The Effect of Human Capital on Economic Growth in Developed Countries

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Abstract

The purpose of this article is to explore the effect of highly shilled workers on economic growth. We examine this by using growth accounting. I find that the number of Ph.D. and Master has no statistically significant impact on TFP, but the number of Ph.D. and Master in all areas I investigated has a statistically significant impact on trend GDP. My results indicate that Ph.D. and Master recipients are important in promoting long-term economic growth in developed countries. Additionally, as an implication for the Japanese economy, the government should not decrease the subsidy for universities, and the Japanese society should not underestimate the ability of Ph.D. and Master students for their impact of economic growth.
JEL classification code E24, J24, O47

Keywords Human Capital, Economic Growth, Growth Accounting

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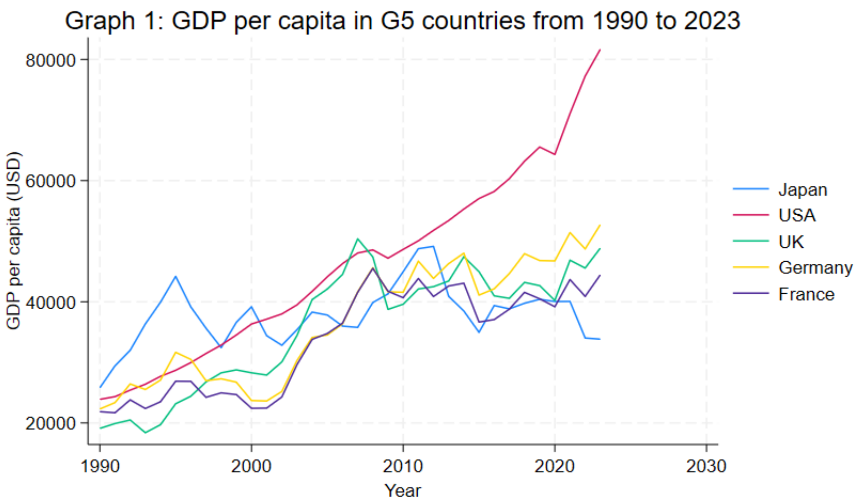
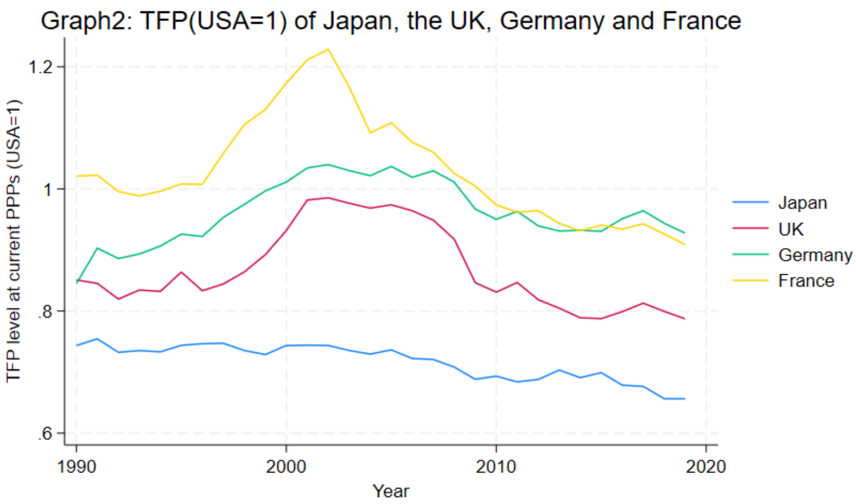
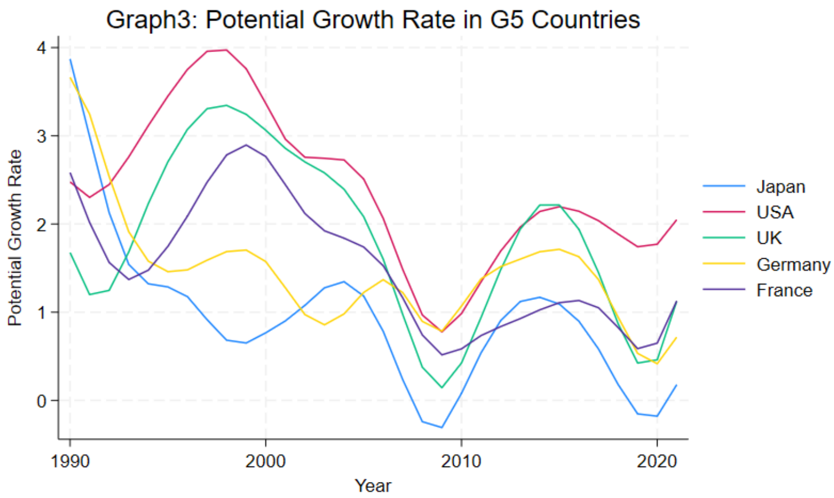
1.Introduction

The most significant and difficult problem is long-term stagnation of the Japanese economy. Japan finished its economic catch-up to the United States and major European countries in terms of GDP per capita and Total Factor Productivity in the late 1980s. However, from around 1990, the Japanese economy stopped growing and the difference between GDP per capita, Total Factor Productivity (TFP), and the potential growth rate of Japan and that of the USA became larger. These are shown in Graphs 1, 2, and 3 below. Here, the TFP is calculated as the just residual of growth rate of capital and labor forces without human capital.





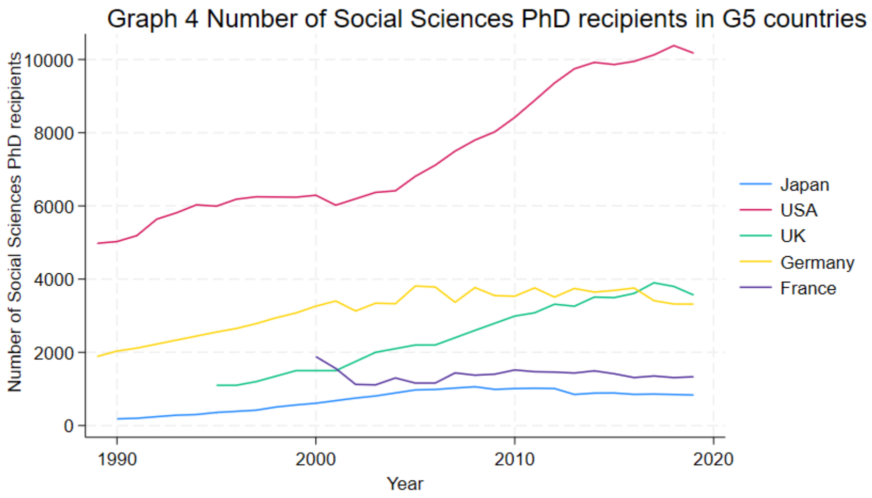
Different people have proposed different causes for this phenomenon. The first is the lower productivity growth rate. Hayashi and Prescott (2002) argued that Japan's lost decade is not caused by a breakdown of the financial system, but rather caused by a low productivity growth rate. The second is a lower level of deregulation. Hoshi and Kashyap (2011) found that the entry regulation for nonmanufacturing industries was not relaxed and was not relaxed overall from 1995 to 2005. The related one is what is called "Zombie firms". By defining Zombie firms as unprofitable firms with low stock market valuation from 4 percent in the late 1980s to 15 percent in 2007, Banerjee and Hofmann (2022) found that there was a negative relationship

