The Pennsylvania State University

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DOES THE PROJECT OF WORLD CLASS UNIVERSITY (PHASE I)
SPUR SCIENTIFIC PRODUCTIVITY IN STEM FIELDS? :
A STUDY OF POLICY IMPACT IN TAIWAN

A Dissertation in
Higher Education
by
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Abstract

High profile, selection-and-supplemental funding, university excellence initiatives are becoming increasingly popular national R&D strategies globally. The central goal is to stimulate an R&D “Matthew effect” among selected universities to competitive globally among research-intensive universities by purposely funding accumulated advantage in science productivity.

A difference-in-differences evaluation of the effects of Taiwan’s much-publicized World Class University Project (WCU) on scientific productivity from 2001 to 2010 yields unexpected findings. Significant financial resources provided to the selected WCU universities (treatment group) did increase production of scientific papers and publication in prestigious journals. But, counter to the program’s chief goal, the Non-WCU universities (comparison group) increased their rate of production more than the WCU universities during the same period. This study also found that after the policy implementation the Non-WCU universities were more actively cutting into the private R&D funding market. The change of Non-WCU universities was driven by the demand to go after other financial resources to build up their capacity for next round of competition.

A possible diffusion effect of institutional norms, greater inter-institutional competition, and isomorphism around science productivity generated by the implementation of WCU Project is examined and discussed in light of the global spread of university excellence initiatives.
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Chapter 1: Research Overview

1.1 Introduction

Higher Education systems and individual faculty working in higher education institutions are under increasing pressure to be more productive in research. This trend is much more apparent, when the society demands universities to produce more research to support economic development. Since the late 20th century, many developing or even developed countries started investing big amounts of money in the development of research universities.

Taiwan is one of countries believing in the research university's contribution on knowledge creation and high-end talent cultivation. In 2006, the World Class University Project (hereafter, the WCU Project) initiated by Taiwan Ministry of Education (hereafter, MOE) is one of remarkable cases reflecting this global movement.

In accordance with the policy statement announced by MOE, the WCU Project is designed to establish internationally competitive research universities through concentrating extra funds in a small amount of chosen research universities. The WCU Project is divided into two phases. The first phase spans from 2006 to 2010 followed by the second phase, spanning from 2011 to 2016. Every five years, the chosen universities compete with the new applicant universities again to decide which university can win the status of the research university as well as can be retained in the WCU Project.

During the first phase, a total of 1.5 billion US dollar of extra funds was used in this project. In this project, 11 chosen research universities were granted the title of “World Class Universities” (hereafter, WCU universities) and received an affluent
amount of institutional-based money over a period of five years. During the second phase, 12 chosen World Class Universities enjoy this privilege.

To evaluate the performances of each WCU university, MOE created an accountability system to monitor the progress of each chosen WCU university. This accountability system contains a bunch of performance indicators to present the progress of development. These indicators could be grouped into three main categories: (1) the performance in the world university ranking system; (2) the amount of research publications in international journals; (3) the R&D funds received from the private sector to support university-based research (MOE, 2005). Annually, WCU universities submitted their annual performance reports to MOE to demonstrate their progress. Every five years, MOE conducted a summative assessment to renew the status of WCU universities. This periodic review creates a competition window as well as a certain period of preparation for those new applicant universities that were not chosen at the first phase and wanted to compete at the second phase.

Because the WCU Project spent so many resources on a small group of universities, voices from supporting and opposition camps never stop. Over the past years, the domestic scholars have contributed some scholarship works to help understand the policy effect of WCU Project generated (Ho, 2009; Chu, 2015). However, limited by merely descriptive studies and the absence of compelling evidence provided by pre-existing empirical studies, the conclusion with respect to the policy effect still remains uncertain.

