified a multitude of predictors to estimate the quantity of KCI and SCI papers generated. Specifically, Model 1 encompasses the entirety of the 33,305 science and engineering academics who possess efficacious values, whereas Model 2 assesses the dependent variables of the 5,806 recently inducted science and engineering academics within the three-year span commencing from 2017.

The subsequent exposition on several independent and control variables is predicated upon Model 2. Obtaining a degree overseas has a negative and significant impact on the production of KCI papers while obtaining a domestic degree has a positive and significant impact on the production of KCI papers. This suggests that academics who received their training overseas are more likely to publish in SCI journals rather than KCI journals.

In terms of funding sources, all four variables related to funding are positive and significant predictors for SCI papers. However, for KCI papers, government funding is a positive and significant predictor, while overseas funding is a negative and significant predictor. This indicates that different funding sources selectively influence KCI publications. Domestic government funding and overseas funding have opposite effects on publishing KCI papers.

The gender of academics is a significant predictor of the type of papers they produce. Female academics are more likely to produce KCI papers, while male academics are more likely to produce SCI papers. In terms of age, there is an inverse U-shaped relationship between age and productivity for both SCI and KCI papers, with research productivity dropping quickly after a certain age point. KCI publication is more sensitive to age, meaning that the effect of aging on productivity is stronger in KCI publications.

In terms of disciplines, engineering, agricultural and maritime sciences are better predictors for KCI papers than medical and pharmaceutical sciences, with natural sciences being the baseline. This suggests that academics in the former two areas are more likely to be productive in KCI papers compared to those both in natural sciences and medical and pharmaceutical sciences. On the other hand, for SCI papers, engineering, agricultural and maritime sciences are weaker predictors, while medical and pharmaceutical sciences are stronger predictors. This indicates that academics in natural sciences are more likely to be productive in SCI papers compared to those in other disciplines.

In terms of environmental factors such as institutional location and legal status, being a public university is a positive predictor for both KCI and SCI papers, suggesting that academics in public universities tend to have better academic performance. However, being located in the capital area is positive for SCI papers but negative for KCI papers. This could be because universities in the capital area may place more emphasis on publishing in SCI journals over KCI journals.

Model 2 explores the cohort of scholars newly appointed in higher education institutions between 2015 and 2017. This model facilitates an examination of the influence of independent and control variables on the performance of junior academics, as ascertained by the quantity of KCI and SCI publications. The most noteworthy discovery is that unlike Model 1, the attainment of education abroad is not a significant predictor for academic performance in both domestic and international arenas. In essence, we may conclude that young academics trained domestically are academically capable enough to compete with their peers trained abroad.

The findings derived from Model 1 align with the outcomes of Kwon et al. (2015), Lee and Jang (2013), and Um et al. (2012), thus exhibiting a similar trend among the broader academic population. In contrast, the results obtained from Model 2, which pertain solely to junior academics, fail to provide empirical support for the assertions made by either Kwon et al. (2015) or Shin et al. (2014). More specifically, while the T-test outcomes for junior academics in the field of engineering science lend credence to the claims put forth by Shin et al. (2014), the results of other T-tests support Kwon et al. (2015), as shown in Appendix Table 4. Comparing Table 1 and Appendix Table 1, junior academics receive less financial support yet write more SCI articles.

Regarding research funding, the direction and the magnitude of beta coefficients and their significance are similar to those in Model 1. In contrast, three of four beta coefficients became significant. In other words, the amount of research funding has a negative influence on publishing activities in domestic journals. These results imply that the size of research funding is a negative effect on domestic publications and is a negative effect on international publications.

Stated differently, scholars who possess limited financial resources are more inclined to disseminate their research findings through domestic publications.

In terms of the personal characteristics of junior academics, such as gender, age, and discipline, the beta coefficient's direction and magnitude in Model 2 were not noticeably different from those in Model 1. While the beta coefficient of age square was larger in Model 2, the negative impact of age remained stronger in Model 2. Additionally, for junior academics, distinguishing between engineering and natural science did not significantly affect their SCI publications.

