The Impact of Government Support for the Graduate School on the Research Productivity of Professors and Students*

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This paper examines the effect of major funding projects for graduate education in Korea, the BK21 and the WCU program, on the research productivity of professors and young researchers. We apply the standard DID method which compares the increase in research outputs measured by papers per year between the groups, before and during the project period. The DID estimates show that the effects are quite different for the different majors, but mostly indicate that the BK21 project was more effective in terms of research productivity of participating professors, especially in the science and engineering majors. In terms of the productivity of graduate students, the results show that there has been increase in the research productivity of locally-educated Korean doctorates after the graduate funding programs, mainly in natural science and engineering majors.

Keywords: Research fund, Research Productivity, BK21, WCU

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Ⅰ. Introduction

This paper examines the effect of government research grants to the graduate school on the research productivity of professors and graduate students using the individual level data set derived from the National Research Foundation of Korea. From the late 1990s, Korean government tried to establish world-class research universities by giving unprecedently large amount of research funds to a few selected universities. The most notable funding programs are the Brain Korea 21 (henceforth, BK21) project, which started in 1999 and the World Class University (henceforth, WCU) project, which started from 2009. These two programs took very different funding schemes. In the BK21 project, most of research fund had been given to the graduate students as grants. In the WCU project, much of the research fund had been used to promote international academic cooperation, mainly by inviting renowned scholars abroad, including some Nobel Prize laureates. Also, in the WCU project, research teams are encouraged to open a new department or a program inside a department.

This contrasting feature of funding schemes provide us a rare opportunity to empirically evaluate the effect of different research funding schemes on the productivity of major researchers in the university — professors and graduate students. When we investigate the research productivity of professors, we compare the research outputs between the two treatment groups, which consist of participants of the BK 21 and the WCU projects, and the comparison group, which consists of top researchers among non-participants. We applied the standard DID method which compares the increase in research outputs measured by number of papers per year among these groups, before and during the projects. From this investigation we try to evaluate the efficiency of two different research schemes for the different academic disciplines.

In the case of research productivity of students, we compare the research productivity of Korean doctors who got their doctorates in Korea and those who got theirs in the USA, where it is widely believed to have the best graduate programs in the world in many academic disciplines. Again, we applied the standard DID method which compares annual production of papers of these two groups of doctors before and after the BK 21 project.

If we recognize that the research productivity of professors and graduate students is a good proxy for the quality of graduate schools, we can expect to get some evidence to determine whether the government funding for the graduate studies made any positive and significant effects on the quality of the graduate studies from these empirical investigation. In addition, we try to evaluate the relative efficiency of contrasting research funding schemes for different academic disciplines, and thereby to draw some policy implication for better research funding schemes.

The rest of this paper organized as the following. In section 2 we briefly review the related literature. Section 3 explains institutional backgrounds. Section 4 introduces the data set and the framework of empirical investigation. Section 5 presents empirical results and discusses the policy implications. Section 6 concludes the paper.

Ⅱ. Literature Review

There are not a few empirical studies on the research productivity. Recently, Aksnes (2012) provides an extensive literature review on the scientists' research productivity,[1] and documented that demographic factors, such as age and gender have close relationship with the research output. As for the age, although the results of previous studies have not always been entirely consistent, it is quite firmly established that there is a quadratic relationship between age and productivity. The pattern has been found across many fields and nations. For example, in the economics literature, Levin and Stephan (1991) find that the life cycle effects are present in physics and earth science, Goodwin and Sauer (1995) find similar effects of age on research output in economics, and Oster and Hamermesh (1998) find that economists' productivity over their careers as measured by publication in leading journals declines very sharply with age. As for the gender, many studies have shown large gender differences in scientific productivity.

Availability of resources, both in terms of financial support and human resources, affect the research productivity as well. Kyvik (1991) reports that scientists who have more graduate students and technicians tend to be more productive that those who do not have as many supporting staffs.[2] As we will see later, the result of this paper can be explained in line with this observation.

Institutional or organizational characteristics can also affect the research productivity. For example, according to this review, many studies have shown that the productivity of publications at individual levels tends to increase within the hierarchy of academic positions. Some studies find that such factors as department climate, age structure, a higher level of freedom are correlated with the publication productivity, though it is

1) This review is not confined to the economics literature. It is just natural that researchers in any field have much interest in the research productivity and there is indeed large literature with authors from various academic fields. But it should be also noted that economists' analysis employed the most rigorous statistical analysis.

2) Aknes (2012) explains that this is due to the fact that the students and technicians will do much of the time consuming data collection and data analysis work, and that supervisors may become coauthor of publications mainly written by graduate students and research associates

difficult to establish causal relationship – One can argue that rather than favorable institutional characteristics affect the productivity of an individual, the productive individual is more likely attracted by those institutions.

Meanwhile, there are not many empirical studies on the relationship between funding and research output, especially at the individual level. Some studies find weak positive relationships between the research fund and the outputs for the different academic disciplines. Averch(1988) estimates the determinants of the citation per dollar of NSF funding for a random sample of 93 projects in chemistry. He finds only a very modest relationship between citations per dollar and characteristics of the principal investigators affiliated institutions although their characteristics do have some impact on citations per dollar. By contrast, for behavioral and neural sciences, Averch(1987) finds that even principal investigator’s characteristics are unrelated to citations per dollar.

Aroma and Garmbrardelia (2005) find that NSF funding has only a modest effect on publication output, using dataset of 1473 applications to the NSF in economics during 1985-1990. More recently, Jacobs and Lefgren (2011) estimate the impact of receiving an NIH grant on subsequent publications and citations. They find that receipt of an NIH research grant leads to only one additional publication over the next five years, which is only a 7% increase. Their interpretation of this small effect is that the loss of NIH grants simply leads to shift to another source of research fund in the presence of many alternatives. Methodologically this study uses rich data set that includes information about successful and unsuccessful applications and tried to handle the issue of selection bias.

As for the empirical analysis on the Korean graduate funding projects, we had very few. A monograph by RAND Corporation (2008) points out that the net effect of BK21 on human resource and the national R&D capacity building “compared to other projects” has not been verified yet. This monograph explains the conceptual framework of evaluating BK21 project in detail, but there is no empirical analysis and result there. Kim(2015) empirically examines the effect of the Brain Korea 21 project on the research productivity of participating professors, and found that in many of the science and engineering majors, the effects are positive and significant, whereas in most of the humanities and social science majors the effects are insignificant or even negative. He interprets the result as evidence that the grants to graduate students can be an effective way of increasing the research productivity of professors in some majors that require extensive experiments and help from research assistants.

This paper extends Kim's(2015) analysis in two directions. The first extension is to include another major graduate funding project. The second one is to include analysis on new doctors’ productivity to evaluate the effect of the funding on the educational quality.