In order to close this gap, this study aims to directly examine the effect of the WCU Project by using a quasi-experiment method, which is Difference-in-Differences design. It is worth noting that the policy effect along with the implementation of any higher education policy like the WCU Project could be
broader than government’s expectations. However, the research production in WCU universities is the main interest of the implementation of the WCU Project; therefore, this study concentrates the efforts on the investigation of the research activities.

To be more precisely, this study has to define the scope of research target. As mentioned earlier, the WCU Project has two phases, the first phase and the second phase. Even though two phases are called as the WCU Project, these two phases are divided by a new round competition. The content of the WCU Project in two phases has a slight difference as well. Plus, the second phase is still ongoing; therefore, its policy effect is not ready for policy impact analysis. Based on these two reasons, this study limits the scope of the investigation on the first phase of the WCU Project and its expected policy impacts.

Furthermore, in accordance with the empirical studies (Wood, 1990; Dunder & Lewis, 1998), compared to the social science and humanities, the STEM fields rely much more on the provision of R&D funds. Therefore, this study only focuses on the impact of WCU Project on research activities in the STEM fields.

Three core questions aligned with the policy goals set by MOE for the WCU Project are listed as following:

1. Does the divergence or convergence on the growth of scientific production occur between WCU universities and Non-WCU universities following the policy intervention?
2. Does the provision of additional Governmental R&D funds in WCU universities crowd in or crowd out the private R&D funds, or neither?
3. What are driven forces leading the observed changes, if has any?
This introductory chapter outlines the background of this study. It explains the purpose, the aims, and the approach taken to conduct this study. The significance of the study is discussed, and an overview of the dissertation that finishes the chapter.

1.2 Background of the Study

The WCU Project was initiated in an era when the world class university ranking system became influential on the formation of national higher education policy. The pressure derived from the ranking result was so profoundly that the policymakers in Taiwan eventually absorbed the value system embedded in the ranking system and integrated these values into the WCU Project. A number of research publications and the private R&D funds in university-based research picked up as two main performance indicators exactly reflected the influence of world ranking system on the design of the WCU Project.

Even though the WCU Project expected that the injection of extra R&D funds can increase research publications as well as the private sector’s R&D investment, from the theoretical perspective, the causality between the injection of extra R&D funds and the production of expected research outcomes still remains debatable. First, scholars have been debating whether public R&D funds could really spur the private R&D funds, offset it or even have no impact.

On the other hand, there have two competition approaches referred to study the driven forces leading the growth of research publications. The traditional approach, proposes that the injection of extra R&D funds can bolster the growth of scientific production in the chosen universities. Nevertheless, integrated the insights from the organization theory, the alternative approach argues that the competitive pressure could stimulate the non-chosen universities. As a result, the gap between chosen universities and non-chosen universities could thus reduce.
The quality of public policy is based on an accurate assessment of the effectiveness of policy. As a public policy, the WCU Project has been proceeding for almost ten years since 2006. In accordance with its time frame, by the end of 2016, the WCU Project would be replaced with a new project. David et al. (2000) argued that the efficient allocation of government expenditures requires a clear understanding of the circumstances under which investment is likely to be most productive. While approaching to the transition of policy, it is crucial that the policymakers are informed about the concrete results derived from a scientific empirical study. With a clear understanding and well-informed knowledge, the policymakers involving in the formation of the new policy could identify the existing systematic weakness and find the way to fix them accordingly.

1.3 Purpose of the Study

Although the interest of this study is stimulated by the practical needs of policy effect evaluation, the research findings derived from this study are essential to the theoretical development in two aspects.

