European Journal of Government and Economics

ISSN: 2254-7088

Brain drain and economic growth: evidence of productivity growth from brain circulation

Woosik Yu[a*]

[a] Graduate School of International Studies, Seoul National University, Seoul, Republic of Korea

*** Corresponding author at:** woosik@snu.ac.kr

Abstract. This paper analyzes the effect of the so-called 'brain drain' on economic growth through the channel of growth in total factor productivity. We analyze panel data that measure the severity of brain drain, which are from IMD and the U.S. National Science Foundation. Our analysis shows that middle-income countries have more brain drain compared to the group of high-income countries. Also, emerging economies that grow fast tend to experience more brain drain. Our results from fixed effects regression models show that that brain drain has a significant and positive impact on economic growth, and the main channel is productivity growth. This can be considered as evidence of the positive effects of 'brain circulation', which is one of the brain drain phenomena that settlement of the talents in advanced countries can eventually help improve the productivity of home country by the sharing of advanced technologies and skills around them with colleagues in motherland. Therefore, a strategy of utilizing overseas resident talents should also be considered, alongside the brain-attraction policy.

Keywords. brain drain, brain circulation, economic growth, total factor productivity

JEL Codes. O11; O15; O47; F43

DOI. https://doi.org/10.17979/ejge.2021.10.1.7831

1. Introduction

As globalization deepens, issues with brain drain are often discussed worldwide. Brain drain refers to a state or a phenomenon in which a country cannot utilize its effective labor of human resources or human capital. This phenomenon is largely divided into internal brain drain and external brain drain. Internal brain drain refers to the phenomenon in which domestic personnel with specialized skills are engaged in jobs unrelated to their majors, and external brain drain refers to the state in which competent talents of a country reside in other foreign countries, and their productivity contributes to the production of other countries. The brain drain to be addressed in this study is the second concept, the external brain drain.

Whenever the 'Brain Drain Index' is announced at the International Institute for Management Development (IMD) in Switzerland every year, developing countries have continuously raised serious questions about the negative impact of brain drain on economic growth as well as national productivity and competitiveness. The argument is that the more serious the outflow of competent human resources to foreign countries, the less experts and research personnel in the home country, and this results in the weakening of the country's research and technology competitiveness and reduction of innovation, which in turn adversely affects economic growth.

On the contrary, some argue that brain drain may have a positive effect on the national economy and competitiveness. In South Korea during the 1970s, the 'brain drain' had even been regarded as an act of 'traitoring' and the students residing abroad after the completion of their studies were harshly blamed. However, in recent days, as described in Saxenian (2005) and Teney (2021), the practical concept of 'brain circulation' came up in which the students or workers who studied and were employed abroad do not return to their home country right away, but return after working abroad and acquiring advanced learning and skills, or contributing to the motherland through various human networks built up while living abroad. In this regard, brain drain is considered a positive phenomenon as the first step for the brain circulation.

As such, there are not many studies that quantitatively analyze the direct relationship between brain drain and economic growth using growth regression models, although brain drain can be a major factor in economic growth, either through the leakage of human capital or through the technological progress from brain circulation. Therefore, in this study, we intend to supplement the prior study by conducting an empirical analysis of the effects of external brain drain on economic growth using growth regression models, while looking at the time series trend for brain drain situations of several selected countries.

2. Literature review

Studies on the negative effects of the flight of skilled workers on the national economy and competitiveness are conducted by Grubel and Scott (1966), Bhagwati and Hamada (1974), and McCulloch and Yellen (1977). In addition, Docquier and Rapoport (2008) presented empirical analysis that since the 1990s, the migration of skilled workers (brain drain) has increased by a greater margin than that of ordinary workers, and explained the factors behind the brain drain.

However, studies by Mountford (1997), Stark, Helmenstein, and Prskawetz (1997), Beine, Docquier and Rapoport (2001), and Cinar and Docquier (2004) suggest that the migration of the talents to advanced technology-holding countries could have a positive impact on economic growth and competitiveness in the home country. According to Beine et al. (2001), immigration of talents can have both a 'brain effect' when returning home after acquiring advanced technology and a 'drain effect' that occurs when not returning home, and when brain effect is large enough under the open economy model, brain drain can have a positive effect on economic growth. Stark et al. (1997) also presented a research that said the dissemination of skills and knowledge gained in advanced technology-holding countries could help improve the home country's technological prowess when migrant talent returns. Cinar et al. (2004) also argued that the home remittance of competent people who moved to developed countries had a positive effect on economic growth of the home country, as is often seen in the cases of immigration of workers from developing countries. Moreover, Vidal (1998) explored brain drain's positive effect on human capital formation, and Saxenian (2005) described the process of brain circulation from brain drain with lowered transaction costs associated with digitization, and how it ultimately helps the development of technology in home country, using the data of Chinese- and Indian-born engineers in the United States (U.S.).

More recently, Kang, Lim, and Hwang (2013) provided empirical evidence of brain drain's indirect but positive influence on national competitiveness through R&D investment and accumulated human capital. Also, Lodigiani, Marchiori, and Shen (2015) showed that brain drain could have both positive and negative effects on GDP per capita through the technology diffusion at origin from the high-skilled diaspora, depending on the region's relative distance to the technological frontier.

Amid this widespread agreement and objection to the severity of brain drain, this study seeks to infer the effects of brain drain on economic growth and technological growth (a possible channel to economic growth) of home country, using the data that proxies the degree of brain drain.

3. Motivation

We were intrigued by the concept of 'brain circulation', one of the positive results from brain drain. As described in the above sections, talents who studied and were employed abroad can benefit their motherland through their acquisition of frontier technology and skills and sharing of their knowledge to their colleagues living in motherland, or co-workings with colleagues in home country.