Table 5. ZINB estimation of KCI and SCI productivity

Variable	Model 1		Model 2	
	KCI	SCI	KCI	SCI
Country (1=Overseas Degree)	-0.192*** (0.025)	0.179*** (0.017)	-0.12 (0.076)	0.003 (0.039)
Grant_government	0.00004* (0.00002)	0.0004*** (0.00001)	-0.00003* (0.0001)	0.0002*** (0.00004)
Grant_private	-0.0002 (0.0001)	0.001*** (0.00004)	-0.002* (0.001)	0.0004** (0.0002)
Grant_inner	-0.0001 (0.0003)	0.002*** (0.0001)	-0.0004** (0.002)	0.001*** (0.0003)
Grant_overseas	-0.004** (0.002)	0.003*** (0.0004)	0.004 (0.006)	0.004*** (0.001)
Gender (1=Male)	-0.639*** (0.029)	0.335*** (0.021)	-0.787*** (0.069)	0.321*** (0.042)
Age	0.381*** (0.02)	0.021* (0.011)	0.321*** (0.059)	0.041 (0.031)
Age2	-0.003*** (0.0002)	-0.0004*** (0.0001)	-0.003*** (0.001)	-0.001*** (0.0003)
Disciplines_ engineering	0.544*** (0.031)	-0.159*** (0.019)	0.640*** (0.092)	-0.011 (0.045)
Disciplines_agi and mar	0.400*** (0.051)	-0.129*** (0.036)	0.572*** (0.139)	-0.179** (0.087)
Disciplines_medi and phar	-0.403*** (0.035)	0.016 (0.021)	-0.180*** (0.094)	0.089* (0.046)
NU (1=National /Public Univ)	0.174*** (0.024)	0.279*** (0.016)	-0.026*** (0.065)	0.256*** (0.034)
Region (1=capital Area)	-0.268*** (0.025)	0.395*** (0.015)	-0.573*** (0.065)	0.487*** (0.033)
Constant	-11.193*** (0.531)	-0.790*** (0.287)	-8.887*** (1.44)	-1.384*** (0.743)
Observations	33,305	33,305	5,806	5,806

Environmental characteristics, including the university's location and legal standing, have a comparable significance and direction of influence, with just a slight variation in their magnitude. Notably, being a national institution had a favorable effect in Model 1 but a negative effect in Model 2. This suggests that younger academics situated in capital cities within Korea are more likely to benefit from national affiliations.

VI. Conclusion

This study aims to investigate the unique characteristics of the Korean academic system in relation to brain circulation, with a specific focus on the impact of overseas-trained academics on research activities within the Korean academic system. To achieve this, we formulated two research questions related to the demographic properties of Korean academics in science and engineering over the past 50 years and the research productivity of overseas returnees. Our literature review and analysis yield several intriguing findings as follows

Firstly, brain circulation is a crucial factor in the formation of a sustainable academic system in South Korea, particularly given the country's relative weakness in breeding enough qualified individuals to sustain its academic sector. In other words, during the early stages of the Korean innovation system, there was an opportunity to tap into a global knowledge pool, thereby facilitating an understanding and imitation of new technologies developed by advanced countries. However, as the Korean economy has matured, the academic system has started to produce domestically-trained PhDs, who now comprise the majority of individuals in Korean universities, resulting in a decrease in the number of PhDs who have received training overseas.

Secondly, in the South Korean labor market for academic professionals, there has been a notable preference for individuals who have returned from overseas training based on the perception that they are highly qualified. This preference has resulted in an increased likelihood for Korean students who study abroad to obtain academic positions, particularly in the capital area or in public universities in their home country. However, as the academic system has expanded significantly, the production of domestic PhDs has also increased, resulting in domestically-trained academics becoming a major driving force behind the development of the Korean academic system over the past decade. Consequently, the job market for overseas-trained academics has become more competitive due to the emergence of qualified domestic degree holders and a longer time gap between the year of degree completion and the year of recruitment.

Thirdly, when it comes to personal characteristics, we have observed a consistent trend of gender balance improvement among academic professionals over the past 40 years, particularly among those who hold domestic degrees. In terms of age, we have found that overseas degree holders tend to be older than domestic degree holders. Therefore, among the younger academic group in Korean universities, there is a greater representation of domestically-trained academics. Additionally, disciplinary differences indicate that overseas-trained academics tend to specialize in engineering and natural sciences, which are fields that are closely associated with industrial innovation in Korea.

Fourthly, based on the descriptive statistics, we show that, excluding medical and pharmaceutical sciences, approximately 50% of the academic population comprises individuals who have received training overseas. Interestingly, the total number of domestically-trained academics was found to be greater than the number of overseas-trained academics. In terms of research funding, overseas-trained academics tend to receive more funding than domestically-trained academics, even when group size is taken into account. Additionally, overseas-trained academics tend to produce more papers, particularly those published in SCI journals, on average, compared to domestically-trained academics.

Fifthly, regarding influencing factors for research productivity, our research has identified that overseas training has a noteworthy and favorable impact on the creation of internationally renowned journals after accounting for other factors such as funding, personal attributes (such as gender, age, and discipline), and environmental factors (such as legal status and location of the affiliated universities). However, if we apply the same statistical model only to junior academics, the prestigious status of overseas education has disappeared. This finding emphasizes the possibility for the Korean academic system to develop into a successful and self-sustaining institution.