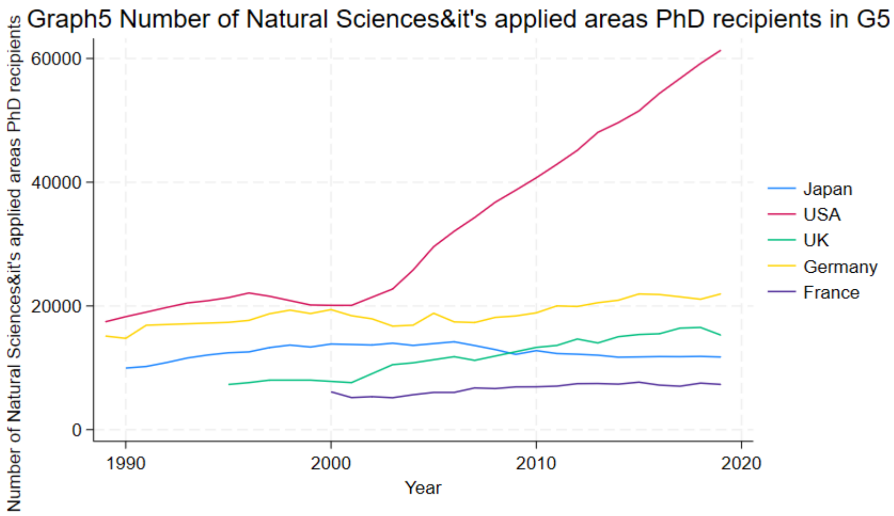


between the nominal interest rate and the number of Zombie firms in the 14 developed countries, including Japan. This result implies that a rise in the number of Zombie firms may have a harmful impact on productivity and economic growth in these nations. The third is harmful economic policies. Kenneth, Iwaisako, and Adam (2015) argue that the Japanese government and monetary authorities in particular, made crucial mistakes that contributed to the initial slowdown and subsequent stagnation. According to them, policymakers repeatedly failed to admit previous mistakes and change course, even after the problems of chronic recession and deflation became obvious. The fourth is the lower productivity of small and medium-sized enterprises, which account for more than two-thirds of employment. Jones (2022) argues that SMEs are the primary responsible for the relatively low level and growth of productivity in Japan by looking at the statistics that labor productivity in large companies is more than double that of SMEs. The fifth one is huge public debt in Japan. The Japanese debt to GDP ratio was 258.2 percent in 2023 and Eberhardt and Presbitero (2015) conducted the sophisticated econometric analysis and found that there is a negative relationship between public debt and growth. The sixth is aging. The elderly account for 27.3 percent of the entire Japanese population. Braun and Ikeda (2022) there is a downward pressure on the price level, real interest rates, and output.The seventh is lack of demand. Fukao et.al (2016) argues that the cause of Japan's long-term stagnation is lack of demand caused by the increase in the real interest rate due to the excess saving problem.

In this paper, however, the different cause will be proposed. More recently, there has been a profound increase in interest in human capital. In particular, it has been argued that investment in human capital will bring an increase in productivity that contributes to economic growth. For example, Chun et al. (2016) found that the non-RD intangible have not contributed to economic growth after 1995 in Japan, because expenditures in off-the-job training has decreased rapidly due to the harsh restructuring.

However, there is little research that examines the effect of human capital on economic growth in developed countries in the last 30 years. Moreover, few studies have investigated the direct relationship between highly skilled workers and economic growth in advanced economies. In fact, Japan has lower graduate students compared to other advanced countries, and this problem is shown in the following graphs.





In this article, the relationship between highly skilled workers and economic growth will be investigated. To address this gap in the literature, as a proxy for highly skilled workers in that country, the number of Ph.D. and Master Recipients will be used. We show that the number of Ph.D. and Master recipients in all disciplines has a significant impact on trend TFP, but not the TFP itself. This article proceeds as follows. First, existing research is reviewed. Second, the model and data in this paper are introduced. Then, the result will be discussed. Finally, the conclusion is shown.

2.Literature Review

The effect of human capital on economic growth has long been considered to be the most important topic in economic growth. The treatment of human beings as a form of capital goes back at least to Adam Smith. Spengler (1977) discusses the nature of human capital in Smith's *Wealth of Nations*. Smith considered that in addition to buildings, machines, and land improvements,the concept of "fixed capital" should also include "the acquired and useful abilities of all the inhabitants or members of the society. The acquisition of such talents, by the maintenance of the acquirer during his education, study, or apprenticeship, always costs a real expense, which is a capital fixed and realized, as it were, in his person"(p.32).

Becker (1964) broadened the concept of human capital from that of formal schooling to include additional sources of human capital accumulation such as on-the-job training (both general and specific on-the-job training), informal gathering of information that enhances a worker's productivity, and other investments to improve " emotional and physical health". This research is based on growth theory.

The most important concept for this article is defined here. Human capital is defined asthe knowledge, skills, and physical strength of the person.

The existing research which considered the effect of human capital on economic growth is reviewed here. The classical research is Mankiw, Romer and Weil (1992), which used the Solow growth model to examine the determinants of GDP per capita. Here, they used the fraction of the working-age population enrolled in secondary school as a proxy for the human capital and found that 50 percent of income differences in their sample of 98 non-oil countries to differences in human capital. On the contrary, Klenow and Rodriguez-Clare (1997) use years of schooling attainment as input to a human capital aggregator and find instead that human capital accounts for 10 to 30 percent of income differences.

On the other hand, Hanushek and Woessmann (2007) found that not so much the amount of spending on education that matters for growth, but rather the quality of education. Using PISA scores to construct an aggregate measure of education quality, they found a significantly positive correlation between the average growth rate and the average quality of education over that period of 1860-2000.

The past research is summarized by Benos and Zotou (2014). According to them, the most popular proxy for education quality are literacy rates, school enrollment rates, measured in years of schooling of the working-age population. In addition, three measures are used in order to account for qualitative differences across education systems, namely student-teacher ratios, educational expenditures, and international text scores.

Also, there is literature which deals with the human capital in the era of information technology. For instance, Hulten(2018) emphasized the importance of education and skill development for economic growth in the information era and concluded that it seems reasonable to conclude that a strong educational system - one that provides a full range of skill development - remains an essential part of America's economic prosperity. Furthermore, Levy and Murane (2013 5) argued that for the foreseeable future, the challenge of 'cybernation' is not mass unemployment but the need to educate many more young people for the jobs computers cannot do.

In addition, there is literature which discusses human capital in developed countries. Aghion, Boustan, Hoxby, and Vandenbussche (2005) found that the closer a state gets to the technological frontier, the more growth enhancing it becomes to invest in higher education. Furthermore, Vandebussche, Aghion and Meghir (2006), used the fraction of the working-age population with some higher education by using the Barro and Lee data. They found that it is more important to extend years of higher education close to the technological frontier. Holmes (2013) points out that equality of education is more important than years of schooling, but international academic tests such as PISA show the quality of secondary education but do not show the quality of higher education as students take them when they are 15 years old. Then, this paper uses the number of researchers per 1 million people as a proxy for the quality of higher education and found that researcher-population ratio is statistically significant to explain GDP per capita growth rate in 34 countries between 1996 and 2006.

Murata (2024) is a paper conducts a review of papers use growth model incorporates human capital by using the Japanese data. According to Murata (2024), the most popular proxy for human capital of Japanese people is the ratio of bachelor holder or its equivalent to population. He also plotted the relationship between labor productivity and graduate students' ratio and found that there is a positive correlation relationship between the two.

Nevertheless, as far as I know, no research has examined the effect of highly qualified workers on economic growth in developed countries in the last 30 years. Thus, I hypothesize that highly qualified workers are important in rich nations to promote economic growth.

3.The model

To examine our hypothesis, the growth accounting methods will be used in this paper. Growth accounting is the contribution decomposition by using the production function. Here, I assume the Cobb-Douglas production function.

$$Y_t = F(K, H, AL) = K_t^\alpha H_t^\beta (A_t L_t)^{1-\alpha-\beta}$$

where $0 < \alpha < 1$, $0 < \beta < 1$, and $\alpha + \beta < 1$.

Y_t is the total amount of the final good at time t, K_t is the capital stock, L_t is total employment, A_t is technology at time t, and H_t denotes human capital at time t.