The first thread of the literature relevant to this study is the impact of public R&D funds on the scientific productivity. The traditional approach indicates that the injection of institutional-based additional R&D funds like the WCU Project would result in the divergence on the growth of scientific production between chosen universities and non-chosen universities (Shin, 2009; Zhang et al., 2013). However, integrated insights from the organization theories (Bowen, 1980; James, 1990; Pfeffer & Salancik, 2003), this study proposes a competing approach, claiming the convergence between two groups could occur because the scientific productivity of non-chosen universities could be driven by the intensified competitive pressure.
Second, in research policy field, the dynamics between public R&D funds and private R&D funds is a classical puzzle. The crowding-in effect and crowding-out effect, two totally opposite arguments, are still waiting to be investigated. Rose-Ackermar (1981), Sugden (1982), and Segal and Weisbrod (1998) posited a theory suggesting private R&D funds increases with increases in public R&D funds, thereby creating a “Crowding-In Effect”. Conversely, Seong et al. (2008) posited that the public R&D funds would not necessarily result in the increase of private R&D funds. It might even result in the reduction of private R&D funds. This phenomenon is called as “Crowding-Out Effect”. Different from this zero-sum approach, Leyden and Link (1991) argued that the dynamics of public R&D funds and private R&D funds would present only in the condition that the infratechnology connection among the universities and the private sector is well forged. In this sense, the provision of public R&D funds like WCU Project could has no any impact on the private sector’s R&D investment.

To appropriately answer these two research questions, this study first investigates whether the injection of extra R&D funds resulted in either divergence or convergence on the growth of scientific production between WCU and Non-WCU universities. And then, this study investigates after the implementation of WCU Project, either crowding-in effect or crowding-out effect, or none of them appeared with respect to the relationship between the public R&D funds and the private R&D funds. These two analysis tasks are conducted based on the quantitative method.

The research findings derived from the quantitative analysis can present and confirm “what” has happened. Nevertheless, to understand “how” and “why” causes the observed changes, this study relies on the qualitative method to explore the answers and explanations.
In short, the purpose of this study could be summarized into the following two points:

1. **Policy Impact Analysis:**

   This study examines the policy effect of the WCU Project. This study focuses on two main aspects relevant to the research activities: the growth of scientific publications and the growth of private R&D funds, respectively. Meanwhile, this study also investigates the impact of the environmental change derived from the WCU Project on the behaviors of universities.

2. **Theoretical Verification and Building:**

   This study verifies the robustness of the competing theoretical arguments. In the aspect of the relationship between the implementation of WCU Project and the growth of the scientific production, did divergence or convergence appear? Furthermore, in the aspect of the relationship between public R&D funds and private R&D funds, did crowding-in effect or crowding-out effect exist in the context of the WCU Project? The mechanism resulting in the causality is explored.

### 1.4 Aims and Approaches

There are three specific aims in this study. The first is to examine the causality between the injection of extra R&D funds and the growth of scientific publications in WCU universities and Non-WCU universities. The second is to examine the causality between the injection of extra R&D funds and the change of private R&D funds. The last but not the least is to explore the mechanism resulting in the organizational behaviors if the causality in certain aspect is confirmed.

Descriptive statistics are used in the study to provide information on independent and dependent variables. The visualization of data helps to depict the longitudinal
trajectory over past decade. The results are analyzed by using inferential statistics on the variables. The study reveals the confirmed change that can be attributed to the policy intervention.

A panel dataset is constructed through merging multiple data resources. They include “the National Science and Technology Activities Survey”, “the Digest of Education Statistics”, and “Science Citation Index Dataset”. The first two datasets are administrative data collected annually by the Taiwan Ministry of Science and Technology (MOST) and Taiwan Ministry of Education (MOE). The final one is purchased from Thomson Reuters Company.

The variables in this constructed panel dataset include the amount of R&D funds of every university received in STEM fields (public R&D funds and private R&D funds), the scale of R&D research manpower in STEM fields (the amount of faculty) and the amount of published papers in STEM fields.

All of 145 Taiwan universities are included in this merged dataset. And the time coverage of data spans from 2001 to 2012. To ensure the comparability between two groups, 14 Non-WCU universities that their research performances comparable with 10 WCU universities are assigned to the group of Non-WCU universities.