With an awareness that brain drain can adversely affect society in the sense of human capital flight, we hypothesized that brain drain could also have a positive effect on economic growth, as many other researchers claim. However, our main argument is more comprehensive. We hypothesize that brain drain helps achieve economic growth through productivity growth. Brain drain can induce brain circulation, and brain circulation helps home country's technological progress. Technological progress ultimately improves productivity of production, and results in growth of income.

Particularly, the total factor productivity (TFP) is predicted to be mostly affected by the brain drain via brain circulation and technology diffusion. TFP refers to the productivity of an economy's composite inputs that are used to produce national output, and in neoclassical growth theory, economic growth rate converges to the growth rate of TFP in the long run (steady state). Thus, TFP can be a proxy for a country's productive efficiency and technological level.

TFP growth is one of the key components and channels for the economic growth in a simple growth model of $Y = TX$ where Y is national income, T is total factor productivity, X is composite input, and N is population. From the model, the income growth can be derived:

$$\frac{Y}{N} = T \cdot \frac{X}{N} \quad [1]$$

Then, $\frac{Y}{N} = y$ is national income per capita and $\frac{X}{N} = x$ is composite input per capita. When converting to growth terms, national income per capita growth (g_y) can be expressed as the sum of growth of total factor productivity (g_T) and growth of per-capita composite input (g_x) as described in equation [2]:

$$g_y = g_T + g_x \quad [2]$$

This implies that there are two main channels to which economic growth can be achieved: increasing growth rate of TFP or growth of composite input per capita. As the key hypothesis of this paper is that brain drain may enhance technology and productivity of home country through technological diffusion, testing the effects of brain drain on TFP growth will be the focus of our empirical analysis, as a channel to achieve income growth.

4. Empirical landscape

Before analyzing the data, we will look at the main explanatory variables of the paper along with the descriptive statistics (see Table 1). In this study, two indicators are used as key variables that can proxy the degree of brain drain. The first data was established using the 'Brain Drain Index' survey data from the World Competitive Executive Opinion Survey of the International Institute for Management Development (IMD) in Switzerland. The criteria number in IMD Competitiveness Yearbook is '3.2.21' and its title is 'Brain drain'. The survey question is "Brain drain ([of]well-educated and skilled people) does not hinder competitiveness in your economy"[1] with a scale from zero to ten, and is asked to influential entrepreneurs worldwide. Recent years of data can be downloaded online at website of IMD World Competitiveness Online[2], and the past data can be found in IMD World Competitiveness Yearbook series. As mentioned above, the index values of the original data are distributed from 0 to 10, and the more severe the brain drain is, the more negative impact it has on economic and management activities, and the closer it becomes to zero. In this study, the corresponding brain drain index values were subtracted from 10, so that the higher the brain drain is, the higher the values are. This newly defined IMD brain drain index is referred to as the 'brain drain index' in this paper. The indicator covers data from 61 countries and provides a total of 22 years of time series values from 1995 to 2016. This data is important in the sense that it can give information on how the entrepreneurs feel about brain drain of the country, as the entrepreneurs are the front-line agents who put the up-to-date technologies into practical uses, and they are eager to employ the talented the most.

[1] The IMD World Talent Ranking Methodology (2019)
[2] https://worldcompetitiveness.imd.org/CustomSearch

Table 1. Descriptive statistics of brain drain index and share of doctorate recipients staying in the U.S.

	Sample Size	Mean	Standard Deviation	Minimum	Maximum	No. of Countries	Period
Brain drain index[3]	1,174	4.779	1.582	1.04	8.85	61	1995~2016
PhD ratios staying in the U.S.	287	0.628	0.167	0.10	0.92	41	2010~2016
Brain drain index	210	5.379	1.322	2.75	8.85	30 (common sample counties)	2010~2016 (common sample period)
PhD ratios staying in the U.S.	210	0.609	0.145	0.21	0.92		

Note. Third and fourth rows are for common sample period (2010~2016) and sample country list (30 countries). Source: IMD World Competitiveness Executive Opinion Survey, US National Science Foundation

Table 2. Rankings of IMD Brain Drain Index by Country in 2016[4].

Rank	Country	B.D. Index	Rank	Country	B.D. Index	Rank	Country	B.D. Index
1	Hungary	8.44	22	Lithuania	5.97	43	Canada	4.20
2	Venezuela	8.44	23	Argentina	5.90	44	Israel	4.17
3	Bulgaria	8.04	24	Mongol	5.83	45	Iceland	4.08
4	Ukraine	8.00	25	Jordan	5.78	46	Chile	3.94
5	Croatia	7.84	26	Brazil	5.73	47	Belgium	3.89
6	South Africa	7.23	27	Japan	5.58	48	Indonesia	3.76
7	Slovakia	7.13	28	Spain	5.49	49	Germany	3.64
8	Kazakhstan	7.05	29	Mexico	5.23	50	Britain	3.58
9	Slovenia	6.85	30	France	5.22	51	Singapore	3.51
10	Russia	6.75	31	Italy	5.14	52	Finland	3.46
11	Greece	6.68	32	India	5.09	53	UAE	3.38
12	Portugal	6.61	33	Ireland	4.93	54	Luxembourg	3.35
13	Latvia	6.58	34	Rumania	4.55	55	Netherlands	2.80
14	Poland	6.58	35	Turkey	4.49	56	Hong Kong	2.78
15	Estonia	6.51	36	Cech	4.46	57	Denmark	2.75
16	South Korea	6.40	37	Thailand	4.41	58	Sweden	2.70
17	Taiwan	6.31	38	Qatar	4.41	59	USA	2.67
18	Philippines	6.23	39	Austria	4.35	60	Swiss	2.03
19	Columbia	6.07	40	Australia	4.31	61	Norway	1.68
20	China	6.05	41	New Zealand	4.30			
21	Peru	5.98	42	Malaysia	4.28			

Note. Source: IMD World Competitiveness Executive Opinion Survey.