By taking the natural logarithm on both side, we get

$$lnY_t = \alpha lnK_t + \beta lnH_t + (1 - \alpha - \beta)(lnA_t + lnL_t) \cdots (1)$$

By taking the lag, we get

$$lnY_{t-1} = \alpha lnK_{t-1} + \beta lnH_{t-1} + (1 - \alpha - \beta)(lnA_{t-1} + lnL_{t-1}) \cdots (2)$$

By calculating (1)-(2), $lnY_t - lnY_{t-1}$

$$= \alpha(lnK_t - lnK_{t-1}) + \beta(lnH_t - lnH_{t-1}) + (1 - \alpha - \beta)(lnA_t - lnA_{t-1} + lnL_t - lnL_{t-1})$$

Since the growth rate is small for advanced countries, by denoting g is the growth rate of each variable,

$$g_Y = \alpha g_K + \beta g_H + (1 - \alpha - \beta)(g_A + g_L)$$

By following Mankiew, Romer and Weil (1992), I set $\alpha = 0.3$ and $\beta = 0.28$. Using these parameters, the growth rate of the TFP was calculated. After the calculation of TFP, I regressed the lagged number of the Ph.D. recipients of several disciplines in each year in each country on TFP calculated above by using robust standard error. In addition, I regressed the lagged number of the Ph.D. recipients several disciplines in each year in each country on the trend TFP by using robust standard error. This is because the TFP contains the cyclical factors which seem to be irreverent to high-skilled workers. As a robustness check, the lagged number of the Master degree recipients of several disciplines in each year in each country were also used. The regression model was expressed by the following equations.

$$TFP_{i,t} = \beta_0 + \beta_1 \text{logNumber of Ph.D. recipients}_{i,t-s} + \epsilon_{i,t}$$

$$\text{Trend TFP}_{i,t} = \beta_0 + \beta_1 \text{logNumber of Ph.D. recipients}_{i,t-s} + \epsilon_{i,t}$$

$$TFP_{i,t} = \beta_0 + \beta_1 \text{logNumber of Master recipients}_{i,t-s} + \epsilon_{i,t}$$

$$\text{Trend TFP}_{i,t} = \beta_0 + \beta_1 \text{logNumber of Master recipients}_{i,t-s} + \epsilon_{i,t}$$

where i represents G5 countries and t represents year. s represents lag and here I used 3,5 and 10. This is because it is natural to assume that it takes several years to have innovation or productivity growth bought by Ph.D. and Master holders. Log shows the natural logarithm and I took the natural logarithm to ease my interpretation of the coefficients. To estimate the coefficients of these regressions, Ordinary Least Squares Estimation (OLSE) is used.

4.Data

Task performance data were coded using Excel and Stata. Output-side real GDP at chained Purchasing Power Parity (PPPs), the capital stock at current PPPs and number of person engaged comes from Penn World Table. The data is annually and available until 2019.

The number Ph.D. and Master recipients by academic areas in G5 countries comes from "International Comparison of Education Statistical Indicators" published by the Ministry of Education, Culture, Sports, Science and Technology (MEXT) in Japan. This report was published annually, in general, and the publication ended in 2013. I used from 1993 to 2013 version of International Comparison of Education Statistical Indicators to obtain data. In order to get the more recent data, "Education Statistics in Foreign Countries (*Shogaikoku no Kyoiku Tokei*) was utilized. This is published from 2014 by the MEXT and in the appendix, the data is shown.

For the regression analysis, the following data was used as data for some years and some areas were not recorded. For the Ph.D. and Master in Natural Sciences (hereafter NS), Engineering, Agricultural Science (hereafter AS), and Medical Sciences, Density, Pharmaceutical Science and Health Sciences (hereafter DMSDPSHS) in Japan, the data from 1990 to 2019 are used. For Social Sciences (hereafter SS) and Education Ph.D. and Master recipients in Japan, the data from 1990 to 2019 except for 2001 and 2004 are used. For Ph.D. and Master in NS, Engineering, AS, DMSDPSHS, SS and Education in the USA, the data from 1991 to 2019 except for 1998, 2002 and 2004 are used. For Ph.D. and Master in NS, Engineering, AS, DMSDPSHS, SS and Education in the UK, the data from 1995 to 2019 except for 1998, 2002 and 2009 are used. For Ph.D. in NS, Engineering, AS, DMSDPSHS, SS and Education in Germany, the data from 1991, 1995 to 2019 is used. For Master in NS, Engineering, AS, DMSDPSHS, SS and Education in Germany, the data from 2007 to 2019 is used. For Ph.D. and Master in NS, Engineering, AS, SS and Education in France, the data from 2000 to 2019 is used. Note that the data for Ph.D. and Master in NS, Engineering, and AS were aggregated. For Ph.D. and Master in DMSDPSHS in France, the data from 2000 to 2019 except for 2001 is used.

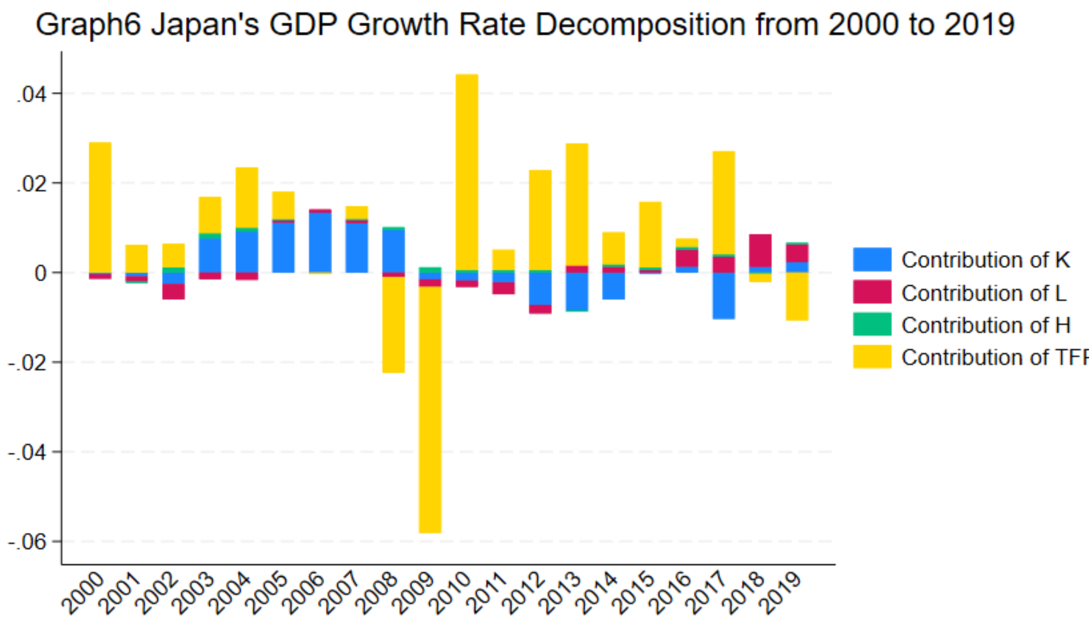
To compute the TFP in the model of production function with human capital, the proxy for human capital in each country is required. Here, I used the completion rate of upper-secondary education as a proxy for human capital in growth accounting. The completion rate of upper-secondary education in the USA, the UK, Germany, and France comes from Our World in Data.

The database is constructed from statistics of the United Nations Educational, Scientific, and Cultural Organization (UNESCO) and covered the completion rate of upper-secondary education from 1991. Since Japanese data was not there, I used the data provided by MEXT. The enrollment and dropout rate of high schools is provided by MEXT, so as the completion rate of upper-secondary education, I deducted the dropout rate of high schools from the enrollment rate in each year. The data is available from 1982.