Ⅲ. Institutional Background: the BK21 vs the WCU

The first phase of the BK21 project has started in 1999. It was a seven-year project. After the first phase, the second phase of the BK21 project started in 2006. Like the phaseⅠ, the main purpose of this project is to foster world class research graduate schools in various academic disciplines. To achieve this policy goal, the program was designed to provide most of the research funds to graduate students and young post-doctoral scholars. And the unit of fund beneficiary is the research group that consists of professors, post-doctors, doctoral students and master students. To get the BK21 funds, a research group should apply to the fund by submitting the group's research proposal to the National Research Foundation of Korea(henceforth KRF). KRF reviews and evaluates the proposals and then selects research groups in each major.

There are several important restrictions in the application for the BK21 funding. First, a research group should consist of more than 70 percent of faculty members in the departments that have a doctorate program with enrolled doctoral candidates. Second, the number of faculty members participating in the research group must be more than seven for humanities and social science groups, more than ten for basic science groups, and ten to twenty five for applied science groups. In addition, all the participating professors produce more than a minimum average number of publications for the prior three years. This selection criterion is related to the issue of the comparison group, as we shall see below. Third, all research groups must secure matching funds from their universities, which must be higher than 5 percent of the level of BK21 funding from the government. All these preconditions are favorable to large research universities with relatively large research funds.

BK21 recipient research groups are selected at the beginning of each seven-year phase.[3] A very unique feature of the BK21 funding scheme is that, although largest portion of it is spent as a scholarships and stipends, individual recipients are not selected on their own merit. The award selection criteria are based on the qualifications of the research group to which the individuals belong; the excellence of their department, and their university's commitment to the department, institutional reform, and research infrastructure. But the most important selection criterion is the research ability of participating professors. There have been annual evaluations for the research group and there are a few cases that some groups are eliminated from the project. In

3) As of 2012, the second phase has been ended, and in the third phase the program

the vacant spot some new research group comes in, again after the selection process.

The amount of BK21 research fund is about 280 million US dollars annually. The seven-year total amounts about 2 billion US dollars. Each research group has little discretion in managing the research fund in that there are important restrictions. <Table 1> presents the major spending items and restrictions on spending. The major spending item is grant to young researchers, including graduate students, post-doctoral researchers. Other than grants, there is a category called “international corperation, which usually spent on hosting or participating in international academic conferences. The operational cost includes incentive for the professors (less than 300 US dollars per year), salaries for assisting staffs, and other small expenses like conference registration fee and the publication fee. The lack of pecuniary incentive for professors is another important aspect of the BK21 projects.

It should be noted that while the international cooperation was encouraged, such collaborations were not widely occurred. Participating international conference has been the major form of the international cooperation, and inviting world-class scholars was rare and there had been few, if any, continuing relationship. This is one of the reasons that Korean government decided to launch another project, the WCU.

<Table 1> Budget Items of BK 21 Project

Category	Major Spending Items	Prohibited Items
Grants to Students	◦ Master (more than $500 per month) ◦ Doctors (more than $900 per month per students)	◦ more than maximum amounts set by government ◦ Over 30 days of oversees training
Grants to New PhDs	◦ Post-doc; more than $2000 per month ◦ Part-time Professor; More than $2500 per month	◦ more than maximum amounts set by government
International Academic Cooperation	◦ Participating International Conferences ◦ Inviting World-class Scholars	◦ Fees for the professor (when he is the only Participants) ◦ Passport, Visa fee, etc
Operational Costs	◦ incentive for the professors (less than 300 dollars per year) ◦ Salaries for assisting staffs ◦ conference registration fee, publication fee, etc	◦ Land, building etc ◦ equipment facilities. ◦ Consulting fee for the participants ◦ Patent related fees for the individuals etc

Before comparing the two projects, let us briefly review some important financial restrictions applied to these projects. In the case of the BK21 projects, grants to the student should be more than 60% of the total funds in the natural science and engineering fields endowed to the graduate students. Maximum portion is 72%. Grants to the young post-doctoral scholars make another 20% of the total budget. In the perspective of professors, about 80% of research funds are going to the supporting staff. Remaining 20% are going to the international academic cooperation and operational costs. Participating in international conferences is very much encouraged but fund is given only when professors are accompanied by students and young post-doctors.

As of 2010, there are around 400 research groups in natural science and engineering area. On average 500 thousand US dollars are given to each research group. The financial restriction is observed well by participating research groups. On average 63% of fund were given to the graduate students in 2010. Around 20% are given to the post-doctoral scholars. About 12% of funds are spent for the international academic cooperation on average and operational costs take about 8%.

In the case of humanities and social science, the research groups are generally smaller in terms of the size of funds. The total fund for each research group is about 250 thousand US dollars research group, which is about half of science and engineering majors. Like science and engineering majors more than 80% of funds were spent for the graduate students and post-doctoral scholars.

In terms of the financial restriction the WCU projects are quite similar to the BK21 project. Most of all, the recipient unit is the same, namely a research team composed of professors and graduate students and post-doctors. But it has a different funding scheme from the BK21 program. There are three types of research teams in the WCU program. In the type 1, fund is given to research teams that make a new department or a distinct program inside the department. The type 2 fund is given to research teams that invite a foreign scholar and work with him/her. The type 3, very much similar to the second type, funds are given to research teams that invite renowned foreign scholars, usually Nobel Prize winner or a strong candidate, and work with him/her. There is common factor between the BK21 and the WCU program in that the funds are given to research teams composed of professors, students, and new doctorate. But in the WCU program, international cooperation was much emphasized and it is possible to make smaller teams.

The funds for the WCU projects are divided into three categories. For each research team, grands to students or foreign scholars take the largest part, more than 40% of the total fund. Research infrastructure including laboratory and equipment takes about 40% as well. Remaining 20% are overhead costs. As a result of the WCU project, 34 new department or majors were established, and 288 foreign scholars are invited. As the project emphasizes the international cooperation many English courses are offered 242 out of 302 new courses. <Table 2> summarizes key features of the BK21 and the

WCU projects.

<Table 2> Comparison of the BK21 and the WCU Project

	BK21	WCU
Purpose	Providing research fund to group of researchers to enhancing the quality of post-graduate education, and thereby fostering world-class graduate programs	Enhancing research productivity in some key academic fields, and fostering the next generation researchers. Providing new research environment through the cooperation with foreign scholars.
Unit of Recipients	research group or team	New department or new major within the department(type 1) Research team with individual foreign scholar(s) (type 2) Inviting world-class scholars (existing department, type 3)
duration	Seven years, 2006-2012	Five years, 2008-2012
Number of Recipient Unit	58 research teams in the humanities and social sciences (41 teams from the national competition and 17 from local-based competition) 150 research teams in the natural science and technology (94 teams from the national competition and 56 from local-based competition)	34 departments or majors (type1), 43 research teams (type 2), 46 research teams (type 3), total 123 new departments or research teams
Size of Funds	Total $ 200 million (2011), $ 30 million for Social Science and Humanities $ 170 million for Natural Science and Engineering $ 400,000 million for each unit on average, and $ 900,000 for each unit on average for natural science and engineering	Total $ 140 million (2011) $ 2.9 million for type 1 $ 800,000 for type 2 $ 180,000 for type 3

Ⅳ. The Data and the Empirical Framework

4.1. The data

The basic data set is the BK21 and the WCU database. Each research team reports basic information such as the number of research members and their publications to

National Research Foundation of Korea(Henceforth KRF). KRF gathers information and manages the database. Accordingly, the BK21 and the WCU data sets have detailed information on the research output of professors participating in the program.