[3] Values were subtracted from 10.
[4] The higher the value, the more serious the degree of brain drain is.

The second brain drain proxy data are from the U.S. National Science Foundation's 'Doctorate Recipients from U.S. Universities' dataset, which can be downloaded from NSF website[5]. More specifically, the data we used are taken from the 'Share of doctorate recipients with temporary visas intending to stay in the U.S. after doctorate receipt'. In this paper, we will refer all of the doctorate degrees in this data as 'Doctor of Philosophy (Ph.D.)', though we are aware that not all doctorate-level degrees are Ph.D. degrees. Thus, we will call this variable as 'Share of Ph.D.'s staying in the U.S.' for convenience. The variable takes a value of zero to one, and covers data of U.S. Ph.D. recipients from a total of 41 countries over the world with the seven-year time series availability from 2010 to 2016. The U.S. universities' Ph.D. graduates, who are considered to be the frontiers of advanced technology, can be classified as the 'top-class' professionals in their fields, and therefore, we postulate that the higher the percentage of them remaining in the U.S. is, the higher the level of brain drain their home countries face.

4.1. IMD Brain Drain Index data

First, Table 2 of IMD brain drain index rankings by country shows that Hungary, Venezuela, and Bulgaria are ranked the first, second and the third as of 2016. Not surprisingly, the upper-ranked countries are mostly middle-income or lower-middle-income countries, rather than the richest or poorest countries. As described in the table above, seven out of the top 10 countries, i.e., Hungary, Bulgaria, Ukraine, Croatia, Slovakia, Slovenia, and Russia, are Eastern European countries. This is likely to be the result of the recent increase in joins of these East European countries into the European Union, acquiring domestic labor's freedom of movement and employment in advanced countries such as U.K., Germany, and France.

We chose four countries, South Korea, China, Japan, and U.S. as samples to review time-series trends of individual economies. We chose China because it is one of the fast-growing countries with largest population size in the world, U.S. because of its largest GDP and highest technology level with top-class quality of human capital, South Korea because it is known as a miraculous example case where education and human capital played important roles to escape from the 'middle-income trap' and achieve sustained rapid growth, i.e., 'six-percent six-decade' growth. Finally, Japan was selected because it is widely known that it has become a trend in Japan that Japanese students do not pursue doctorate program abroad, and at the same time, the economy has been slowing down for decades despite its large size.

[5] https://www.nsf.gov/statistics/doctorates/

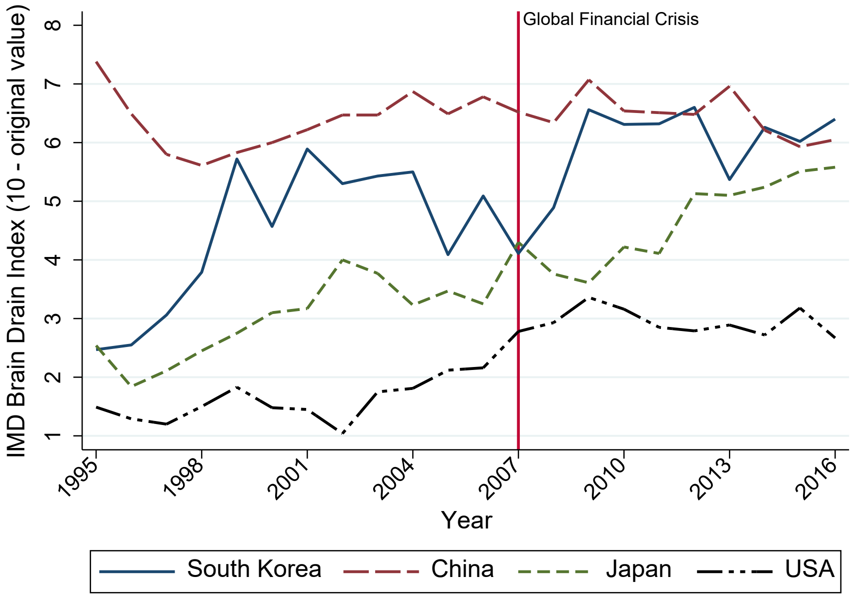

Figure 1. Time series of IMD brain drain index of South Korea, China, Japan, and U.S.A. Source: IMD World Competitiveness Executive Opinion Survey

Figure 1 shows that China's IMD brain drain index has been somewhat flat with some up and downs, but decreasing since 2013, while that of Japan has been rising. Moreover, in recent years, South Korea's IMD brain drain index exceeded that of China (in years 2012, 2014, 2015, and 2016). In 2016 South Korea was ranked 16th at 6.40, surpassing China's 6.05 (20th). Also, it is interesting to notice that South Korea's brain drain has leaped dramatically during the global financial crisis, in years 2007 and 2008, and since then, the trend is more or less flat, aside from the one-time negative shock in 2013.

4.2. NSF Doctorate Recipients from U.S. Universities data

Next, Table 3, the 2016 U.S. NSF's ranking of the share of Ph.D. recipients staying in the U.S. after their completion in the course, tells that Iran, Bangladesh and Venezuela are at the top of the list. Unlike the IMD brain drain index, six of the top 10 countries are made up of Asian countries, Iran, Bangladesh, Nepal, India, China, and Taiwan, while only two Eastern European countries, Bulgaria and Romania, are listed in the top 10. Also, Venezuela, a South American country, and Nigeria, an African country, are ranked third and eighth, respectively. This is attributed to the absence of the effect of Eastern European countries' membership status in the European Union. In other words, there are no visa problems for U.S. Ph.D. holders from Eastern Europe who have gone to settle down in the advanced European countries such as U.K. and Germany, and they are not counted and not reflected in this ranking. This is because the top universities and research institutes in Europe do not lag far behind compared to those of the U.S. in terms of research environment and the quality of co-workers.