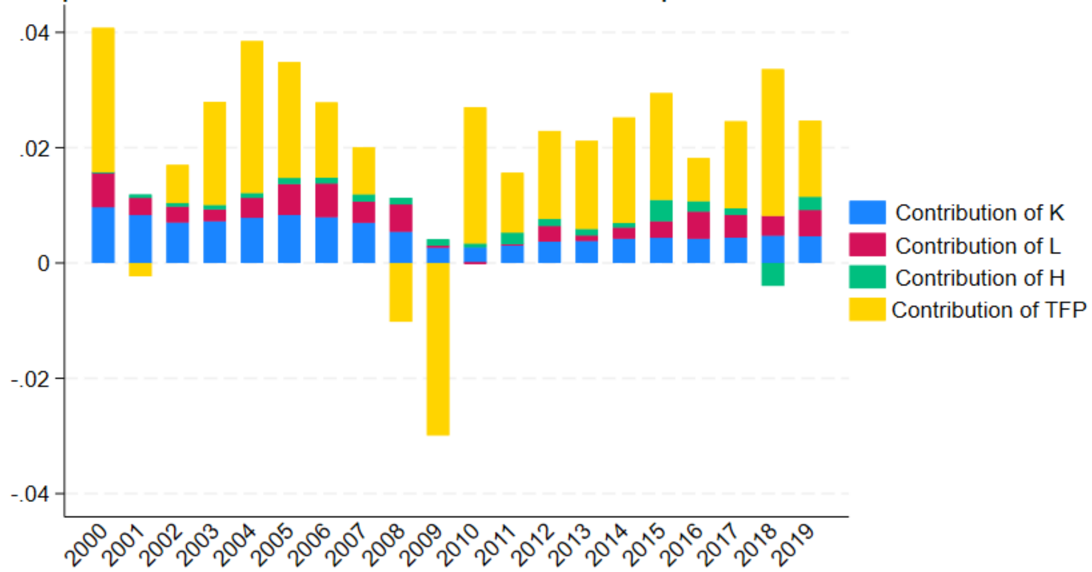
The trend TFP is computed by employing the Hodrick-Prescott filter to the TFP calculated above.

5.Result

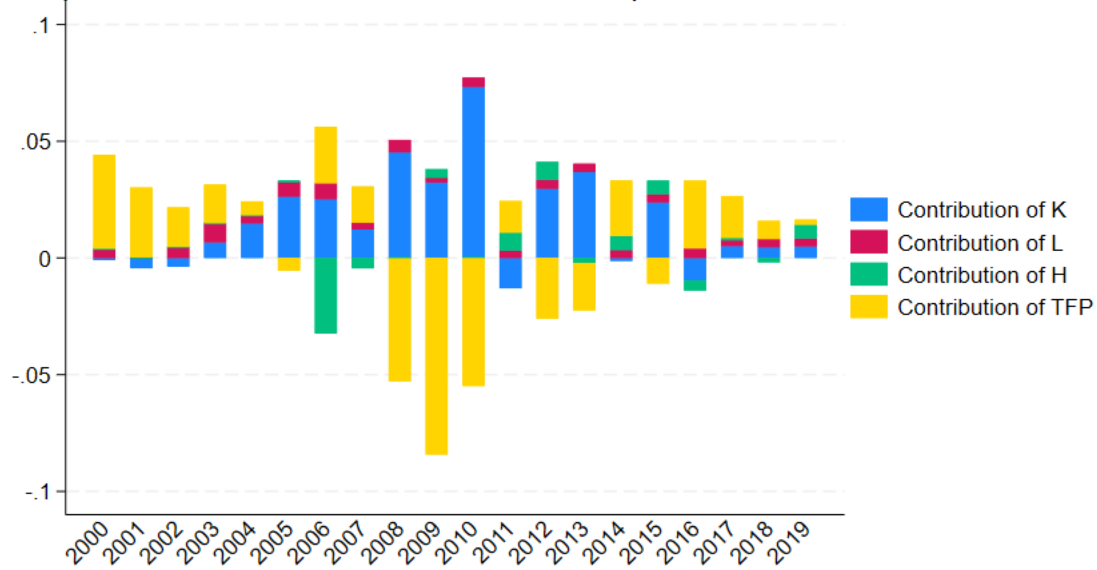
My aim is to answer the following question: How important is the effect of high-level human capital on economic growth in developed nations? My hypothesis was tested by regression analysis with its explanatory variables are the number of Ph.D. and Master students as a proxy for human capital which contributes to innovation and productivity growth in each country. To conduct this regression, I use growth accounting with the completion rate of upper-secondary education as a proxy for human capital in each country. The results are shown in graphs and tables. In the graph, K represents capital, H represents human capital, and L represents labor force.



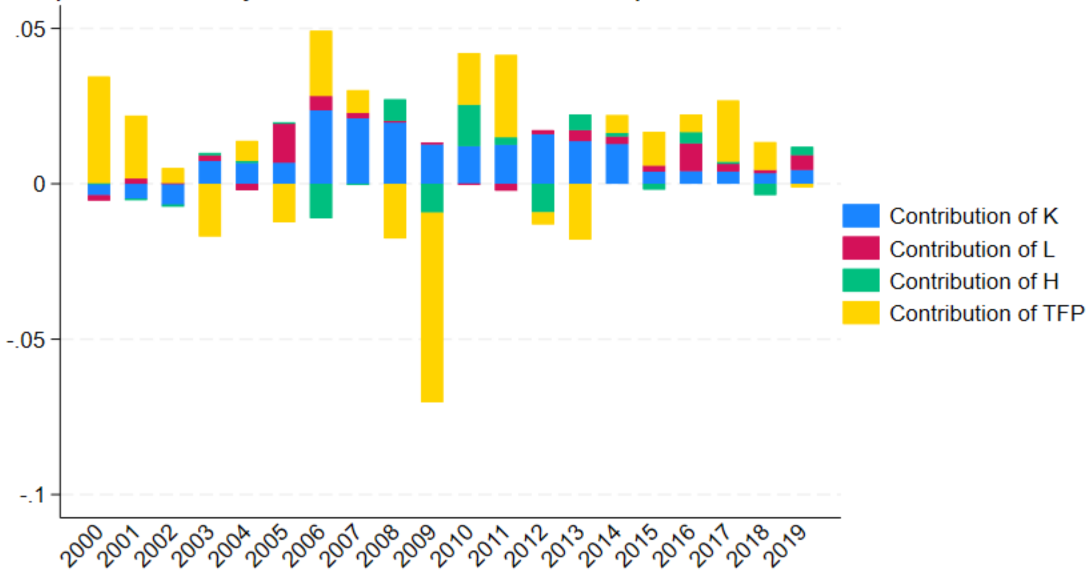
Graph 7 The USA's GDP Growth Rate Decomposition from 2000 to 2019



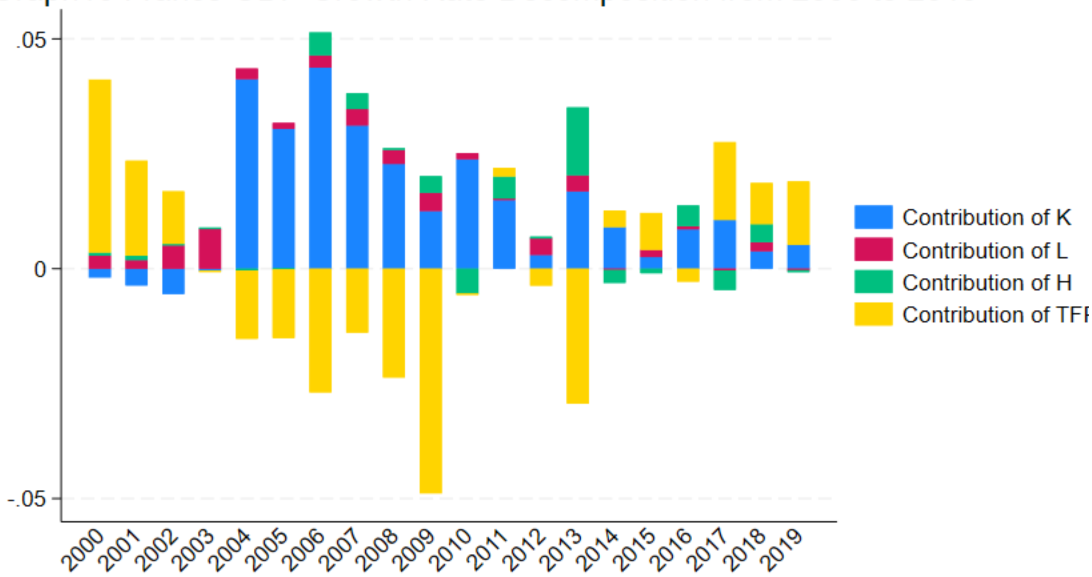
Graph8 The UK's GDP Growth Rate Decomposition from 2000 to 2019



Graph 9 Germany GDP Growth Rate Decomposition from 2000 to 2019



Graph10 France GDP Growth Rate Decomposition from 2000 to 2019



The result indicates that TFP is the most important factor in all 5 countries and the contribution of human capital is relatively small and roughly the same among 5 countries as the completion rate of upper-secondary education is almost the same in advanced countries.