Yet without the information about a proper comparison group, namely a group of researchers who do not participate in the project with comparable research ability, the strict evaluation is not possible. To compose a control group we also use a dataset drawn from the KRF's researcher data base. This data set has information about the research output of individual researchers who agreed their information made public. About 15% of researchers agreed to reveal their information about their research output. The data set is based upon this 15% sample.

In Korea, every new doctorate recipient is supposed to register KRF on-line. Once registered, the information is updated whenever researchers report their research output to KRF on-line. In the case of published paper they report the title, the year of the publication, the name of the journal, and the number and names of co-authors. They also report if the paper is published in the science citation indexed (henceforth SCI) or social science citation indexed (henceforth SSCI) journals. In this paper, we only counted papers in the SCI or SSCI journals as ones published in the international journal. Likewise we only counted papers published in the Korean citation indexed (henceforth KCI) journals in case of the national journal.[4] There is some verification process in the KRF's part to check if researcher's report is correct. It takes some time and accordingly there is possibility of some measurement errors in the number of published paper, especially in recent years.

Before discussing the control group, let us think about the differences in research outputs among different majors. Comparing research productivities of different academic disciplines has practically no meanings, especially when we measure the productivity in terms of quantity of the output as in this paper. Let us look at examples.

<Table 3> shows the average number of annual publications per researcher for some science majors from 1995 to 2010. In calculating the number of publications we give the value 1 for the single-author paper. When there are two or more authors we count it 0.5 when the researcher is the first or the corresponding author. Otherwise, when the number of authors is n, we simply count it as 1/n. In this manner we can calculate the number of papers that each researcher produced in specific year.

We present the number of papers per researcher in the SCI and KCI journals. From the table, we can immediately notice two facts. The first one is that the research productivity of Korean scholars has been increased in every science major from 1995 to

4) KRF evaluates the quality of each journal every two years, and determines KCI indexed journal. Since many universities count only papers published in KCI in the faculty evaluation, professors try to publish their works in those journals.

2010. For example, the average number of papers in the SCI journals in physics was 0.27 in 1995, 0.515 in 1999, the beginning year of the phase I of the BK21, and 1.5 in 2006, the beginning year of the Phase II of the BK21, and almost 2 in 2010, the final year we have the data. This is huge increase. We can find similar patterns in other majors as well. In chemistry the number of annual publications per person has been increased from 0.22 in 1995 to 1.87 in 2010.

The second notable fact is that the difference in the number of publications among science majors. We can see this more clearly when we derive the quantity publication index relative to mathematics. The annual average per-person publications of physics and chemistry are more than twice as many as that of mathematics in 2010. In the case of biology it is more than 1.5. Under the assumption that the research efforts of different majors are not systematically different, it might be reasonable to interpret these differences largely as the difficulty of publication. To anyone who tries to estimate the research productivity, the most obvious implication of this difference is that one should compare research productivity of scholars major by major.

<Table 3> Annual Average Publication Per-person in SCI Journals (Natural Science)

	Annual publication per person				Ratio (Math=1)		
Year	Math	Physics	Chemistry	Biology	Physics	Chemistry	Biology
1995	0.069	0.277	0.222	0.116	3.99	3.21	1.67
1996	0.104	0.308	0.242	0.148	2.96	2.33	1.42
1997	0.134	0.396	0.337	0.138	2.96	2.52	1.03
1998	0.160	0.454	0.297	0.194	2.83	1.86	1.21
1999	0.151	0.512	0.339	0.184	3.39	2.25	1.22
2000	0.202	0.612	0.367	0.247	3.02	1.81	1.22
2001	0.260	0.666	0.450	0.268	2.57	1.73	1.03
2002	0.255	1.093	0.675	0.393	4.29	2.65	1.54
2003	0.458	1.440	1.077	0.637	3.14	2.35	1.39
2004	0.520	1.328	1.084	0.817	2.56	2.09	1.57
2005	0.643	1.545	1.239	0.761	2.40	1.93	1.18
2006	0.589	1.515	1.277	0.834	2.57	2.17	1.42
2007	0.775	1.547	1.498	0.982	2.00	1.93	1.27
2008	0.733	1.653	1.620	1.087	2.26	2.21	1.48
2009	0.862	1.608	1.740	1.155	1.87	2.02	1.34
2010	0.883	1.995	1.872	1.378	2.26	2.12	1.56

We can find similar pattern in the social sciences. When we derive the same index, namely annual publications per-person for several social science majors, we can see how it is hard to publish SSCI journal papers in Korea. As of 2010, the per-person SSCI journal publication is less than 0.3 in economics. Also we can notice big differences in the numbers of publications among different majors. For example, the number of per-person SCI journal publications in economics major is almost six times more than that of education major in 2010.[5] Yet, it should also be noted that the average annual publication of economics major is only one-seventh of physics major. Again we can say that there is no meaning in comparing the number of publications, say, of individual economist with that of a physicist.

<Table 4> Annual Average Publication Per-person in SSCI Journals (Social Science)

	Annual publication per person				Ratio (Education=1)		
Year	Education	Economics	Pub. Admin	Sociology	Economics	Pub. Admin	Sociology
1995	0.017	0.035	0.023	0.047	1.98	1.30	2.67
1996	0.023	0.074	0.018	0.075	3.23	0.80	3.28
1997	0.034	0.032	0.009	0.011	0.96	0.28	0.33
1998	0.024	0.047	0.004	0.037	1.96	0.18	1.55
1999	0.025	0.081	0.034	0.033	3.27	1.38	1.34
2000	0.035	0.032	0.018	0.033	0.92	0.51	0.96
2001	0.033	0.087	0.015	0.016	2.67	0.46	0.49
2002	0.032	0.065	0.020	0.008	2.06	0.64	0.25
2003	0.022	0.127	0.019	0.021	5.79	0.87	0.98
2004	0.024	0.185	0.030	0.079	7.79	1.24	3.32
2005	0.036	0.185	0.046	0.060	5.08	1.27	1.65
2006	0.057	0.216	0.037	0.095	3.77	0.65	1.66
2007	0.045	0.201	0.054	0.120	4.46	1.19	2.66
2008	0.054	0.185	0.046	0.181	3.40	0.84	3.32
2009	0.048	0.232	0.061	0.138	4.79	1.26	2.84
2010	0.050	0.290	0.048	0.100	5.76	0.96	1.99

We can also see differences in the ratios between the national and international publications in different majors. In <Table 5>, we present the ratio between the national to the international publications for different majors. In all of the natural science majors this ratio is decreasing over time, meaning that researchers in Korea try more and more to publish their works in the international journals. For example, in physics and chemistry this ratio is around 0.2 to 0.25 in 1995, meaning that Korean researchers in these majors published four to five times more papers in the international journals than

5) We can suspect the assumption of the same research effort in the social science majors. The research effort and difficult in publications among different academic field would be an interesting future research topic.

in the national journals. In 2010 this ratio dropped to around 0.1. This is common in many natural science majors.