Table 3. Rankings of Share of new Ph.D.'s Staying in the U.S. by Country in 2016[6].

Rank	Country	No. of US PhD Recipients	Share of Staying in the US	Rank	Country	No. of US PhD Recipients	Share of Staying in the US
1	Iran	695	0.911	22	Italy	167	0.659
2	Bangladesh	185	0.903	23	Kenya	61	0.656
3	Venezuela	27	0.889	24	Argentina	63	0.635
4	Bulgaria	44	0.886	25	Spain	73	0.616
5	Nepal	226	0.885	26	Columbia	187	0.615
6	Romania	51	0.882	27	Mexico	222	0.613
7	India	2,203	0.872	28	Germany	183	0.612
8	Nigeria	111	0.847	29	Turkey	472	0.576
9	China	5,534	0.809	30	Brazil	155	0.568
10	Taiwan	593	0.779	31	Canada	407	0.565
11	Philippines	51	0.765	32	Britain	115	0.548
12	Vietnam	124	0.718	33	Japan	166	0.530
13	Greece	84	0.714	34	Israel	83	0.518
14	Ukraine	31	0.710	35	Pakistan	102	0.451
15	Lebanon	58	0.707	36	Jordan	98	0.449
16	Ghana	87	0.701	37	Indonesia	92	0.435
17	Russia	108	0.694	38	Singapore	90	0.389
18	South Korea	1,228	0.668	39	Chile	130	0.323
19	Australia	42	0.667	40	Thailand	185	0.303
20	France	105	0.667	41	Saudi Arabia	238	0.101
21	Egypt	118	0.661				

Note. Source: U.S. National Science Foundation

Interestingly, Figure 2 shows a different pattern in the number of Ph.D.'s between South Korea and China. Korea's share of doctorate recipients staying in the U.S. sharply increases since 2013 while that of China continuously drops since 2012. Moreover, the number of new Ph.D. graduates from Korea decreases since 2012, while that of China has risen continuously and significantly at least from the year 2010, showing the seemingly opposite trends. In Korea, a high percentage (52.4%) of doctorate holders are starting their research career as non-regular workers (Song et al., 2016)[7], which are often discriminated against not only by the threat of job security but also by limitations to research activities, wages, children's education supports, and welfare systems compared to the full-time positioned workers.

On the other hand, since the 1990s, Chinese government started an initiative called 'Thousand Talents Plan (TTP)' or so-called 'The Salmon Project', of which the goal is to bring back 1000 talents to China who have studied in advanced countries by providing exceptional benefits

[6] The higher the value, the more serious the degree of brain drain is.
[7] In 2016, 75.5% of South Korea's new doctorate recipients are employed or confirmed to be employed, and among them, only 63.1% are employed for full-time regular positions, and 36.9% are employed for temporary (non-regular) positions. In sum, more than half (52.4%) of South Korea's doctorate recipients are either unemployed or employed for temporary jobs.

including financial reward of one million yuan per person, housings, medical insurance, and even the high-quality education opportunities for their children. (Oh, 2016).

This plan, which is also translated as the 'The Recruiting Program of Global Experts', aims to recruit world-class scholars, entrepreneurs, professional technicians and manager-level talents over the next five to ten years and deploy them to state-driven research projects, state-owned enterprises and banks, and industrial technology complexes (Lee, 2018). As a result of these efforts, many Chinese doctorate recipients appear to be returning to their home countries to settle down, and graduate students actively seek for Ph.D. study opportunities in the U.S. because they are aware of these rewards.

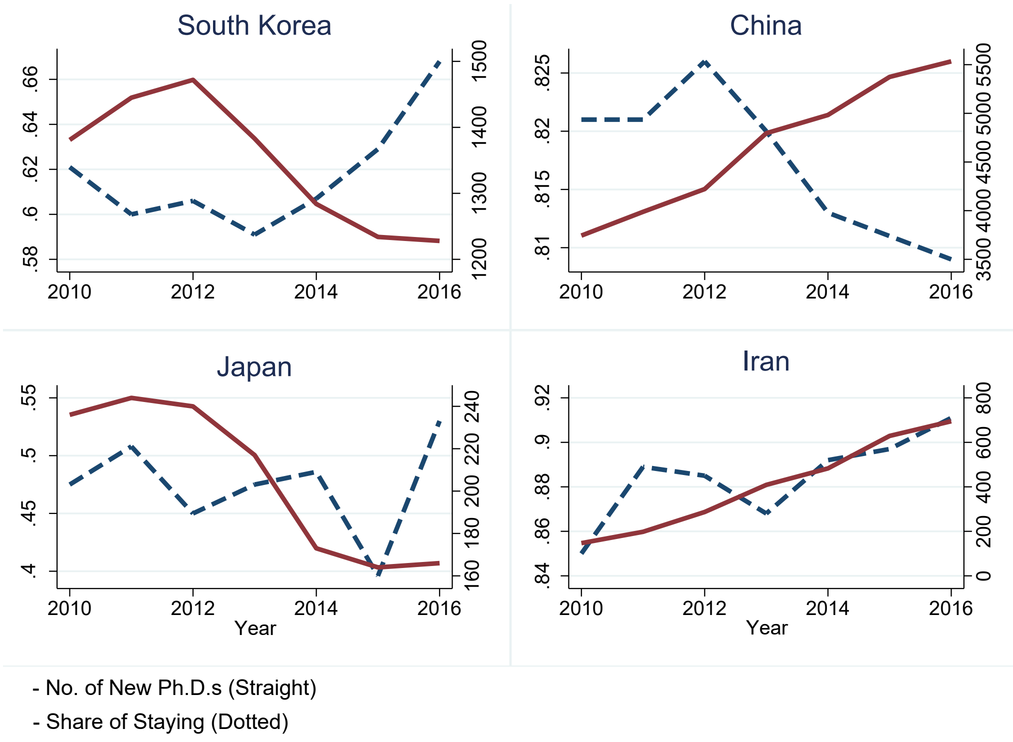

Figure 2. Number of U.S. Ph.D. recipients and the share of them intending to stay in the U.S. Source: U.S. National Science Foundation