A mixed methodology is used for the study. The quantitative data is used for policy effect analysis. Interviews are used for qualitative analysis. Qualitative interview techniques usually refer to in-depth forms of interviewing with the goal of exploring and elucidating specific questions by allowing the interaction between interviewee(s) and interviewer to shape the data collected (Mason, 2002). Conducting these interviews can enrich this study with additional critical viewpoints.

This study successfully interviews five senior administrators. They are from MOE, WCU and Non-WCU universities, respectively. They either served as the
policy maker in MOE or senior administrators in universities during the period of policy implementation. Their knowledges help this study to explore the factors driving the transformative change observed in quantitative analysis.

1.5 Significance of the Study

This study makes several contributions to the fields in the research policy and higher education policy, both at the theoretical and practical level.

First, the findings derived from this study indicates that the university’s behaviors are driven by the inter-institutional competition, and isomorphism around science productivity because of the implementation of WCU Project. This study provides concrete evidences, compensating the void in the current empirical studies regarding how universities, particularly for those directly exposed to the competitive pressure, strategically react to the open competition.

Second, this study finds no compelling evidence to show that receiving the WCU Project crowded in or crowded out the private R&D funds. There has no apparent change in the WCU universities with respect to the private R&D funds received after the policy intervention. In contrast, this study finds after the policy intervention, the group of Non-WCU universities had an apparent increase in their national share of private R&D funds. This implies that these Non-WCU universities were actively cutting into this market.

1.6 Structure of the Research

This study is structural into six chapters that contain a research overview, the global and local context, the theoretical framework, methodology, research findings and a conclusion. The following paragraphs describe the structure and contents of the study to orient readers to the themes and arguments in each of the chapters following this introduction.
Following on from this first chapter, chapter 2 focuses on the global and local context that facilitated the implementation of the WCU Project. It serves as the provision of background knowledge for readers to overview the contemporary context.

Chapter 3 presents the empirical findings regarding the relationship between public R&D funds, private R&D funds and the growth of scientific production. It critically discusses the theoretical frameworks that are used in the respective fields, which leads to a framework for the present study.

Chapter 4 presents the methodology and the research methods. In the quantitative analysis part, this chapter describes the procedure used to compile the group of WCU universities and the group of Non-WCU universities for the following quasi-experiment analysis. Then, the detailed information about the generation of independent variables and dependent variables is provided. Lastly, this study introduces the estimation equations proposed to capture the policy effect. In the qualitative analysis part, this chapter describes the background of interviewees, the technique for text data collection and analysis, and ethical consideration.

Chapter 5 presents and analyzes the quantitative data that are collected from 10 WCU universities and 14 Non-WCU universities. The hypotheses are tested at the end of this chapter. Three main themes derived from the in-depth interview explain why the observed change occurred.

Lastly, chapter 6 summarizes the major findings of this study, highlights the contributions that this study makes to the theory of how the introduction of the competition-based budgetary allocation affects the scientific production in university-setting, the policy implications for the policymakers.
1.7 Limitations of the Research

There have three research limitations facing this study. The first is the scope of policy effect. As shown in the policy statement, the improvement of scientific production in WCU universities is one of multiple goals in the WCU Project. In addition to the scientific production, the improvement of campus infrastructure and teaching quality are also the goals of this project. The policy effects accompanying with these efforts are not investigated in this study.

Second, the policy effect can be further classified as the short-term effect and the long-term effect. While the short-term effect often refers to the immediate reaction adopted by the institution; the long-term effect often reflects the structural change. In fact, both of the short-term effect and the long-term effect are meaningful for the policy effect analysis in certain particular aspects. Constrained by the data availability, the long-term effect could not be investigated in this study. Therefore, this study interprets the policy effect from the perspective of the short-term effect.