But in the social science majors, the pattern is quite different. We can see from the <Table 5> that most of the social science research outputs are published in Korea. The publishing ratio between the national journals to international journals are 21.9 in education, 2.8 in economics, 16.9 in public administration, and 8.4 in sociology in 2010. Besides economics, this ratio has been increased from 1995, which is just the opposite of natural science majors. Though not being presented in the form of tables it should be noted that very few papers of the humanities majors were published in the international journals.

This is another piece of evidence that the comparison of individual researchers' productivity should be done within the same majors. Reflecting these differences in the publishing pattern, we will concentrate on papers published in the international journals when we examine the natural science and the engineering majors. In the social science and the humanities majors we will examine both the international and national journals.

<Table 5> National-International publication Ratio (Selected Majors)

	Natural Science				Social Science			
Year	Math	Physics	Chemistry	Biology	Education	Econ	Pub Admin	Sociology
1995	1.73	0.24	0.23	0.63	6.47	4.25	11.33	4.57
1996	1.71	0.19	0.25	0.72	6.83	2.42	18.10	3.00
1997	0.74	0.19	0.26	1.14	5.15	8.77	36.40	24.39
1998	0.75	0.15	0.32	0.65	9.98	5.35	81.83	7.94
1999	0.69	0.21	0.23	0.64	12.70	3.87	13.77	7.90
2000	0.56	0.14	0.26	0.49	9.78	9.92	21.63	6.74
2001	0.45	0.14	0.32	0.52	11.13	4.18	34.31	29.37
2002	0.95	0.11	0.30	0.50	13.81	5.78	26.78	59.77
2003	0.41	0.08	0.15	0.34	22.60	3.91	26.25	23.26
2004	0.54	0.11	0.15	0.29	22.72	2.11	17.05	5.99
2005	0.44	0.07	0.14	0.33	14.06	2.10	10.92	8.29
2006	0.33	0.09	0.14	0.27	10.38	2.29	14.29	6.74
2007	0.36	0.10	0.09	0.22	13.62	2.87	9.99	4.65
2008	0.37	0.10	0.10	0.22	13.20	2.94	11.34	2.42
2009	0.39	0.11	0.12	0.24	17.20	3.17	11.75	5.26
2010	0.34	0.11	0.12	0.24	21.09	2.82	16.93	8.37

4.2. Framework for the empirical analysis

We try to estimate the effect of different research funding schemes to the research productivity of professors using the information about the project participants and the non-participants.[6] To do it we need to compare the productivity change before and after the research funding projects between treatment groups and comparison group. The obvious treatment groups are those professors who are participating in the project. Since the participating professors are the best researchers in the leading graduate programs, it is just natural that they produce large amounts of research output before and after the project. But the question should be "Did their research outputs increased because of the government funding programs? What if they could not have research funds like BK21 or WCU?" Considering the research environment in Korean universities, the lack of such research funds mostly means the lack of good research assistants for many academic disciplines in the case of BK21 program, and the research assistant plus lack of international cooperation in the case of the WCU program.

In an ideal situation, where we have information on the rank or scores of all the research teams in the selection stage, including those eliminated, we can apply regression discontinuity approach to evaluate the causal relationship of the fund. Unfortunately, we do not have proper information on the selection process. What we do know about the selection process is that the most important criterion of selection is the quantity and the quality of the research that the faculty members have produced. So the first qualification of the control group is that it should be composed of professors that have revealed the highest research performances among non-participants.

One can raise questions whether this could be a proper control group, but this seems to be the only possible way to find the control group of researchers that have shown similar ability to research, with the given data set. With the lack of information about individual researcher's characteristics that has closely related to the research output, the output itself would be the best criterion that selects researchers who are close to the top researchers who were selected as fund recipients.

Another important fact about this control group is that professors in this group might suffer from the loss of graduate students *because of* these research projects. Before the introduction of the first phase of the BK21 project in 1999, it has been the convention

6) It should be emphasized again that the aim of this section is not the evaluation of the BK21 or the WCU projects themselves. Rather, we want to compare the effect of these two projects on the productivity of participating professors. It must be noted that the main purpose of the BK21 project is fostering scholars of younger generation through high quality institutions. But, the research productivity of professors is a very important selection criterion and at the same time it is the major performance indicator in the annual review.

in Korean academia, unlike that of the USA, that undergraduate student of any university usually chose the same university for their graduate study if it had graduate program. But with un-precedent increase in grants given to a few departments in each major, many prospect graduate students have chosen departments with BK21 funds. This made a big decrease in the number of incoming students, especially with better qualification, to many graduate programs that were not selected.

Some professors argue that the whole structure of the BK 21 and the WCU projects is counterproductive for their research, because of little pecuniary incentive and high costs of the administrative burdens. For example, they should write extensive research proposal to be selected, and once selected, they should write annual report, which is quite time-consuming. Despite all these complaints, almost all professors in top research schools made research teams and submitted proposals. Along with the pressure from the university, a concern of losing research assistant was the major reason of this "revealed preference" for the large government funding project. It is very likely that researchers in the control group can get many kinds of research funds. But among many research funds in Korea, there is none other than the BK21 or the WCU that permits so large portion of funds for the graduate students.

This unique feature of the funding scheme — high compensation for the graduate students or foreign scholars and little compensation for the professor — can provide a useful policy experiment that we can evaluate the importance of the research assistance and co-authors in the research process of different majors. By constructing the control group of researchers with compatible abilities, yet lacking stable source of fund for the research assistants, we can make a setting that compares "BK21 project or WCU project vs. all the other research funding projects."

In the case of the WCU program, the international cooperation or co-work with foreign scholars is an additional treatment upon the research assistance. Research teams receiving the WCU fund must invite foreign scholars and should pay for them. Whatever the contents of the cooperation, it is the most important feature that distinguish the WCU projects from the BK21 projects.

To compare the relative efficiency of two different projects, we run two separate regressions; one including the BK21 project participants and non-participants in the sample, the other including the WCU project participants and non-participants. More specifically, we get the DID estimates from the following two equations.

$$PubIndx_{it} = \alpha_0 + \alpha_1 YBK + \alpha_2 DBK + \alpha_3 YBK^* DBK + \Gamma_1 RCH_{it} + \delta Time + a_i + \epsilon_{it}$$

$$PubIndx_{it} = \beta_0 + \beta_1 YWCU + \beta_2 DWCU_{it} + \beta_3 YWCU^* DWCU + \Gamma RCH_{it} + \delta Time + a_i + \epsilon_{it}$$

In the above equation $PubIndx_{it}$ is the index of research output of individual *i* in the year *t*. It is measured by the total number of annual publications adjusted with the number of co-authors, as explained in the previous section.[7]

YBK is the dummy variable taking the value 1 for the years of BK21 project, namely after 2006. *DBK* is the dummy variable taking the value 1 for the individual participating in the BK21 project. The coefficient of this variable is the differences in the annual publications between the participants and non-participants before the phase II of the BK21 project. The coefficient of the interaction term *DYB*DBK,* α_3 is the DID estimator measuring the net effect of participating in the BK21 project.