Next, I regressed the lags of Ph.D. recipients on the calculated TFP. In the tables, SS denotes Social Sciences and SAA denotes the sum of natural sciences, engineering, agricultural science, medical sciences, density, pharmaceutical sciences, and health sciences. NS denotes natural sciences, AS denotes agricultural science, and DMSDPSHS denotes medical sciences, density, pharmaceutical science, and health sciences. Each regressor is the number of Ph.D. recipients in each area. L3 represents a 3-year delay, L5 represents a 5-year delay, and L10 represents a 10-year delay. In the appendix, as a robustness check, the result of regression with its regress is shown to be Master recipients, but the result was pretty similar.

Table 1: The effect of number of Ph.D. students in natural sciences and applied areas on TFP

	(1)	(2)	(3)
L3.logPh.D.SAA	0.016*		
	(0.008)		
L5.logPh.D.SAA		0.012	
		(0.009)	
L10.logPh.D.SAA			0.010
			(0.009)
Constant	-0.134	-0.092	-0.075
	(0.083)	(0.088)	(0.091)
Observations	104	96	73
R-squared	0.032	0.016	0.011

Robust standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

Table 2: The effect of number of Ph.D. students in natural sciences, and engineering on TFP

	(4)	(5)	(6)	(7)	(8)	(9)
L3.logPh.D.NS	0.006					
	(0.005)					
L5.logPh.D.NS		0.005				
		(0.005)				
L10.logPh.D.NS			0.008			
			(0.006)			
L3.logPh.D.Engineering				0.001		
				(0.008)		
L5.logPh.D.Engineering					0.001	
					(0.008)	
L10.logPh.D.Engineering						0.006
						(0.009)
Constant	-0.023	-0.020	-0.053	0.015	0.013	-0.034
	(0.041)	(0.047)	(0.051)	(0.065)	(0.071)	(0.074)
Observations	87	81	63	87	81	63
R-squared	0.012	0.009	0.024	0.000	0.000	0.005

Robust standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

Table 3: The effect of number of Ph.D. students in AS, medicine and related areas on TFP

	(10)	(11)	(12)	(13)	(14)	(15)
L3.logPh.D.AS	0.002					
	(0.008)					
L5.logPh.D.AS		0.001				
		(0.009)				
L10.logPh.D.AS			-0.004			
			(0.009)			
L3.logPh.D.MSDPSHS				0.005		
				(0.005)		
L5.logPh.D.MSDPSHS					0.002	
					(0.005)	
L10.logPh.D.MSDPSHS						-0.001
						(0.006)
Constant	0.008	0.019	0.047	-0.020	0.008	0.021
	(0.054)	(0.059)	(0.062)	(0.039)	(0.040)	(0.045)
Observations	87	81	63	103	95	72
R-squared	0.001	0.000	0.003	0.013	0.001	0.000

Robust standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

Table 4: The effect of number of Ph.D. students in social sciences and education on TFP

	(16)	(17)	(18)	(19)	(20)	(21)
L3.logPh.D.SS	0.004					
	(0.004)					
L5.logPh.D.SS		0.002				
		(0.004)				
L10.logPh.D.SS			0.005			
			(0.005)			
L3.logPh.D.Education				0.002		
				(0.002)		
L5.logPh.D.Education					0.001	
					(0.002)	
L10.logPh.D.Education						0.004
						(0.003)
Constant	-0.011	0.010	-0.022	0.011	0.017	-0.005
	(0.033)	(0.033)	(0.036)	(0.018)	(0.018)	(0.021)
Observations	102	94	71	85	79	61
R-squared	0.006	0.001	0.013	0.005	0.002	0.018

Robust standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

The results of the regression analysis show that the number of Ph.D. students has no statistically significant impact on TFP except for 3-year lagged Ph.D. of natural sciences and its applied areas. Next, I regressed the lags of Ph.D. recipients on the trend TFP. The results are shown in the following tables.

Table 5: The effect of number of Ph.D. students in natural sciences and applied areas on trend TFP

	(22)	(23)	(24)
L3.logPh.D.SAA	0.010***		
	(0.004)		
L5.logPh.D.SAA		0.012***	
		(0.003)	
L10.logPh.D.SAA			0.018***
			(0.002)
Constant	-0.077**	-0.098***	-0.156***
	(0.036)	(0.034)	(0.017)
Observations	104	96	73
R-squared	0.060	0.096	0.411

Robust standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

Table 6: The effect of number of Ph.D. students in natural sciences, and engineering on trend TFP

	(25)	(26)	(27)	(28)	(29)	(30)
L3.logPh.D.NS	0.005**					
	(0.002)					
L5.logPh.D.NS		0.006***				
		(0.002)				
L10.logPh.D.NS			0.008***			
			(0.002)			
L3.logPh.D.Engineering				0.001		
				(0.005)		
L5.logPh.D.Engineering					0.003	
					(0.004)	
L10.logPh.D.Engineering						0.010***
						(0.002)
Constant	-0.020	-0.030*	-0.052***	0.014	0.001	-0.067***
	(0.018)	(0.018)	(0.015)	(0.039)	(0.036)	(0.020)
Observations	87	81	63	87	81	63
R-squared	0.040	0.066	0.261	0.001	0.005	0.166

Robust standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

Table 7: The effect of number of Ph.D. students in AS, medicine and related areas on trend TFP

	(31)	(32)	(33)	(34)	(35)	(36)
L3.logPh.D.AS	0.004					
	(0.006)					
L5.logPh.D.AS		0.005				
		(0.005)				
L10.logPh.D.AS			0.007**			
			(0.003)			
L3.logPh.D.MSDPSHS				0.004**		
				(0.002)		
L5.logPh.D.MSDPSHS					0.004**	
					(0.002)	
L10.logPh.D.MSDPSHS						0.004***
						(0.001)
Constant	-0.005	-0.010	-0.031*	-0.008	-0.012	-0.022**
	(0.039)	(0.031)	(0.017)	(0.014)	(0.014)	(0.008)
Observations	87	81	63	103	95	72
R-squared	0.011	0.016	0.075	0.032	0.039	0.103

Robust standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

Table 8: The effect of number of Ph.D. students in social sciences and education on trend TFP

	(37)	(38)	(39)	(40)	(41)	(42)
L3.logPh.D.SS	0.003					
	(0.002)					
L5.logPh.D.SS		0.004**				
		(0.002)				
L10.logPh.D.SS			0.006***			
			(0.002)			
L3.logPh.D.Education				0.002*		
				(0.001)		
L5.logPh.D.Education					0.002*	
					(0.001)	
L10.logPh.D.Education						0.004***
						(0.001)
Constant	-0.006	-0.012	-0.031**	0.010	0.007	-0.009*
	(0.017)	(0.016)	(0.013)	(0.009)	(0.009)	(0.005)
Observations	102	94	71	85	79	61
R-squared	0.021	0.035	0.183	0.024	0.034	0.233

Robust standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

Unlike the effect of Ph.D. recipients on TFP, Ph.D. recipients in all areas have a highly statistically significant impact on the trend TFP. The effect of Ph.D. in natural sciences was strongest in terms of the size of estimated coefficients (the largest) and relatively low standard errors. The result shows that 1 percent increase in the number of Ph.D. recipients in natural sciences contributes to approximately 0.008 percent increase in the GDP in 10 years later on average with other things equal. Similarly, 1 percent increase in the number of Ph.D. recipients in engineering contributes to about 0.01 percent increase in the GDP in 10 years later with other things equal. The influence of social sciences and education was also statistically significant, but the influence was also smaller than that of natural sciences. The former may contribute to better institutions or decision makers in private companies and the latter might contribute to create better education methods or products. The aggregation of medical sciences, density, pharmaceutical sciences and health sciences are statistically significant and the effect over time seems same.