Third, almost during the same period, MOE announced several institutional-based projects aimed to increase the governmental appropriation on those Non-WCU universities. These additional funding resources could cause the contamination of the comparison group. This scenario is hard to avoid, particularly in the area of public policy (Seong et al., 2008). However, in this study, this concern could be minor. According to the survey data administered by MOST (2013) (shown in Figure 3 of Chapter 4), the governmental R&D funds (including all resources from governmental agencies) received by the group of Non-WCU universities almost have no change compared to the group of WCU universities. On the other hand, the status of “WCU University” is exclusively to the group of chosen universities. This special group is treated by MOE and other governmental agencies differentially. Even the
public media has been widely using this term to refer to this special group of universities. The differentiation of institutional reputation attached to the WCU universities and Non-WCU universities is very clear.

1.8 Chapter Summary

This study is aware of that in the field of research university policy there is a gap between the public policy and the policy evaluation. This gap generates uncertainty and limits the capacity of policy makers and researchers to answer how the research activities of universities would be affected. A self-constructed dataset merging from “National Science and Technology Activities Survey”, “the Digest of Education Statistics”, and “Science Citation Index Dataset” provides a unique advantage for this study to answer this fundamental question. The approaches and techniques implemented in this study could be a good reference for future policy researchers to consider while the similar policy evaluation task needs to be conducted.
Chapter 2: Global and Local Context

2.1 Introduction

This chapter aims to serve two purposes. The first is to provide readers a global contextual understanding. The driving forces behind the expansion of knowledge production and nation’s attempts to establish the World-Class University are carefully explored. The second is to provide a comprehensive review regarding the development of higher education in Taiwan, followed by the content and design of the WCU Project (Phase I). This arrangement aims to highlight the linkage among globalization, the nation’s reaction and the formation of a specific policy.

2.2 The Global Spread of University Excellence Initiative

Long historical trends in scientific discovery led mid-20th century scientometricians to mark the advent of big science—extensive science production (de Solla Price, 1986). They also predicted that over the next few decades, the exponential growth would slow, resulting in lower rates of increase in production at the upper limit of a logistic curve.

However, their prediction is incorrect. Zhang, Powell & Baker (2015)’s estimate of the number of worldwide science publications from 1900-2011 shows that “big science” was itself transformed by unprecedented production beginning just after mid-century, with no decline or slowing of exponential growth up to today. According to Zhang et al. (2015)’s analysis, the expansion of knowledge production was first powered by rebuilt European science system in the 1950s, then by expanded capacity in East Asia, especially in Japan (1970s-present), China (1980s-present) and South Korea (1980-present). And the driving forces behind the expansion of knowledge production were from the rising competition across nations and international collaboration among scientists.
Why should nations involve in the formation of science policy and invest resources on scientific capacity building? From the perspective of functionalists (Bernal, 1939), development, industrialization, and increased societal complexity are thought to create a functional need for scientific and technical advances, and also provide the resources required for science to flourish. In the lens of functionalists, the universities are seen as supporting institutions in its society, which provide a supply of educated people and form the organizational and normative structure necessary for science to grow and flourish within a society (Ben-David, 1971).

From the perspective of neo-institutionalists, the nation’s investment on scientific infrastructure is not only driven by the economic needs. Meyer (1987) argued that in today’s globalization society, the national societies are surrounded by and embedded in trans-national organizations, culture, and discourse, often referred to as “world society” or the “world polity”. Science, like education, is culturally valued among Western societies and taken for granted as an important social institution. What was formerly known as “Western science” is taken up by international organizations (e.g. UN, UNESCO, and World Bank) and aggressively promoted as a global model for organizing science everywhere.

The World Bank and development consultants began to advise nations to augment investment in science as a strategy to develop, while UNESCO and dozens of international scientific associations began sending out project workers to aid the creation of national science policy and infrastructures. UNESCO even began to offer plans for setting up national science policy and ministries, and sent consultants to hasten the process in many countries (Finnemore, 1991). In addition, numerous international non-governmental organizations pursued similar agendas (Schofer, 1999). In short, the neo-institutional perspective suggests that international
organizations played a central role in affecting the expansion of science around the world.