In the same manner *YWCU* is the dummy variable taking the value 1 for the years of the WCU project, namely the year 2009 and 2010. *DWCU* is the dummy variable taking the value 1 for the individual participating in the WCU project. The coefficient of the interaction term *YWCU*DWCU,* β_3, is the DID estimator measuring the net effect of participating in the WCU project. By comparing two DID variables we can determine which program works better for the productivity of participating faculty members.

We add the time trend variable to control for the general increasing trend of publications. There are several reasons for the increasing trend in the number of publications in all academic fields. At the university level, increasing number of universities adopted stricter faculty promotion system since late 1990s. This induces the effort from the professors, and made increasing trend of research outputs. In the case of humanities and social science majors, the number of KCI journals has been increased in 2000s, contributing the trend of increasing number of publications.

There should be some control variables related to the researcher’s characteristics (RCH). Unfortunately, we do not have many variables in the data set. The only variable we can use is the age of the researcher. To control for the life-cycle aspects in the research activity, we add age and squared age in the regression.

In the estimation, selecting proper control groups is the key issue. The control groups are composed of professors who are endowed doctoral degree before 2006 and produced most annual average number of papers among non-participants. The numbers of professors in the control groups are the same as the numbers of participating professors, namely, the sum of the number of professors participating in the BK21 or the WCU project. We use the same control group for both projects. The research performances in

7) It must be noted that this index does not properly reflect the quality of the published works. We try to reflect the quality by limiting papers published in SCI, SSCI, AHCI, or KCI journals, but there are wide variety in the quality of those journals. It would be better if we can used the information on the impact factors. While not impossible, it is not easy to gather all information on the impact factors of different journals at different times. So we only use this quantitative index in this paper and leave the analysis of quality-adjusted measures of publication as a future research topic.

terms of the average annual publication from 1999~2010 are presented in <Table 6>.

We can see that the number of annual average publications is higher in the treatment group in many majors. But in some majors such as mathematics and economics, the control group's number is higher. Between the two treatment groups, participants of the WCU program shows higher productivity. It must be noted that the numbers of participants are much smaller in the WCU program, and it is possible that the selection process is more restrictive to the most productive researchers. It is also interesting to note that there are some very productive researchers that are not selected in the WCU project. When we select the same small number of the most productive researchers among non-participants of the WCU program their average annual publications are much higher than the WCU participants in many majors. Typically, it is more than twice as higher. This large gap implies that the productivity of professors is not the only selection criterion in the WCU program. For example, it is possible that some of the productive scholars are hired in less renowned institutions.

<Table 6> The Number of the Annual Average Publications in the International Journal (1999-2010)

	BK21 parti.	WCU parti.	non BK21[1)]	non WCU[2)]	non parti.[3)]
Physics	2.25 (132)	2.13 (31)	1.17 (132)	4.83 (31)	0.95 (147)
Biology	1.03 (153)	1.32 (20)	1.41 (153)	3.65 (20)	1.3 (162)
Chemistry	1.82 (158)	3.31 (32)	1.16 (158)	3.46 (32)	0.94 (169)
Mathematics	0.69 (61)	0.85 (7)	0.95 (61)	3.16 (7)	0.93 (62)
Electronic Engin.	1.41 (235)	3.32 (18)	0.63 (235)	4.51 (18)	0.57 (243)
Computer Science	0.76 (144)	1.91 (8)	0.41 (144)	2.9 (8)	0.41 (144)
Mechanical Engin.	1.15 (148)	1.2 (12)	0.57 (148)	4.6 (12)	0.56 (150)
Economics	0.39 (50)	0.18 (2)	0.45 (50)	2.38 (2)	0.44 (51)
Education	0.11 (40)	0.46 (3)	0.33 (40)	0.94 (3)	0.32 (42)
History	0.01 (25)	0.01 (3)	0.26 (25)	0.65 (3)	0.24 (28)

Notes:

1) Non-BK21 means groups of the most productive professors who do not participate in the BK21 program. Each group includes the same number professors as the BK21 participants. It possibly includes those who participate in the WCU program. Likewise,
2) Non-WCU means groups of the most productive professors who do not participate in the WCU program. Each group includes the same number professors as the WCU participants It possibly includes those who participate in the BK21 program
3) Non-parti. means group of the most productive professors who participate neither in the BK21 nor the WCU program. Each group includes the sum of the BK and the WCU participants. Due to some professors who get both funds, this number is not the same as the sum of the BK21 the WCU participants.
4) Numbers in the parenthesis are the number of project participants.

Now think about the effect of the research fund on the quality of the graduate education programs. If we can distinguish the recipients of graduate funding from non-recipients, it would be relatively easy to infer the effect of the project by comparing the performances of two groups. But we do not have such information. It might be possible to identify institutions that Korean doctors got their degree, but there is no guarantee that they are actually fund recipients, since there are not a few individual non-recipients in the fund receiving institution.

With this difficulty of identifying true recipients, we take an indirect way to get information about the quality of education before and after the funding project. We look at the performances of doctors who get their doctoral degree from Korean institution. That is, rather than ask whether the research funding projects enhance the productivity of recipients, we ask whether graduate funding programs lifted the general quality of graduate education in Korea. This is justifiable since that is the ultimate purpose of the funding project.

To answer this question we compare the performance of doctors from Korean institutions with those from US institutions, which are widely believed to have highest graduate education quality in the world. More specifically, we compare the performance of doctors from Korean institution with those form US institution before and after the major graduate funding programs. We estimate the following simple equation for different cohort of doctors.

$$PubIndx_{it} = \beta_0 + \beta_1 DKOR + \Gamma RCH + \delta Time + a_i + \epsilon_{it}$$

The sample is composed of Korean doctors who got their doctorates in Korea or in the USA. In the above equation, *DKOR* is the dummy variable indicating doctors who got doctorates in Korea. We estimate the equation for three different cohorts of doctors; those who get doctorate (1) from 1995 to 2000, (2) from 2001 to 2005 (3) after 2006. The coefficients of the dummy variable *DKOR* can be interpreted as the performance gap between doctors from Korean institutions and those from the US institutions. By looking at the changes in the performance gap for these different cohorts, we can determine if the performance gap has been decreased after the funding projects for graduate programs began. The differences of two estimates derived from different cohort sample can be considered as DID estimator indicating change in the performance gap. If the research funding projects made some positive effects we can find a decreasing performance gap.

Let us first look at the simple average numbers of annual publications. It is clear that Korean doctors are more productive in recent years than the past. In <Table 7> we compare the same cohorts of Korean doctors who get their degree in Korea and in the US. There is not a clear pattern that can be applied to all the majors, but we can see that in some majors the performance gap has decreased. Physics is a very distinctive case that recent graduates from Korean institutions are more productive than those from the US institutions in terms of number of papers. The cohort of doctors in physics who got their degree between 1995 and 2000, the performance gap between US doctors and Korean doctors is about 0.6 papers per year. The gap was narrowed to 0.4 papers for 2001~2005 cohort. For 2006~2010 cohort, doctors from Korean institutes produce 0.5 more papers than those from US institutions. But in humanities and social science majors, the performance gap has not been narrowed. Like the effect on professors' productivity, the effects on graduate students are small for humanities and social science majors. One possible reason is that in those academic disciplines, researchers tend to publish their works in national journals. We will check this possibility in the next section, presenting the result of regression analysis.