By combining the statistical significance and size of coefficients and standard errors, I may be able to conclude that natural sciences and its application are more important for economic growth. As a general conclusion, Ph.D. and Master recipients contribute to efficiency and/or innovation.

6.Discussion and Conclusion

The aim of this article was to evaluate the effect of high-level human capital on economic growth in advanced economies. There has been limited research investigating the relationship between highly skilled workers and economic growth. The results of the present study suggest that the number of Ph.D. and Master has no statistically significant impact on TFP, but the number of Ph.D. and Master in all areas which I investigated has a statistically significant impact on trend GDP in each country.

The current results supported my hypothesis that highly qualified workers promote long-run economic growth. This empirical analysis could explain the stagnation of the Japanese economy with a relatively low number and a decrease in graduate students. Japan had a difficulty in creating innovation after catching up to the US and European countries, and this problem at least partially can be explained by the limited role of graduate students in the Japanese economy who can contribute to creating new knowledge. If the decline in the number of graduate students continues, the difference in TFP between the United States and Japan will continue to expand.

Furthermore, the Japanese government has cut the budget for research subsidies, but this is undesirable. In order to promote long-run growth, the expenditure to produce highly qualified people is essential since it may be crucial to innovation and/or efficiency in the economy.

There are some limitations in this paper. For example, the direct causation cannot be checked, and the insignificance of Ph.D. and Master recipients on TFP and signficance of Ph.D. and Master recipients in some fields on trend TFP is not fully explained.

Future research should focus on the quality of graduate students, not just the number of graduate students. This is because it is likely that a Ph.D. in each institution has a difficult impact on economic growth. In a microeconomic analysis, Chevalier (2014) indicates that attending a higher-quality university, measured by various rankings and quality proxies (5 dimensions of quality: research assessment score, student/staff ratio, academic expenditures per student, mean entry grades, and graduate prospect) leads to better employment prospects and higher wages.

Furthermore, increasing the number of other advanced countries such as other European countries, Canada, Australia and New-Zealand will be interesting.

Finally, investigating whether or not skills and knowledge acquired in the Ph.D. and Master classes is worthwhile, as underutilized human capital is a severe problem, at least in Japan. As an example, Kawaguchi and Toriyabe (2022) use PIAAC data to find the reason of the gender wage gap in Japan and found that Japanese reading and mathematical ability is higher than that of the UK and US, but frequency of skills used in their occupation is lower than the two countries. Especially, Japanese women use their skills less frequently. The same situation may happen to graduate students in Japan. If that is true, Japanese firms and the government have to utilize the high human capital effectively, so that Japan can grow more.

Appendix

A. The number of Ph.D. and Master recipients in G5 countries are shown in the following graphs. In this table, HA represents humanity and arts. HE represents home economics.

Table 9: The number of Ph.D. recipients in each area from 1990 to 2019 in Japan

Year	HA	SS	NS	Engineering	AS	MS&D&PS&HS	Education	HE
1990	129	183	835	1967	719	6436	40	
1991	175	200	892	2094	870	6356	49	5
1992	214	243	1009	2362	824	6656	60	3
1993	272	283	1168	2783	922	6712	72	3
1994	322	301	1135	3069	1008	6861	76	5
1995	363	358	1243	3297	1108	6782	85	5
1996	377	388	1315	3411	1043	6800	96	6
1997	459	420	1481	3580	1094	7108	84	5
1998	531	506	1542	3934	1100	7091	129	4
1999	573	563	1579	3800	1147	6825	141	8
2000	644	610	1586	3964	1241	7053	127	17
2001			1602	3955	1248	6962		
2002	793	751	1651	3921	1258	6853	191	13
2003	872	808	1679	4077	1348	6869	179	10
2004			1543	3915	1257	6902		
2005	922	973	1633	4195	1321	6760	240	12
2006	1048	985	1669	4177	1378	6981	228	16
2007	1004	1025	1686	4073	1233	6603	254	21
2008	1098	1060	1525	3954	1222	6241	234	25
2009	1060	988	1480	3758	1170	5762	273	23
2010	1104	1010	1534	3693	1233	6315	284	17
2011	957	1019	1436	3599	1046	6229	267	23
2012	1009	1011	1394	3636	1059	6106	269	36
2013	932	850	1423	3456	1062	6099	257	31
2014	861	887	1377	3538	941	5856	318	17
2015	846	889	1390	3275	912	6181	278	28
2016	839	852	1436	3243	933	6206	308	21
2017	856	860	1408	3246	942	6205	280	15
2018	854	848	1403	3253	913	6273	323	20
2019	844	835	1295	3161	917	6372	304	25

Table 10: The number of Master recipients in each area from 1990 to 2019 in Japan

Year	HA	SS	NS	Engineering	AS	MS&D&PS&HS	Education	HE
1990	2889	2282	2984	13117	1868	1273	2036	154
1991	3022	2672	3204	14346	2028	1316	2436	168
1992	3203	3095	3504	16309	2372	1403	2666	195
1993	3492	3613	3862	18198	2622	1659	2850	221
1994	3831	4169	4457	20352	2971	1749	3204	201
1995	4398	5135	4946	22610	3136	1871	3699	290
1996	4670	5751	5302	23620	3289	1941	4095	279
1997	4731	6033	5382	24082	3439	2302	4215	290
1998	5292	6759	5683	24610	3262	2264	4249	289
1999	5409	7578	5516	25133	3385	2460	4368	284
2000	5629	8328	5724	26957	3661	2841	4593	245
2002	6700	10254	5794	28893	3880	3670	5093	302
2003	6793	9698	6064	29446	4108	4037	5069	271
2005	7276	9499	6518	31252	4339	4851	4931	283
2006	7475	9544	6371	30635	4211	5312	5089	265
2007	7393	9040	6638	31372	4258	5443	5109	299
2008	7178	8805	6542	31629	4377	5750	5073	271
2009	7010	8817	6529	31337	4314	6184	4684	395
2010	7179	8942	7253	33158	4677	6441	4482	306
2011	7308	9192	7205	36126	4652	4790	4502	311
2012	7315	8768	7129	34594	4388	4655	4481	294
2013	6852	8304	6934	32935	4231	4724	4463	267
2014	6668	7949	6910	32148	4009	4824	4311	265
2015	6585	7837	6805	32240	4019	4800	4253	276
2016	6594	7786	7008	32344	4096	4739	4113	269
2017	6480	7700	7034	32659	4226	4998	3836	255
2018	6586	7893	7270	33721	4203	5064	3696	254
2019	6309	8084	7483	33567	4350	5165	3597	264

Table 11: The number of Ph.D. recipients in each area from 1989 to 2019 in the US

Year	HA	SS	NS	Engineering	AS	MS&D&PS&HS	Education	HE
1989	7966	4979	8927	5691	1272	1543	6922	303
1990	7990	5026	9361	6098	1185	1614	6697	255
1991	8388	5189	9716	6406	1214	1661	6864	293
1992	8862	5638	10017	6804	1173	1767	7030	345
1993	9160	5814	10341	6958	1278	1902	6908	365
1994	9786	6030	10354	7154	1264	2069	6905	388
1995	9579	5993	10560	7395	1271	2119	6676	414
1996	9887	6183	10460	7747	1217	2672	6751	382
1997	10233	6250	10791	6988	1302	2484	6729	424
1999	10556	6239	9991	6306	1181	2676	6830	357
2000	10659	6292	9600	6500	1139	2855	6716	388
2001	10079	6020	9250	6152	1166	3523	6997	355
2003	10664	6370	10117	7071	1185	4361	7088	329
2004	11906	6413	10868	7902	1173	5868	7681	331
2005	11100	6808	12097	8938	1194	7344	7584	340
2006	11443	7112	12551	9897	1272	8355	8261	337
2007	11659	7497	13082	10071	1257	9886	8491	323
2008	12234	7799	13540	9784	1328	12112	9028	333
2009	12869	8025	14321	9583	1147	13660	9233	296
2010	13755	8418	14574	10219	1246	14681	9623	320
2011	14102	8882	14974	10813	1333	15767	9990	325
2012	14397	9357	15280	11540	1411	16926	10572	351
2013	14448	9747	15971	12349	1407	18328	10920	335
2014	14370	9921	15677	12632	1561	19776	11772	335
2015	14180	9862	15780	12561	1508	21671	11829	374
2016	14138	9948	16039	12796	1561	23963	12687	317
2017	13999	10126	16413	13296	1496	25563	12780	274
2018	13776	10380	16279	13829	1613	27473	13020	285
2019	13786	10173	15873	13951	4886	26656	13051	281