In what mechanism the formation of national policy was affected by the international pressure? Chabbott (1999) argued that western models of science-led development are cognitively dominant in the world. Supported by economists and other professional elites, the policy prescriptions emanating from the world polity are often accepted as truth—even in the absence of clear empirical evidence (Schofer et al., 2000). Policymakers and governments in developing nations do not have the resources to develop their own systems of policy research could provide alternate views.

The global spread of Universities Excellence Initiative starts since the late 20th century exemplifies the argument made by the neo-institutionalists. Baker (2014) pointed out that over past several decades, we are witnessing the rise and flourishing of what can be called the “super research university”, initially in the United States but increasingly as a model aspired to by many research universities throughout the world. In accordance with the survey conducted by this study (displayed in Figure 1 and Table 1), in nearly two decades from 1995 to 2013 twenty-three countries implemented some form of an university excellence initiative with the intent of transforming selected institutions into internationally recognized research-intensive universities. Such initiatives are appearing among Asian and European nations, where the most dramatic recent increases in the growth rate of global scientific production have occurred (Zhang et al., 2015).
Figure 1:

Global Spread of University Excellence Initiative, 1995 to 2013

![Map showing the spread of university excellence initiatives](image_url)

Source: Own survey based on the public governmental documents

Table 1:

<table>
<thead>
<tr>
<th>Country</th>
<th>Year</th>
<th>University Excellence Initiative</th>
</tr>
</thead>
<tbody>
<tr>
<td>China</td>
<td>1996</td>
<td>China 211 Project</td>
</tr>
<tr>
<td>Canada</td>
<td>1997</td>
<td>Canada Networks of Centers of Excellence</td>
</tr>
<tr>
<td>Chile</td>
<td>1999</td>
<td>Chile Millennium Science Initiative</td>
</tr>
<tr>
<td>South Korea</td>
<td>1999</td>
<td>Brain Korea 21 Program</td>
</tr>
<tr>
<td>Finland</td>
<td>2000</td>
<td>Program for Centers of Excellence in Research</td>
</tr>
<tr>
<td>Switzerland</td>
<td>2001</td>
<td>National Centers of Competence in Research</td>
</tr>
<tr>
<td>Japan</td>
<td>2002</td>
<td>Centers of Excellence for 21st-Century Plan</td>
</tr>
<tr>
<td>New Zealand</td>
<td>2002</td>
<td>The Centers of Research Excellence</td>
</tr>
<tr>
<td>Norway</td>
<td>2004</td>
<td>Norwegian Centers of Excellence</td>
</tr>
<tr>
<td>Sweden</td>
<td>2005</td>
<td>VINN Excellence Center</td>
</tr>
<tr>
<td>Country</td>
<td>Year</td>
<td>Initiative</td>
</tr>
<tr>
<td>------------</td>
<td>------</td>
<td>------------------------------------------------</td>
</tr>
<tr>
<td>Denmark</td>
<td>2006</td>
<td>Denmark Globalization Fund</td>
</tr>
<tr>
<td>Germany</td>
<td>2006</td>
<td>Germany Excellence Initiative 2006</td>
</tr>
<tr>
<td>South Africa</td>
<td>2006</td>
<td>South Africa Research Chair Initiative</td>
</tr>
<tr>
<td>Taiwan</td>
<td>2006</td>
<td>World-Class University</td>
</tr>
<tr>
<td>India</td>
<td>2007</td>
<td>University with Potential for Excellence</td>
</tr>
<tr>
<td>Russia</td>
<td>2007</td>
<td>Federal Universities</td>
</tr>
<tr>
<td>Singapore</td>
<td>2007</td>
<td>Research Centers of Excellence</td>
</tr>
<tr>
<td>France</td>
<td>2008</td>
<td>Operation Campus</td>
</tr>
<tr>
<td>Malaysia</td>
<td>2009</td>
<td>Accelerated Program for Excellence</td>
</tr>
<tr>
<td>Spain</td>
<td>2009</td>
<td>International Campus of Excellence</td>
</tr>
<tr>
<td>Thailand</td>
<td>2009</td>
<td>Thailand National Research University Initiative</td>
</tr>
<tr>
<td>Australia</td>
<td>2011</td>
<td>ARC Centers of Excellence</td>
</tr>
<tr>
<td>Poland</td>
<td>2012</td>
<td>KNOWs (elite research university)</td>
</tr>
</tbody>
</table>