On the other hand, for Japan and Iran, the number of Ph.D. recipients and the share of Ph.D.'s staying in the U.S. move in the same direction. In Japan, both the number of Ph.D. recipients and the share of Ph.D.'s staying in the U.S. show downward patterns by 2015. In the case of Iran, both variables show a pattern of upward movement, and the gradients are steep. In particular, the number of U.S. doctorate recipients from Iran grows rapidly from 147 in year 2010 to 695 in 2016. Iran was selected as a new sample for analysis simply because its 'share of Ph.D.'s staying in the U.S.' was the highest among the sample countries as of 2016.

Table 4. Pearson correlation analysis between brain drain index and selected macroeconomic variable.

Variables[8]		Correlation Coefficient	P-value
Brain Drain Index	Share of Staying in the US	0.519	0.000
Brain Drain Index	Total Factor Productivity	-0.477	0.000
Brain Drain Index	GDP per Capita	-0.452	0.000
Brain Drain Index	Human Capital Index	-0.271	0.000
Share of Staying in the US	Total Factor Productivity	-0.283	0.000
Share of Staying in the US	GDP per Capita	-0.415	0.000
Share of Staying in the US	Human Capital Index	-0.255	0.000

4.3. Correlation Analysis of Brain Drain Indicators

Table 4 shows the results of Pearson correlation tests between the brain drain variables and key macroeconomic variables. We are presenting this correlation analysis to show the landscape of macroeconomic data and their relationships with brain drain variables before moving on to the regression analysis.

First, there was a strong correlation between IMD brain drain index and the share of Ph.D. recipients staying in the U.S. The higher the share of Ph.D.'s staying in the U.S. is, the higher the brain drain index is. In addition, both variables have negative correlation with the key macroeconomic growth variables, i.e., total factor productivity, per capita GDP, and human capital index. The more technically advanced, or the more productive the countries are, the richer the countries are, and the higher the human capital index is, the less brain drain there is.

5. Empirical analysis

5.1. Model Specification

In this study, we use these two variables described earlier, IMD's 'brain drain index' and NSF's 'share of Ph.D.'s staying in the U.S.' as key explanatory variables and explain the economic growth and total factor productivity growth using fixed-effects linear regression models. The growth regression models are represented by the following six reduced-form equations such that:

$$Model\ 1:\quad g\_y_{i,t\sim t+5} = \beta_0 + \beta_1 BDI_{i,t} + \gamma X_{i,t} + \nu_t + \upsilon_i + \varepsilon_{i.t} \qquad [3]$$

$$Model\ 2:\quad g\_y_{i,t\sim t+5} = \beta_0 + \beta_1 SSU_{i,t} + \gamma X_{i,t} + \nu_t + \upsilon_i + \varepsilon_{i.t} \qquad [4]$$

$$Model\ 3:\quad g\_y_{i,t\sim t+5} = \beta_0 + \beta_1 SSU_{i,t} + \gamma_0 NPR_{i,t} + \gamma_1 X_{i,t} + \nu_t + \upsilon_i + \varepsilon_{i.t} \qquad [5]$$

[8] Total factor productivity index is 'ctfp' from Penn World Table (PWT) 9.1 (Feenstra RC, Inklaar R & Timmer MP, 2015), GDP per capita is 'rgdpe/pop' from PWT, human capital index is 'hc' from PWT.

$$Model\ 4{:}\quad g\_T_{i,t\sim t+5} = \beta_0 + \beta_1 BDI_{i,t} + \gamma X_{i,t} + \nu_t + \upsilon_i + \varepsilon_{i.t} \quad [6]$$

$$Model\ 5{:}\quad g\_T_{i,t\sim t+5} = \beta_0 + \beta_1 SSU_{i,t} + \gamma X_{i,t} + \nu_t + \upsilon_i + \varepsilon_{i.t} \quad [7]$$

$$Model\ 6{:}\quad g\_T_{i,t\sim t+5} = \beta_0 + \beta_1 SSU_{i,t} + \gamma_0 NPR_{i,t} + \gamma_1 X_{i,t} + \nu_t + \upsilon_i + \varepsilon_{i.t} \quad [8]$$

where $g\_y_{i,t\sim t+5}$ and $g\_T_{i,t\sim t+5}$ are average annual growth rates of home country i's income (per-capita GDP) and total factor productivity from year t to year $t+5$, respectively. $BDI_{i,t}$ and $SSU_{i,t}$ denote country i's Brain Drain Index and share of doctoral graduates staying in the U.S. at year t, respectively. $NPR_{i,t}$ represents the number of U.S. Ph.D. recipients of country i in year t. This term is included to control for the differences in capacities of sample countries to send their students for U.S. doctoral programs. $X_{i,t}$ is a set of external environmental and policy variables that may affect the dependent variables, namely, lagged income (lagged GDP per capita), years of schooling, fertility rate, investment to GDP ratio, government spending to GDP ratio, trade openness, and terms of trade change. These variables are often used in literature with conventional growth regression models such as Barro (2016) and Lee (2017). Moreover, ν_t and υ_i are included to control for the year- and country-specific fixed effects, respectively. $\varepsilon_{i.t}$ represents the error term.

The followings are summary statistics of variables used in regression analysis. Table 5 is a summary statistics table for the regression models that use IMD brain drain data, and Table 6 is the table for the models that use NSF Doctorate Recipients from U.S. Universities data. Since IMD data contains more country samples with a longer time span, the regression models that use this data have more observations than those that use NSF data. The correlation matrices of all used variables are presented in the appendix (see Table A1 and Table A2).