Table 12: The number of Master recipients in each area from 1989 to 2019 in the US

Year	HA	SS	NS	Engineering	AS	MS&D&PS&HS	Education	HE
1989	37077	115182	13985	38282	3373	20354	86057	2153
1990	38341	118504	13689	37986	3295	21228	88904	2021
1991	40455	126483	14170	39431	3735	23065	92668	2412
1992	42549	133669	14189	43152	3965	25718	96028	2479
1993	44590	140459	14975	44527	4119	28025	98938	2421
1994	46941	143068	15327	44386	4353	31243	101242	2864
1995	46578	144598	16035	43234	4569	33398	106253	2917
1996	47233	148551	15182	41333	4516	35958	110087	2888
1997	47224	153969	15265	43245	4475	39260	114691	2914
1999	47467	164373	14451	45490	4375	42456	124240	2830
2000	47800	168205	14799	47981	4281	43617	129066	2801
2001	48408	174024	14726	48148	4519	43644	136579	2616
2003	55483	199365	17418	61129	4783	44939	162345	1794
2005	66425	211543	19674	56688	4640	51380	174620	1983
2006	61924	216865	19470	54844	4623	54531	176572	2080
2007	64111	226615	20444	58375	4684	58120	175880	2199
2008	67678	241696	20767	63174	4877	62620	178564	2453
2009	74763	255306	22422	65042	5211	69084	182139	2580
2010	77858	270305	23556	70970	5773	75579	185009	2918
2011	82335	279544	25570	74953	6390	83893	178062	3157
2012	84142	278561	27303	76774	6339	90931	164624	3253
2013	84173	279921	28217	80487	6544	97403	154636	3121
2014	82787	276511	29339	91473	6426	102897	146561	3148
2015	83459	278039	31282	106290	6681	110348	145781	3228
2016	82073	278256	32513	115249	6844	119273	145680	3295
2017	82851	284458	34819	113282	6967	125216	146367	3308
2018	83130	292823	36591	109435	7288	131569	146432	3287
2019	82484	293735	37791	112341	7393	135324	146975	3280

Table 13: The number of Ph.D. recipients in each area from 1995 to 2019 in the UK

Year	HA	SS	NS	Engineering	AS	MS&D&PS&HS	Education
1995	1100	1100	4000	1700	400	1200	200
1996	1100	1100	4000	1900	300	1400	300
1997	1300	1200	4300	1900	400	1400	300
1999	1400	1500	4300	1800	300	1600	300
2000	1500	1500	4100	1800	300	1600	500
2001	1500	1500	4000	1600	300	1700	500
2003	1900	2000	5600	2200	300	2400	600
2004	2100	2100	5800	2200	300	2500	700
2005	2200	2200	6000	2400	300	2600	600
2006	2200	2200	6200	2600	300	2700	700
2007	2300	2400	5900	2300	200	2800	700
2008	2400	2600	6100	2600	200	3000	600
2010	2840	2990	7085	2850	220	3140	805
2011	2855	3080	7145	3005	235	3225	735
2012	3120	3315	7790	3175	250	3440	885
2013	3010	3260	7285	3130	250	3350	790
2014	3170	3510	7815	3350	265	3600	850
2015	3410	3495	7910	3535	290	3645	820
2016	3450	3610	7920	3725	260	3595	855
2017	3400	3900	8415	3870	300	3825	905
2018	3460	3800	8535	4000	265	3720	895
2019	3160	3565	7770	3895	195	3410	875

Table 14: The number of Master recipients in each area from 1995 to 2019 in the UK

Year	HA	SS	NS	Engineering	AS	MS&D&PS&HS	Education
1995	7200	30700	7600	8400	900	4500	28100
1996	7800	31900	7800	8800	900	5400	28500
1997	8700	35800	9200	9400	800	5500	26200
1999	9500	37700	11000	9500	900	6500	26600
2000	9900	40500	11200	9900	800	6900	28400
2001	10500	43500	12600	9600	900	7900	30500
2003	14800	63600	19500	12900	1100	11200	38200
2004	15400	66500	19700	15500	1100	12300	41300
2005	16800	68000	19900	16400	1200	13200	41600
2006	16800	68000	19900	16400	1200	13200	41600
2007	18000	71100	20100	17400	1100	16100	43000
2008	18600	73000	20600	17700	1200	16900	34200
2010	22895	89845	27710	24450	1565	20735	38875
2011	23990	95675	27520	25030	1400	22630	41140
2012	24840	93700	26455	23325	1435	22735	41060
2013	24145	91810	25595	21905	1345	23475	42195
2014	23240	94155	26085	22810	1605	24915	39735
2015	23530	91550	26950	23365	1580	25770	39845
2016	23695	91920	27680	23425	1640	27685	40140
2017	26580	96230	33245	24620	1735	29385	41000
2018	28890	106085	36495	24830	2135	31380	42560
2019	28910	107525	34655	25045	1760	30295	41425

Table 15: The number of Ph.D. recipients in each area from 1989 to 2019 in Germany

Year	HA	SS	NS	Engineering	AS	MS&D&PS&HS	Education	HE
1989	1721	1886	4886	1400	1029	7821	205	50
1990	1921	2035	4943	1666	960	7192	190	77
1991	2097	2116	5957	2148	1121	7655	229	61
1995	2148	2554	6642	2155	1038	7512	231	57
1996	2132	2651	6763	2307	1015	7580	262	45
1997	2209	2785	7072	2292	1006	8358	254	61
1998	2196	2944	7333	2172	1043	8774	266	59
1999	2299	3076	7170	2342	1114	8142	267	68
2000	2696	3261	7386	2398	1003	8618	295	65
2001	2571	3403	6844	2299	936	8339	276	48
2002	2366	3130	6296	2332	944	8341	296	48
2003	2494	3342	6111	2153	980	7494	331	53
2004	2419	3329	6043	2112	986	7749	344	63
2005	2839	3811	6720	2336	1186	8572	341	57
2006	2498	3785	6299	2206	999	7919	399	57
2007	2525	3368	6532	2247	982	7553	386	82
2008	2604	3769	6977	2541	947	7678	398	64
2009	2498	3549	7116	2340	913	8009	385	81
2010	2582	3534	7718	2561	940	7661	439	79
2011	2533	3761	8122	2833	948	8109	426	79
2012	2744	3509	8389	2860	983	7679	402	82
2013	2803	3746	9210	3119	840	7353	449	57
2014	2871	3646	9114	3187	886	7733	450	83
2015	2915	3692	9565	3736	930	7707	439	86
2016	3075	3758	9388	3698	931	7829	438	77
2017	2882	3411	9215	3738	1023	7499	412	77
2018	2838	3320	8946	3585	876	7673	389	70
2019	2852	3318	9109	3758	842	8246	396	47

Table 16: The number of Master recipients in each area from 2007 to 2019 in Germany

Year	HA	SS	NS	Engineering	AS	MS&D&PS&HS	Education	HE
2007	1321	4611	2582	3861	678	499	464	161
2008	26571	40207	22251	15063	2729	14406	38044	222
2009	2264	7524	3695	4417	1046	882	660	260
2010	3251	9350	4754	5912	1182	1160	679	309
2011	4962	14605	7225	10079	1492	1267	1096	370
2012	7419	21169	10590	13606	1860	1621	1433	469
2013	10293	26866	14938	18869	2303	1952	2124	483
2014	13355	31979	18238	24998	2675	2122	2501	528
2015	15731	36841	20657	30527	2990	2619	2989	502
2016	17388	39443	22603	34401	3062	2863	3260	529
2017	19101	42906	24931	38321	3340	2898	3356	561
2018	20342	44161	25001	39727	3304	3637	3200	665
2019	20780	46362	25842	40398	3233	3716	3440	617