Source: Own survey based on the public governmental documents

Why the “University Excellence Initiative” became a globally implemented policy? And, why, not only developed countries, the developing countries also involved in this global movement? There is no doubt that the transformation of knowledge-based economy created a policy window for the policymakers to consider how to remain their global competitiveness. However, as for the driving force behind the convergence of participant countries’ behaviors, the popularity of university ranking system played a decisive role. Deem et al. (2008) and Salmi (2009) studied Europe and Asia countries and concluded that the intensified competition among universities to prove their performance through global university league tables or
ranking exercise could be hold accountable for the spread of university excellence initiative.

The impact of university ranking on the formation of “University Excellence Initiative” in local context is profoundly. On the one hand, university ranking and league tables, including the various measures of quality, are becoming highly influential in shaping how contemporary universities are governed and what core activities are undertaken (Altbach & Balan, 2007; Deem et al., 2008). On the other hand, the universities positioned on the top of hierarchy are perceptive of the institutions with best quality and most successful operation. The practices, operations and the governance structure within these leading universities are embraced as world standard and frequently referred for benchmarking exercises.

Abundant of scholarship works were dedicated on the study of the features of these world leading universities (Altbach & Balan, 2007; Mohrman et al., 2008). Salmi (2009) summarized three key elements that are crucial for the establishment of world-class university. They are concentration of talent, abundant resources and appropriate governance. More or less, the participant countries adopted these concepts by integrating these elements into their “University Excellence Initiative”.

2.3 Transition of Higher Education in Taiwan

2.3.1 Brief History of Higher Education Development

Taiwanese higher education began in 1928 when the first university, Imperial Taipei University, was established by the Japanese colonial government (Chang, 2001). As with other Japanese universities of the time, Taiwanese higher education took Germany higher education as its model. The central, colonial government took full responsibility for the administrative control of higher education, and the system was constructed with public institutions as central. Public higher education
institutions were one part of this administrative structure and were completely dependent on the government for funding.

Soon after the end of Second World War, Taiwanese higher education faced its first model transition. In 1945, the Republic of China (Taiwan) reclaimed its sovereignty over Taiwan. Because of the political alliance between the Republic of China (Taiwan) and the United States during the Second World War, followed by the Cold War, the American model of higher education was an important reference for reconstruction of the Taiwanese higher education system (Xu, 2002).

The complexity of this system results from taking an idealized Germany system as a model, while at the same time having points of affinity with the American system. The result is a system of prestigious public universities that rely heavily on the central government for funding and which are, to great extent, insensitive to market forces as well as a very large private university sector.

In the subsections that follow, this study provides a brief historical review of Taiwanese higher education after the Second World War. This study shows that similar to the path taken by most advanced countries during the 20th century, Taiwan experienced a systemic transition from elite to mass to universal higher education (see Table 2; see also Trow 2007).

1945-1960: The Transition from the Germany to American Model. During the fifteen-year period that followed the end of the Second World War, Taiwanese higher education transitioned from a Germany to an American model. Affected by the transition away from Japanese governance, the higher education system that was implemented by the colonial government was either abandoned or modified (Ou, 2006; Xu, 2002; Chang, 2001). The practices implemented in contemporary American universities were transferred to Taiwanese universities. For example, the chair-based
system for appointing university faculty was abandoned. Instead, the department system was introduced to construct the basic unit of university operations. Furthermore, the credit system was used to organize students’ course-taking activities. New degree systems, comprised of bachelor, master, and doctoral programs, and the duration of study for completing these degrees was modeled on American universities (Ou, 2006).