Table 5. Summary Statistics for Model 1 and Model 4 (1993~2017, 61 Countries).[9]

Variable	Obs.	Mean	Std. Dev.	Min	Max
GDP per Capita Growth*	1,342	0.034	0.035	-0.133	0.230
TFP Growth*	1,320	0.003	0.028	-0.146	0.125
Brain drain index	1,361	4.80	1.52	1.33	8.56
Lagged income** (USD)	1,525	23,589	17,852	1,170	136,890
Years of schooling	1,464	9.95	2.20	3.29	13.55
Fertility rate	1,500	1.90	0.64	0.93	4.93
Investment/GDP	1,525	0.248	0.069	0.002	0.640
Government spending/GDP	1,525	0.182	0.064	0.037	0.423
Trade openness	1,525	0.800	0.693	0.068	5.457
Terms of trade change	1,525	0.005	0.064	-0.060	1.789

*: Average annual growth rate from year t to year t+5. **: Value of income for year t-5

9 GDP per capita (or income) is 'rgdpe/pop' from PWT, years of schooling is 'yr_sch' from PWT, investment to GDP ratio is 'csh_i' from PWT, government spending to GDP ratio is from 'csh_g' from PWT, trade to GDP ratio is 'csh_x-csh_m' from PWT, the terms of trade is 'pl_x/pl_m' from PWT, and fertility rate is from World Development Indicator's 'Fertility Rate' variable.

Table 6. Summary Statistics for Models 2, 3, 5, and 6 (2008~2017, 41 Countries)

Variable	Obs.	Mean	Std. Dev.	Min	Max
GDP per Capita Growth*	287	0.022	0.033	-0.133	0.101
TFP Growth*	245	-0.002	0.027	-0.146	0.056
Share of staying in US	410	0.626	0.160	0.122	0.904
Number of US Ph.D. recipients	410	333	780	28	5,454
Lagged income**	410	18,570	14,789	1271	72,583
Years of schooling	360	9.11	2.69	3.11	13.55
Fertility rate	400	2.23	0.96	1.19	5.90
Investment/GDP	410	0.238	0.075	0.076	0.501
Government spending/GDP	410	0.165	0.047	0.059	0.336
Trade openness	410	0.528	0.451	0.084	3.251
Terms of trade change	410	0.013	0.122	-0.042	1.789

*: Average annual growth rate from year t to year t+5
**: Value of income for year t-5

5.2. Results

Table 7 shows the results of linear regression analysis that explain the growth rate of GDP per capita and the growth rate of total factor productivity. All variables take five-year (plus and minus 2 years) moving average forms to rule out the short-term shocks and capture the long-term trend. As mentioned above, the dependent variables, GDP per capita growth and TFP growth, are generated by calculating growth rates from year t to year $t+5$ to see the future (five-year-later) effects of brain drain. The control variable 'Ln (Lagged Income)' took the lagged form, which uses the value of the year five years ahead ($t-5$).

The analysis shows that both the brain drain index and the share of Ph.D.'s staying in the U.S. have significant and positive effects on economic growth and productivity growth. Models that have TFP growth as the dependent variable (models 4, 5, and 6) show greater regression coefficients for key explanatory variables than the models with GDP per capita growth. This implies that brain drain more affects TFP growth and suggest that the main channel of brain drain affecting economic growth is likely to be the productivity growth. In other words, since brain drain does not directly affect income growth, but via TFP growth, the regression coefficient on TFP turns out to be stronger, and this is on the same line with our hypothesis. Also, the differences of fit (R-squared and adjusted R-squared) are higher for models with 'share of staying in U.S.' variable (models 2, 3, 5 and 6), implying that these models better explain the effects of brain drain compared to other models. In addition, the inclusion of controls for the number of U.S. Ph.D. recipients does not alter the regression result, suggesting that the possible sample selection issues related to the magnitude of doctorate recipients are well-controlled.

Table 7. Results of linear regression of economic and total productivity growth.

	Model 1	Model 2	Model 3	Model 4	Model 5	Model 6
	GDP per Capita Growth (t+5)			TFP Growth (t+5)		
Brain Drain Index	**0.012**** (0.012)			**0.013***** (0.003)		
Share of Staying in US		**0.062**** (0.015)	**0.063**** (0.021)		**0.080***** (0.003)	**0.082***** (0.005)
Ln (Number of US Ph.D. Recipients)			0.0004			0.002
Ln (Lagged Income)	-0.041***	0.010	0.010	-0.028***	-0.003	-0.003
Ln (Years of Schooling)	-0.033	-0.003	-0.004	-0.015	0.011	0.006
Ln (Fertility Rate)	-0.045***	-0.014	-0.014	-0.021*	-0.008	-0.006
Ln (Investment/GDP)	-0.031***	-0.016	-0.016	0.013**	0.017	0.018
Ln (Gov. Sp. /GDP)	-0.003	0.070***	0.070***	0.014***	0.081***	0.081***
Ln (Trade Openness)	0.031***	-0.073***	-0.073***	0.030***	-0.046*	-0.047*
Terms of Trade Chg.	-0.096	-0.257**	-0.257**	0.164*	-0.072	-0.071
Country & Year FE	Included	Included	Included	Included	Included	Included
Observations	1,156	273	273	1,150	238	238
R-squared	0.406	0.801	0.801	0.308	0.735	0.735
Adjusted R-squared	0.357	0.754	0.753	0.252	0.669	0.667

Note. p < 0.1, ** p < 0.05, *** p < 0.01; Values in parenthesis are p-values; 'Brain Drain Index' and 'Share of Staying in U.S.' are in natural logarithm terms.