Table 17: The number of Ph.D. recipients in each area from 2000 to 2019 in France

Year	HA	SS	NS	Engineering	AS	MS&D&PS&HS
2000	2436	1884		5615		504
2001	2187	1560		5616		
2002	2095	1124		5617		369
2003	2103	1112		5618		367
2004	2260	1300		5619		371
2005	2290	1161		5620		310
2006	2290	1161		5621		310
2007	2759	1439		5622		368
2008	2782	1376		5623		588
2009	2750	1404		5624		601
2010	2797	1519		5625		516
2011	2827	1471		5626		337
2012	2789	1461		5627		405
2013	2828	1435		5628		327
2014	2774	1495		5629		347
2015	2911	1415		5630		341
2016	2729	1311		5631		232
2017	2759	1354		5632		276
2018	2613	1310		5633		263
2019	2518	1333		5634		297

Table 18: The number of Master recipients in each area from 2000 to 2019 in France

Year	HA	SS	NS	Engineering	AS	MS&D&PS&HS
2000	15066	23330		16977		4777
2001	16759	25829		16978		
2002	18344	29084		16979		4679
2003	19466	31553		16980		4623
2004	20688	33610		16981		4438
2005	22870	38149		16982		4674
2006	22870	38149		16983		4674
2007	26710	42742		16984		5064
2008	26132	41819		16985		6901
2009	26527	43812		16986		7115
2010	29588	46400		16987		7669
2011	45837	47269		16988		8932
2012	42196	47860		16989		9211
2013	40933	48691		16990		9567
2014	40273	49432		16991		10435
2015	43864	49784		16992		10737
2016	45818	49428		16993		10810
2017	47685	50376		16994		10827
2018	51030	49400		16995		10317
2019	50929	49253		16996		10191

B. Robustness Check

As a robustness check, I replace the number of Ph.D. students with Master students. In the first four tables, the dependent variable is TFP and in the last four tables, the dependent variable is trend TFP.

Table 19: The effect of number of Master students in natural sciences and applied areas on TFP

	(43)	(44)	(45)
L3.logMasterSAA	0.010*		
	(0.006)		
L5.logMasterSAA		0.005	
		(0.006)	
L10.logMasterSAA			0.005
			(0.008)
Constant	-0.089	-0.038	-0.032
	(0.066)	(0.071)	(0.084)
Observations	89	80	57
R-squared	0.023	0.008	0.006

Robust standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

Table 20: The effect of number of Master students in natural sciences, and engineering on TFP

	(46)	(47)	(48)	(49)	(50)	(51)
L3.logMasterNS	0.002					
	(0.006)					
L5.logMasterNS		-0.002				
		(0.007)				
L10.logMasterNS			0.003			
			(0.009)			
L3.logMasterEngineering				0.002		
				(0.007)		
L5.logMasterEngineering					0.001	
					(0.008)	
L10.logMasterEngineering						0.001
						(0.009)
Constant	-0.000	0.044	-0.012	0.006	0.010	0.008
	(0.062)	(0.068)	(0.083)	(0.074)	(0.080)	(0.093)
Observations	72	65	47	72	65	47
R-squared	0.002	0.001	0.003	0.001	0.001	0.000

Robust standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

Table 21: The effect of number of Master students in AS, medicine and related areas on TFP

	(52)	(53)	(54)	(55)	(56)	(57)
L3.logMasterAS	0.000					
	(0.009)					
L5.logMasterAS		-0.001				
		(0.009)				
L10.logMasterAS			-0.002			
			(0.010)			
L3.logMasterMSDPSHS				0.004		
				(0.003)		
L5.logMasterMSDPSHS					0.003	
					(0.003)	
L10.logMasterMSDPSHS						0.004
						(0.004)
Constant	0.023	0.030	0.033	-0.021	-0.003	-0.016
	(0.072)	(0.074)	(0.077)	(0.028)	(0.030)	(0.041)
Observations	72	65	47	88	79	56
R-squared	0.000	0.000	0.001	0.015	0.006	0.013

Robust standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

Table 22: The effect of number of Master students in social sciences and education on TFP

	(57)	(58)	(59)	(60)	(61)	(62)
L3.logMasterSS	0.004					
	(0.003)					
L5.logMasterSS		0.002				
		(0.003)				
L10.logMasterSS			0.004			
			(0.003)			
L3.logMasterEducation				0.005**		
				(0.002)		
L5.logMasterEducation					0.003	
					(0.003)	
L10.logMasterEducation						0.003
						(0.004)
Constant	-0.024	-0.003	-0.021	-0.025	-0.009	-0.011
	(0.033)	(0.033)	(0.039)	(0.026)	(0.027)	(0.038)
Observations	89	80	57	72	65	47
R-squared	0.013	0.005	0.017	0.041	0.023	0.018

Robust standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

Table 23: The effect of number of Master students in natural sciences and applied areas on trend TFP

	(63)	(64)	(65)
L3.logMasterSAA	0.004		
	(0.003)		
L5.logMasterSAA		0.006**	
		(0.003)	
L10.logMasterSAA			0.012***
			(0.002)
Constant	-0.024	-0.049	-0.118***
	(0.034)	(0.032)	(0.022)
Observations	89	80	57
R-squared	0.015	0.043	0.390

Robust standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

Table 24: The effect of number of Master students in natural sciences, and engineering on trend TFP

	(66)	(67)	(68)	(69)	(70)	(71)
L3.logMasterNS	-0.002					
	(0.003)					
L5.logMasterNS		0.001				
		(0.003)				
L10.logMasterNS			0.007**			
			(0.003)			
L3.logMasterEngineering				-0.000		
				(0.005)		
L5.logMasterEngineering					0.003	
					(0.004)	
L10.logMasterEngineering						0.010***
						(0.002)
Constant	0.038	0.015	-0.049**	0.025	-0.009	-0.090***
	(0.027)	(0.027)	(0.024)	(0.050)	(0.044)	(0.022)
Observations	72	65	47	72	65	47
R-squared	0.002	0.000	0.118	0.000	0.009	0.292

Robust standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

Table 25: The effect of number of Master students in AS, medicine and related areas on trend TFP

	(72)	(73)	(74)	(75)	(76)	(77)
L3.logMasterAS	-0.002					
	(0.006)					
L5.logMasterAS		0.002				
		(0.005)				
L10.logMasterAS			0.008***			
			(0.003)			
L3.logMasterMSDPSHS				0.003**		
				(0.001)		
L5.logMasterMSDPSHS					0.004***	
					(0.001)	
L10.logMasterMSDPSHS						0.006***
						(0.001)
Constant	0.034	0.008	-0.052***	-0.011	-0.018	-0.042***
	(0.053)	(0.043)	(0.019)	(0.012)	(0.012)	(0.011)
Observations	72	65	47	88	79	56
R-squared	0.002	0.002	0.173	0.033	0.057	0.313

Robust standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

Table 26: The effect of number of Master students in social sciences and education on trend TFP

	(78)	(79)	(80)	(81)	(82)	(83)
L3.logMasterSS	0.003**					
	(0.001)					
L5.logMasterSS		0.003**				
		(0.001)				
L10.logMasterSS			0.004***			
			(0.001)			
L3.logMasterEducation				0.005***		
				(0.001)		
L5.logMasterEducation					0.005***	
					(0.001)	
L10.logMasterEducation						0.005***
						(0.001)
Constant	-0.013	-0.019	-0.035**	-0.023**	-0.025***	-0.031***
	(0.016)	(0.015)	(0.013)	(0.010)	(0.009)	(0.008)
Observations	89	80	57	72	65	47
R-squared	0.030	0.050	0.220	0.114	0.144	0.345

Robust standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

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