Hence, we may argue that the Korean academic system's effective operation within the global research network and the conduction of high-quality academic research necessitate the presence of overseas returnees, despite the attenuated advantages of overseas training. Premature assumptions regarding the termination of reliance on scientifically advanced nations such as the US for overseas training may be unwarranted. Instead, policymakers ought to prioritize the implementation of policy measures that promote research collaboration and facilitate brain circulation, thereby generating mutual benefits for both sending and receiving countries. As such, the Korean government should lead the charge in enticing scientific talent from both the core and periphery regions.

Lastly, this study acknowledges certain limitations and puts forth suggestions for future research. The productivity variables in this study pertain to the count of publications in both domestic and international journals. In order to measure research quality more comprehensively, it is necessary to introduce additional indicators, such as citation counts or journal rankings, despite the assumption here that papers published in international journals exhibit superior quality relative to those in domestic journals. Moreover, certain critics may posit that post-doctoral training holds greater importance than doctoral training in fields like biology. Consequently, it is imperative to differentiate scholars with domestic degrees but with overseas post-doctoral experience and analyze them separately.

Furthermore, because we included university professors only in our statistical analysis, it is difficult to measure the pure impact of an international degree, as we exclude overseas degree holders in firms and public research institutes. We may suggest promising research topics that examine more thoroughly additional drivers (e.g., age, gender, and length of PhD program) and examine domestic mobility between public universities, businesses, and research institutions. In particular, we can calculate the impact of scientists' industry experience on academic output.

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Appendix Table 1. Description of variables for junior academics

Category	Index	Definition and Measurement	Average (standard deviation)
Dependent Variable	Pub_1	KCI-Level Research Outcomes	0.236 (0.530)
	Pub_2	SCI-Level Research Outcomes	0.899 (1.129)
Independent Variable	Country	Dummy of Country Trained (Overseas = 1/ Domestic = 0)	0.250 (0.433)
Control Variable	Fund _gov	Natural Logarithm of the amount of Governments' funding	84.342 (268.987)
	Fund _pri	Natural Logarithm of the amount of private funding	13.151 (72.652)
	Fund _internal	Natural Logarithm of the amount of internal funding	9.357 (37.033)
	Fund _overseas	Natural Logarithm of the amount of overseas funding	0.457 (8.211)
	Age	Age	46.043 (6.122)
	Age2	Age Squared	2157.458 (599.440)
	Gender	Dummy of Females	0.732 (0.443)
	Disp	Dummy of disciplines	0.250 (0.433)
	NU	Dummy of National/Public Univ.	0.354 (0.478)
	Region	Regional Dummy Variable	0.467 (0.499)

Appendix Table 2. Number of junior academics by disciplines and country trained

Disciplines	Sub total	Domestically-trained	Overseas trained
Engineering	1,624 (100%)	601 (63%)	1,023 (37%)
Natural Sciences	968 (100%)	537 (55%)	431 (45%)
Medi/Pharm	2,271 (100%)	2,117 (93%)	154 (7%)
Agri/Maritime	223 (100%)	135 (61%)	88 (39%)
Total	5,086 (100%)	3,390 (69%)	1,696 (31%)

Appendix Table 3. The amount of funding earned by sources and country trained for junior academics (Unit: million won)

Country trained	Total funding	Government	Private	Internal	Overseas
Domestically-trained	326,279	252,959	43,851	28,924	545
Overseas trained	219,480	176,006	23,033	18,665	1,777
Total	545,760	428,965	66,884	47,589	2,322

Appendix Table 4. T-test of research performance by Factors for junior academics

	KCI			SCI		
Disciplines	Group	Obs.	Avg.	Group	Obs.	Avg.
Eng	Overseas	148.92	0.25	Overseas	636.78	1.06
	Domestic	332.48	0.33	Domestic	983.28	0.96
	Combined	481.39	0.30	combined	1620.06	1.00
	Diff		-0.08	diff		0.10
	t-value	-0.077***(0.030)		t-value	0.098(0.068)	
Agri & mari	Overseas	27.55	0.31	Overseas	72.83	0.83
	Domestic	53.35	0.40	Domestic	107.47	0.80
	Combined	80.90	0.36	combined	180.30	0.81
	Diff		-0.09	diff		0.03
	t-value	-0.082(0.080)		t-value	0.032(0.126)	
Medi & phar	Overseas	31.69	0.21	Overseas	114.11	0.74
	Domestic	420.42	0.20	Domestic	1703.13	0.80
	Combined	452.11	0.20	combined	1817.24	0.80
	Diff		0.01	diff		-0.06
	t-value	0.007(0.040)		t-value	-0.064(0.075)	
Nat sci	Overseas	71.48	0.17	Overseas	481.57	1.12
	Domestic	115.63	0.22	Domestic	472.80	0.88
	Combined	187.12	0.19	combined	954.36	0.99
	Diff		-0.05	diff		0.24
	t-value	-0.049(0.033)			0.156***(0.035)	

* diff = mean(Overseas) – mean(Domestic)