However, in model 1, investment to GDP ratio shows a strong and negative relationship with per capita GDP growth rate, and in models 2 and 3, trade openness has strong and negative regression coefficients, and thus, these models seem to be disqualifying to be established as benchmark models and show possibilities of needs for other control variables. On the other hand, the correlation coefficients of models 4, 5, and 6 seem to be consistent with the conventional growth regression models.

Lastly, the authors are acknowledging the potential weakness of the result that even with the year-specific fixed effects method, due to the moving average forms of the variables, there may be a possibility of issues with autocorrelation across time. Also, a more thorough analysis can be conducted with the inclusion of factors that determines the decision of the talented to study abroad in the U.S., as well as the decision to stay in the U.S. or return to the home country. For example, the following factors, which are not considered in this paper's empirical analysis, may improve the models: the baseline living conditions of home country, job and income prospects in the U.S. compared to those of home countries, cultural differences, cost of living in the home countries.

6. Conclusion

According to our international comparisons of brain drain, the patterns of brain drain vary from country to country. Particularly, South Korea and China show stark differences. South Korea's human resource outflow continuously increases and deepens while China's talent outflow is showing a marked decline. Korean media often argue that the deepening of this pattern will reduce the relative quality of South Korea's human capital, and that of China will continue to accumulate and surpass Korea's level soon. In general, middle-income countries rather than high-income group have more brain drain. Also, emerging economies that grow fast tend to experience more brain drain.

However, the results of growth regression analysis show that so-called brain drain has a significant impact on both economic growth and productivity (TFP) growth, implying that brain drain does not always affect the economy in a negative way. Moreover, brain drain has shown to have a more positive association with productivity growth, suggesting that the main channel of brain drain inducing economic growth is likely to be the productivity growth. This can be considered as evidence of the positive effects of 'brain circulation', which is one of the brain drain phenomenon that settlement of the talents in advanced countries can eventually help improve the productivity of home country by sharing of advanced technologies and skills around them with colleagues in motherland.

Therefore, from a policy point of view, a two-track strategy is suggested to simultaneously pursue measures to maximize the improvement of national level of technology, which emphasizes the utilization of overseas resident talents alongside the brain-attraction policy. In this context, developing nations should try avoiding the unconditional brain-attraction policy. Furthermore, the support policies to raise the quality of research institutes and universities to the world-class level, as well as policies that encourage talents-sharing with global frontier firms will also help improve the home country's technological prowess through technology and knowledge diffusion in the long run, as these policies can attract and embrace skilled overseas brain groups.

References

Barro, R. J. (2016). Economic Growth and Convergence, Applied to China. *China and World Economy*. 5(24):5-19. https://doi.org/10.1111/cwe.12172

Beine, M., Docquier, F., & Rapoport, H. (2001). Brain Drain and Economic Growth: Theory and Evidence. *Journal of Development Economics*, 64(1), 275-289. https://doi.org/10.1016/S0304-3878(00)00133-4

Bénassy, J. P., & Brezis, E. S. (2013). Brain Drain and Development Traps. *Journal of Development Economics*, 102, 15-22. https://doi.org/10.1016/j.jdeveco.2012.11.002

Bhagwati, J., & Hamada, K. (1974). The Brain Drain, International Integration of Markets for Professionals and Unemployment: A Theoretical Analysis. *Journal of Development Economics*, *1*(1), 19-42. https://doi.org/10.1016/0304-3878(74)90020-0

Cinar, D., & Docquier, F. (2004). Brain Drain and Remittances: Implications for the Source Country. *Brussels Economic Review*, *47*(1), 103-118.

Docquier, F., & Rapoport, H. (2008). Brain Drain and Human Capital Formation in Developing Countries: Winners and Losers. *The Economic Journal*, *118*(528), 631-652. https://doi.org/10.1111/j.1468-0297.2008.02135.x

Feenstra R. C., Inklaar R., & Timmer M. P. (2015). The Next Generation of the Penn World Table. *American Economic Review*, 105(10), 3150–3182. https://doi.org/10.1257/aer.20130954

Grubel, H. B., & Scott, A. D. (1966). The International Flow of Human Capital. *American Economic Review*, *56*(1/2), 268-274.

IMD World Competitiveness Executive Opinion Survey

IMD World Competitiveness Yearbook

Kang, D. K., E.-S Lim, & J. Hwang. (2013). An Exploratory Study on the Relationship between Brain Drain and National Competitiveness. *IOM MRTC Working Paper Series*, *No. 2013-05*. IOM Migration Research and Training Centre. Republic of Korea.

Lee, J. W. (2017). China's Economic Growth and Convergence. *World Economy*. 40:2455-2474. https://doi.org/10.1111/twec.12554

Lee, K. (2018). Chinese Science Paper Results Exceed the U.S. The Science Times. URL: https://www.sciencetimes.co.kr/?news=%EC%A4%91%EA%B5%AD-%EA%B3%BC%ED%95%99%EB%85%BC%EB%AC%B8-%EC%84%B1%EA%B3%BC-%EB%AF%B8%EA%B5%AD-%EC%B6%94%EC%9B%94%ED%95%9C%EB%8B%A4 (Retrieved on June 3, 2019. In Korean, title translated by the author).

Lodigiani, E., Marchiori, L., & Shen, I.-L. (2015). Revisiting the Brain Drain Literature with Insights from a Dynamic General Equilibrium World Model. *The World Economy*, 39(4), 557–573. https://doi.org/10.1111/twec.12269

McCulloch, R., & Yellen, J. T. (1977). Factor Mobility, Regional Development and the Distribution of Income. *Journal of Political Economy,* 85(1), 79-96. https://doi.org/10.1086/260546

Mountford, A. (1997). Can a Brain Drain Be Good for Growth in the Source Economy? *Journal of Development Economics,* 53(2), 287-303. https://doi.org/10.1016/S0304-3878(97)00021-7

Oh, H. (2016). Leakage of Korean Talents. Chosun Ilbo. http://news.chosun.com/site/data/html_dir/2016/08/08/2016080801521.html (Retrieved on September 26, 2019. In Korean, title translated by the author).