<Table 7> Comparison of Productivity of Korean Doctorate from US and Korean Institution by Majors – Annual Average Production of Papers (International Journals)

	1995~2000		2001~2005		2006~2010	
	US	Korea	US	Korea	US	Korea
Physics	1.23(34)	0.61(47)	1.13(13)	0.71(66)	0.30(11)	0.83(79)
Biology	0.55(59)	0.53(110)	0.73(29)	0.58(154)	0.88(14)	0.35(181)
Chemistry	0.71(31)	0.73(54)	1.08(39)	0.61(60)	0.62(29)	0.50(83)
Computer	0.35(49)	0.11(163)	0.40(33)	0.20(181)	0.40(18)	0.20(151)
Electronic	0.84(54)	0.19(227)	0.80(54)	0.33(194)	0.72(38)	0.40(165)
Mathematics	0.26(24)	0.21(30)	0.45(17)	0.51(44)	0.27(9)	0.26(29)
Mechanical	0.60(35)	0.16(102)	0.83(24)	0.38(76)	0.78(24)	0.34(104)
Architectural	0.26(18)	0.02(72)	0.46(14)	0.07(70)	0.06(10)	0.06(57)
Nuclear	0.61(4)	0.49(4)	0.67(1)	0.12(5)	0.00(1)	0.35(10)
Environmental	0.64(18)	0.20(39)	0.90(20)	0.21(40)	0.63(11)	0.36(31)
Food	0.86(13)	0.28(33)	0.85(16)	0.77(26)	1.05(14)	0.58(25)
Economics	0.20(42)	0.08(40)	0.16(41)	0.04(19)	0.13(15)	0.02(29)
Education	0.10(51)	0.01(131)	0.08(58)	0.01(180)	0.12(50)	0.01(162)
History	0.04(16)	0.01(105)	0.05(8)	0.01(73)	0.07(4)	0.00(60)
Sociology	0.04(22)	0.01(17)	0.18(9)	0.09(13)	0.23(12)	0.00(22)
Public Admin	0.06(9)	0.00(35)	0.05(16)	0.00(44)	0.19(11)	0.00(44)
English Lit	0.03(40)	0.00(55)	0.01(36)	0.00(28)	0.01(17)	0.02(22)

Note: Numbers in the parenthesis are the number of doctors in each category

Ⅴ. Empirical Results

5.1 Comparing Two Different Funding Schemes on the Research Productivity

This section presents major results from estimations of many academic disciplines. We will present OLS, fixed effects and random effects estimation results. Before examining results it should be noted that previous researches pointed out the problems of using DID method in evaluating research fund program. For example, Jaffe (2002) warns that in some case DID method might produce more biased result than simple regression.[8)] It would be better to interpret our result as the maximum estimates of the net effect.

Let us look at the result for physics major shown in <Table 8>. The dependent variable is the number of publications in the SCI journals for each year. In the case of physics the number of the BK participants 132, and that of the WCU is 31. Since there are some professors participating in both projects, and the sum of professors participating either one of the project is 147, and accordingly, the number of the control group is 147. In <Table 8>, We can see very similar result for the BK21 and the WCU. The coefficient of the participating dummy has a positive sign, meaning that the participants had higher performance before the project. But the years dummy had negative sign, meaning that the increasing trend in publication has been weakened. The coefficient of key variable, namely the interaction term of participating dummy and the year dummy variable take the positive sign but are statistically insignificant. Both participants of the project and non-participants produced more research papers in the international journal after the project, and we cannot say participants are more productive because of the project.

8) The following quote from Jaffe (2002) explains this point clearly. “The limitation of this (DID) approach is that it only controls for time-invariant unobservables. To the extent that the agency can and does evaluate the proposed project distinctly from the proposing entity, the resulting selection bias is not eliminated by differencing. In addition, one could imagine other sources of unobserved performance differences that vary across individuals and time. For example, applicants may decide to enter the grant competition when they have been enjoying unusually good (or bad?) recent performance. Any unobserved variation of this kind makes the differences estimator biased; differencing eliminates the time-invariant but introduces a new error related to the deviation in the previous period from the applicant’s ‘normal’ performance. Indeed, depending on the relative magnitude of time-invariant and time-varying individual effects, differencing could produce estimates that are more biased than simple regression estimates”

<Table 8> The Effect of Participating in BK21 or WCU program - Physics

	BK21			WCU		
	OLS	RE	FE	OLS	RE	FE
D_Parti	1.170***	1.068***		1.058***	0.970***	
	(0.138)	(0.224)		(0.169)	(0.321)	
P_Year	-0.450***	-0.502***	-0.533***	-0.509***	-0.539***	-0.547***
	(0.163)	(0.154)	(0.154)	(0.151)	(0.153)	(0.155)
Year*Parti	0.203	0.297	0.361	0.451	0.572	0.635
	(0.194)	(0.243)	(0.242)	(0.520)	(0.559)	(0.559)
age	0.133***	0.247***	0.532***	0.126***	0.197**	0.430***
	(0.0388)	(0.0824)	(0.139)	(0.0377)	(0.0837)	(0.132)
agesq	-0.00108**	-0.00235***	-0.00371**	-0.00111***	-0.00189**	-0.00271*
	(0.000439)	(0.000890)	(0.00157)	(0.000412)	(0.000911)	(0.00152)
trend	0.166***	0.166***		0.160***	0.160***	
	(0.0248)	(0.0247)		(0.0168)	(0.0279)	
No. Obs	3,051	3,051	3,051	1,888	1,888	1,888
R^2	0.094		0.061	0.117		0.110
No. Scholars		279	279		178	178

Notes: 1) The Variable "Parti" is the dummy variable take value if professors take part in the BK21 or WCU project

2) Numbers in the parenthesis are robust standard errors. *** are significant at 1%, ** are significant at 5%, * are significant at 10% levels

<Table 9> presents the DID estimates for some selected majors that we have relatively large number of fund recipients in the sample. Like physics, the DID estimators for the WCU project are insignificant in almost all the academic disciplines. The only exception is mechanical engineering. In this major, the DID estimators are positive and significant for both the BK21 and WCU project, but the absolute value is higher for the WCU program.

It is also notable that there are some cases, like mathematics and economics, that DID estimators take negative value and statistically significant. It is quite notable that the BK21 project appears to make adverse effect in mathematics unlike other science and engineering majors. One of the intuitive reasons for this result is that research assistants in mathematics might not contribute much for the professors' research productivity. The same reasoning can be applied to humanities and social science majors. In many humanities and social science majors, research assistants' roles are limited. But in such science and engineering majors as chemistry and electronic engineering, where laboratory experiments are indispensable part of the research, graduate students who serve as research assistants can greatly enhance the productivity of professors.