Saxenian, A. (2005). From Brain Drain to Brain Circulation: Transnational Communities and Regional Upgrading in India and China. *Studies in Comparative International Development*, 40(2), 35-61. https://doi.org/10.1007/BF02686293

Song, C. Y., Oh, H. Y., Kim, H. J., & Lee, E. H. (2016). Korea Survey of Earned Doctorates, 2016. Korea Research Institute for Vocational Education & Training, KRIVET. Republic of Korea.

Stark, O., Helmenstein, C., & Prskawetz, A. (1997). A Brain Gain with a Brain Drain. *Economics letters*, *55*(2), 227-234. https://doi.org/10.1016/S0165-1765(97)00085-2

Survey of Earned Doctorates, Doctorate Recipients from U.S. Universities, National Science Foundation (NSF), URL: https://www.nsf.gov/statistics/doctorates/

Teney, C. (2021). Immigration of Highly Skilled European Professionals to Germany: Intra-EU Brain Gain or Brain Circulation? *Innovation: The European Journal of Social Science Research*, 34(1), 69-92. https://doi.org/10.1080/13511610.2019.1578197

The IMD World Talent Ranking Methodology (2019). https://www.imd.org/globalassets/wcc/docs/release-2019/talent/imd_world_talent_ranking_methodology_2019.pdf (Retrieved on November 12, 2021).

Vidal, J.-P. (1998). The Effect of Emigration on Human Capital Formation. *Journal of Population Economics*, 11(4), 589-600. https://doi.org/10.1007/s001480050086

Appendix

Table A1. Correlation Matrix for Variables of Models 1 and 4.

	Var1	Var2	Var3	Var4	Var5	Var6	Var7	Var8	Var9
Var2	0.667	1.000							
	(0.000)								
Var3	0.136	0.060	1.000						
	(0.000)	(0.041)							
Var4	-0.327	-0.219	-0.448	1.000					
	(0.000)	(0.000)	(0.000)						
Var5	-0.170	0.039	-0.261	0.427	1.000				
	(0.000)	(0.153)	(0.000)	(0.000)					
Var6	0.041	0.008	0.163	-0.231	-0.509	1.000			
	(0.136)	(0.779)	(0.000)	(0.000)	(0.000)				
Var7	-0.181	-0.085	-0.353	0.409	0.008	-0.087	1.000		
	(0.000)	(0.002)	(0.000)	(0.000)	(0.766)	(0.001)			
Var8	0.268	0.143	0.361	-0.405	0.094	-0.141	-0.413	1.000	
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)		
Var9	-0.022	-0.025	-0.244	0.397	0.266	-0.305	0.391	-0.155	1.000
	(0.412)	(0.371)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	
Var10	-0.069	-0.105	0.128	-0.028	-0.035	0.038	-0.017	0.038	-0.045
	(0.012)	(0.000)	(0.000)	(0.283)	(0.177)	(0.139)	(0.503)	(0.134)	(0.077)

Note. Values in parentheses are p-values; Var1: GDP per capita growth; Var2: TFP growth; Var3: IMD brain drain index; Var4: lagged income; Var5: years of schooling; Var6: fertility rate; Var7: investment to GDP ratio; Var8: government spending to GDP ratio; Var9: trade openness; Var10: terms of trade change

Table A2. Correlation Matrix for Variables of Models 2, 3, 5, and 6.

	Var1	Var2	Var3	Var4	Var5	Var6	Var7	Var8	Var9	Var10
Var2	0.866	1.000								
	(0.000)									
Var3	0.154	0.057	1.000							
	(0.009)	(0.378)								
Var4	0.198	0.031	0.251	1.000						
	(0.001)	(0.635)	(0.000)							
Var5	-0.084	0.094	-0.400	-0.098	1.000					
	(0.155)	(0.144)	(0.000)	(0.048)						
Var6	-0.032	0.209	-0.252	-0.112	0.747	1.000				
	(0.592)	(0.001)	(0.000)	(0.034)	(0.000)					
Var7	-0.196	-0.294	0.082	-0.145	-0.487	-0.560	1.000			
	(0.001)	(0.000)	(0.104)	(0.004)	(0.000)	(0.000)				
Var8	0.157	0.003	-0.079	0.568	0.222	-0.005	-0.330	1.000		
	(0.008)	(0.967)	(0.112)	(0.000)	(0.000)	(0.930)	(0.000)			
Var9	-0.058	0.287	-0.084	-0.156	0.233	0.523	-0.361	-0.222	1.000	
	(0.328)	(0.000)	(0.090)	(0.002)	(0.000)	(0.000)	(0.000)	(0.000)		
Var10	0.019	0.042	-0.323	-0.058	0.688	0.488	-0.361	0.320	0.009	1.000
	(0.753)	(0.512)	(0.000)	(0.246)	(0.000)	(0.000)	(0.000)	(0.000)	(0.862)	
Var11	-0.034	0.060	0.108	-0.036	-0.020	-0.004	0.002	-0.003	0.072	-0.072
	(0.570)	(0.349)	(0.029)	(0.463)	(0.694)	(0.934)	(0.963)	(0.948)	(0.146)	(0.144)

Note. Values in parentheses are p-values; Var1: GDP per capita growth; Var2: TFP growth; Var3: share of staying in U.S.; Var4: number of U.S. Ph.D. recipients; Var5: lagged income; Var6: years of schooling; Var7: fertility rate; Var8: investment to GDP ratio; Var9: government spending to GDP ratio; Var10: trade openness; Var11: terms of trade change