We can summarize the results as follows. In terms of the research productivity of professors, the BK21 made more positive effect than the WCU in some science and engineering majors. So we can say that the BK21 was more favorable to professors' research productivity than the WCU. But in humanities and social science majors, both projects did not make positive effect, and the BK21 usually made negative effect on the productivity of professors in these majors. The negative effects are relatively small in the WCU case. In a sense, the WCU is less harmful than BK21 to professors' research productivity in humanities and social science majors.

It is quite clear that the grant to the graduate student has potential to increase the productivity of professors in some majors that research assistants make large contribution in the research process. Yet it is hard find an intuitive explanation for the weak effect of the WCU project on the research productivity of participating professors in the science and engineering majors.

Also it must be noted that the main purpose of these funding program is not to increase the productivity of professors. Rather the main purpose is to increase the quality of the graduate studies. Next, we will examine the changes in the productivity of Korean doctors from Korean institutions.

<Table 9> **DID Estimators for Selected Academic Disciplines (International Journals)**

	BK21			WCU		
	OLS	FE	RE	OLS	FE	RE
Physics	0.203	0.297	0.361	0.451	0.572	0.635
	(0.194)	(0.243)	(0.242)	(0.520)	(0.559)	(0.559)
Biology	-0.175	-0.225	-0.240	-0.182	-0.224	-0.263
	(0.110)	(0.162)	(0.167)	(0.395)	(0.387)	(0.392)
Chemistry	0.478***	0.527***	0.546***	0.163	0.275	0.346
	(0.131)	(0.166)	(0.168)	(0.464)	(0.584)	(0.577)
Computer	0.160*	0.151*	0.147*	-0.298	-0.238	-0.193
	(0.0905)	(0.0829)	(0.0837)	(0.805)	(0.672)	(0.678)
Electronic	0.452***	0.491***	0.506***	1.122	1.123	1.104
	(0.109)	(0.147)	(0.150)	(0.794)	(0.767)	(0.774)
Mathematics	-0.399***	-0.510**	-0.541**	-0.0419	-0.105	-0.123
	(0.149)	(0.239)	(0.250)	(0.383)	(0.403)	(0.413)
Mechanical	0.346***	0.426***	0.450***	0.912**	0.955**	0.975**
	(0.107)	(0.115)	(0.117)	(0.455)	(0.483)	(0.485)
Economics	-0.277***	-0.303***	-0.312***	-0.219	-0.234**	-0.238*
	(0.102)	(0.0928)	(0.0969)	(0.330)	(0.119)	(0.128)
Education	-0.0880	-0.136*	-0.169**	-0.00717	0.00777	0.0616
	(0.0645)	(0.0806)	(0.0827)	(0.224)	(0.0773)	(0.0629)
History	-0.198***	-0.198*	-0.241*	-0.180	-0.180	-0.200
	(0.0684)	(0.108)	(0.129)	(0.123)	(0.133)	(0.137)

Note: All coefficients are DID estimators. Numbers in the parenthesis are robust standard errors.
***: significant at 1%, **: significant at 5%, *: are significant at 10%

5.2 The Effect of Government Research Funds on the Productivity of Graduate Students

Now, let us look at the performance gap between doctors educated in Korea and those who educated in the USA. <Table 10> presents the estimates of the performance gap in some academic fields from random effects model. In the case of 1995~2000 cohort, doctors from the US institutions produced more papers than those from Korean institution in all academic disciplines. The situation does not change much for the 2000~2005 cohort. But in the case of 2006~2010 cohort, the performance gaps are either narrowed or as in the case of Physics and Nuclear engineering, doctors from Korean institutions produced more papers.

<Table 10> Comparison of Productivity of Korean Doctorate from US and Korea by Majors – Regression Results

	International Journals (SCI or SSCI)			National Journals (KCI)		
	1995~2000	2001~2005	2006~2010	1995~2000	2001~2005	2006~2010
Physics	-0.635***	-0.418	0.532**	-0.00564	-0.0465	0.0309**
	(0.246)	(0.311)	(0.259)	(0.0252)	(0.0861)	(0.0122)
Biology	-0.0858	-0.0989	-0.612	0.0532*	0.0638**	-0.183
	(0.0958)	(0.156)	(0.515)	(0.0323)	(0.0305)	(0.210)
Chemistry	-0.154	-0.439**	-0.124	0.0328	0.0438*	0.0244
	(0.186)	(0.191)	(0.160)	(0.0437)	(0.0229)	(0.0284)
Computer	-0.238**	-0.195**	-0.164*	-0.0740**	-0.0430	0.0998
	(0.0962)	(0.0806)	(0.0896)	(0.0334)	(0.0657)	(0.0642)
Electronic	-0.604***	-0.411***	-0.379***	-0.124**	0.00322	0.128**
	(0.172)	(0.142)	(0.139)	(0.0518)	(0.0562)	(0.0569)
Math	-0.122	0.0254	-0.0278	0.110**	0.0557	0.0464
	(0.0776)	(0.152)	(0.101)	(0.0528)	(0.0340)	(0.0285)
Mechanical	-0.415***	-0.302*	-0.518***	-0.0715	0.145**	0.0318
	(0.110)	(0.171)	(0.161)	(0.0468)	(0.0741)	(0.0699)
Archit.	-0.235***	-0.364**	0.00738	-0.378***	-0.467*	0.0411
	(0.0832)	(0.166)	(0.0399)	(0.146)	(0.244)	(0.102)
Nuclear	-0.0481	-0.622***	0.543***	0.218***	0.0611	0.0609
	(0.269)	(0.0532)	(0.185)	(0.0771)	(0.0581)	(0.0558)
Environ.	-0.394**	-0.575***	-0.220	-0.121	-0.143	0.275*
	(0.174)	(0.184)	(0.266)	(0.112)	(0.154)	(0.154)
Food	-0.496**	0.159	-0.390*	-0.0735	-0.0830	0.212**
	(0.243)	(0.331)	(0.208)	(0.112)	(0.116)	(0.103)
Economics	-0.0619	-0.109***	-0.109*	0.142	0.0376	0.0763
	(0.121)	(0.0380)	(0.0599)	(0.213)	(0.0789)	(0.132)
Education	-0.0837***	-0.0701***	-0.111***	-0.0988	0.0872	0.0591
	(0.0278)	(0.0218)	(0.0338)	(0.0935)	(0.0718)	(0.123)
History	-0.0291	-0.0379	-0.0734	0.0540	-0.247	-0.0322
	(0.0212)	(0.0400)	(0.0665)	(0.0987)	(0.182)	(0.150)
Sociology	-0.0337	-0.114	-0.221**	-0.0790	-0.226	0.209
	(0.0206)	(0.149)	(0.0987)	(0.109)	(0.164)	(0.193)
Pub. Admin	-0.0688*	-0.0508**	-0.190*	0.0991	-0.377***	-0.0821
	(0.0408)	(0.0231)	(0.101)	(0.165)	(0.120)	(0.214)
English Lit	-0.0295**	-0.00711	0.0198	-0.394***	-0.318***	0.0382
	(0.0123)	(0.00528)	(0.0176)	(0.0823)	(0.101)	(0.149)

Numbers in the parenthesis are robust standard errors. ***: significant at 1%, **: significant at 5%, *: are significant at 10%

This clear sign of narrowing gaps can be considered as indirect evidence that major funding projects have somehow succeeded in lifting up educational quality in Korean graduate schools in some science and engineering majors. But there are good reasons to suspect the sample selection could be a decisive factor that made performance gap between the US doctors and Korean doctors smaller in recent years. Consider the doctors from the US institution who work in Korea. Doctors who got their degree ten years ago and stayed in the US for some years showing good performances, have good chances to return to Korea and to be hired in prestigious institutions. Their performance would be better than doctors who get their degree ten years ago, when there are few government funds for graduate student.

Now, let us think about younger cohort. The best young researchers among those who just got their degree in the USA had higher chance to stay in the US than less able researchers. So it is possible that we compare average doctors form Korean institution with less able doctors from the US institution. In the meantime, the large increase in the research fund for graduate studies could make many students stay in Korea rather than chose to study abroad. So the decrease in the performance gap might largely reflect the decrease in the ability gap among graduate students rather than decrease in the educational quality gap in graduate schools.

Considering these selection effect, more proper comparison group should be the group of Korean doctors who studied and are staying in the USA, which is simply not possible with the current dataset. We need to gather information on Korean scholars staying in the USA. While it is very likely that selection bias prevails, it is not likely that all the decrease in the performance gap can be attributable to the selection effects, especially in some cases like Physics.

Meanwhile, in humanity and social science majors, the performance gap measured by the number of publication in international journals does not change much after the major graduate funding projects. The results are similar for the national journals. The positive effect on the research productivity of graduate students after graduation is not clearly seen yet in many academic disciplines.

5.3 Summary and Policy Implications

Now let us summarise empirical results and derive some policy implication from them. <Table 11> summarizes empirical results presented in the previous section. The BK21 project made positive effect in some natural science and engineering majors. The effect of the WCU projects is usually very weak. The only exception is mechanical engineering, where both the BK21 and the WCU made positive effect, and the WCU made stronger effect. In some academic disciplines that the WCU projects work relatively better than the BK21, it is because the WCU projects are less harmful, rather than they make positive effects. There are some possible reasons for this weak effect. Most of all, the emphasis on the international cooperation does not seem to be a wise way to spend research fund efficiently.

All things considered, the BK21 funding scheme seems to be a good one in that it can raise the research productivity of professors while training the future researchers in many natural science and engineering majors. Also, it seems to be a better funding scheme than that of WCU. In some academic fields that research assistants are important input in the research process, it seems just natural that the direct subsidy to the research assistant makes noticeable effects.

But we must worry about the negative effects of funding projects in some majors. It is hard to believe that funding project makes negative effects, but we can think of some possible reasons. For example, we can suspect that the selection of recipients was not based on the individual professors' productivity in some majors. For example, the restriction that more than 70% of faculty members should join the research team can induce some free-riding unproductive recipients to participate in the project. It is also possible that some of the recipients made their maximum effort before the program starts, to be selected, while they have little incentive to work harder after the selection.

Small pecuniary incentive for faculty members can also be a reason for the small effect. Whatever the reason, there should be wiser ways to spend research fund more efficiently. Especially, for some majors that the funds does not make positive effects either professors' or graduate students' research productivity, we need to think about other schemes.

For example, let us consider economics. How can we interpret the negative effects of the BK21 and the WCU project shown in economics? Do we need a big research group in economics? Is it the best way to educate researchers of the next generation to give grants only to students in two or three graduate schools? Why should we distribute grants to graduate students based on their professors' or departments' merit, instead of their own merits?[9] These questions lead us to think that there could be better ways to enhance productivity of current professors while providing higher quality education for the next generation researchers in diverse academic disciplines.

In terms of the educational quality it is very hard to derive policy suggestions. We find that the performance gaps between doctors from the Korean institutions and those from the US institutions have been narrowed in some natural science and engineering

9) In a different context, Conley et. al (2013) recently raised a similar concern with the US data. They find that the research rankings of top economics departments are a surprisingly poor predictor of the subsequent research rankings of their PhD graduates

majors. But there are many academic disciplines that these performance gaps are maintained with all government subsidies. So, it is hard to reach the conclusion that major funding projects enhanced overall quality of graduate education, especially for many social science and humanity majors. Even in some majors that succeeded in decreasing gaps, there are reasons to suspect that it is the selection process rather than educational quality that is the main cause of dragging down the performance gap.

Yet it is not likely that the selection bias explains the entire decreasing gap. It should be also noted that the decreasing performance gap is more evident in such majors as chemistry, electronic engineering, computer science, where the BK21 project make positive effect on professors' productivity as well. This can be interpreted as a sign that research grants to graduate students ultimately enhanced their research productivity, perhaps through the co-work with their professors. In turn it implies that the performances of the current generation and the next generation are highly correlated. If it is indeed the case, the best way to enhance the research productivity of the next generation researchers would be to induce higher productivity of the current generation, whatever the major.

<Table 11> Summary of Results

	BK21 Eff	WCU Eff	Relative Effectiveness	Educ Quality
Physics	—	—	Similar	○
Biology	—	—	Similar	—
Chemistry	○	—	BK21 over WCU	○
Mathematics	×	—	WCU over BK21	—
Electronic Engin.	○	—	BK21 over WCU	○
Computer Science	○	—	BK21 over WCU	○
Mechanical Engin.	○	○	WCU over BK21	—
Economics	×	×	Similar	—
Education	×	—	WCU over BK21	—
History	×	—	WCU over BK21	—

○ Positive effect, — No Effect, × negative Effect

Ⅵ. Concluding Remarks

In this paper, we have examined the effect of research funds to graduate schools on the research productivity of professors by comparing quantity of publications between the projects participants and non-participants. The most notable result is that the effects of the BK21 and WCU projects on professors' research productivity are different for different majors. For the BK21 projects, we find positive effect in many natural science and engineering majors. In these majors, the effects of the WCU are generally weaker than the BK21. The restriction on fund use might be the main cause of this weak effect. There is no reason to believe that international cooperation is the key element in enhancing research productivity for the current generation or future generation researchers. Rather, it seems that one of the key factors of increasing research productivity is the help from research assistants in the academic field where experiments are indispensable in the research process.

While the empirical results are quite clear and have strong policy implication, there are obvious limitations. Most of all, the lack of information about the proper control group is the main problem in the empirical analysis. Especially, it seems very hard to correct the possible selection bias with the current data set. Also our measure of research productivity has clear limitation in that it puts too much weight on the quantity. We need to incorporate information on the quality aspects of research productivity in the analysis.[10] In the case of the research productivity of graduate students, we need better data sets that can identify recipients of funding projects among Korean doctors. All these limitations are naturally suggesting future research directions.

Despite these lacks of empirical rigor due to the limitation of data, the differences in effects among academic disciplines should be taken seriously. For some majors that the BK21 or the WCU projects made weak or negative effect, we should think about revising the funding schemes that reflect the characteristics of the research process of the corresponding academic disciplines.

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10) There are many people in Korean academia who criticise that government and universities put too much weight on the quantity of the research products, and that as a result there are not so many challenging and influential researches as desired.

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