Except for the reforms related to the degree system, the governance of higher education mostly remained unchanged and continued to follow the Germany model. The new national government strictly controlled the operation of universities through government appropriations, administrative regulation, and appointing university leaders (Dong, 1997).

On the other hand, higher education continued to expand in Taiwan. A group of universities which were established in China were moved to Taiwan after 1949. Additionally, the number of private universities increased, and the higher education system was able to accommodate more students. In 1955, about 10 years after the end of the Second World War, Taiwan higher education was composed of six public and four private higher education institutions (MOE, 2016). During this early stage, the gross enrollment rate (GER) at tertiary education level was below 10%. Based on Trow’s (1973) structural–historical theory, Taiwan was at the stage of elite higher education.

1960-1985: Higher Education Expands to Fill the Need for Skilled Labor.
The period between 1960 and 1985, can be best described as a period of expansion of tertiary education, which was spurred by the social demands for a skilled workforce (Chen, 1999). During this period, Taiwan’s economy was transforming into an industry-based society. The demands for well-educated and skilled workers were
driven by the growing economic development and accelerated the expansion of postsecondary education. Most of the expansion took place through the establishment of new junior colleges. These newly established junior colleges provided vocational training courses and prepared the graduates with skills that were demanded by the labor market (Wu & Jian, 2008). This wave of expansion not only expanded the capacity of postsecondary education, it also resulted in the formation of a binary system of tertiary education.

During this period, the academic-oriented track of tertiary education was comprised of 28 universities and colleges. On the other hand, the 77 junior colleges constructed a vocationally-oriented track. Even though the whole system remained at the stage of elite education (Trow, 1973), the tertiary education system accommodated 21% of youth of school age, approaching the threshold of mass education.

1985-1995: Transitioning from Elite to Mass Higher Education. In many countries, the pace of growth of higher education accelerated in the second half of the 1980s; Taiwan was no exception, and followed this trend. Entering the 1990s, Taiwanese higher education started rapidly moving toward mass higher education. Two driving forces facilitated this transition. First, encouraged by political democratization and rising average family incomes, the public urged the government to increase the accessibility of higher education. The Taiwanese public tended to believe that the higher education should be a general right with guaranteed access, rather than a privilege of the few. Second, the transformation of the economy toward a post-industrial structure went hand-in-hand with the education sector providing more professionals, not just technicians (Chen, 1999; Wu & Jian, 2008).
However, the rapid expansion of tertiary education quickly met its financial and structural limits. In a country such as Taiwan, where the national government controls higher education, the costs of creating and maintaining new campuses inevitably increased at a rapid pace. Thus, the solution was to foster structural diversification of the higher education system. The diversification of higher education was achieved through two ways. The first was through upgrading the junior colleges; in this way, new universities, mostly are technological and vocational universities, could be established at relatively low cost and the time-lag between setting up institutions and students actually entering the labor market could be reduced (Goedegebuure, 1992). The second was through the establishment of private universities that effectively share the costs with the national government needed to invest in system expansion and increased access.

The expansion during this period was indeed dramatic. In 1995, the number of postsecondary education institutions increased to 134. Among them, the number of universities and colleges that conferred bachelor’s degrees increased to 60. The whole system accommodated 39% of school-aged youth and entered the stage of mass higher education (MOE, 2016).

1995-2005: A Transition from Mass Education to Universal Education. Between 1995 and 2005, higher education expansion in Taiwan occurred simultaneously with the budget cuts in public funding for higher education and the resurgence of neo-liberal and market-oriented policies (Tai, 2000). Through a series of governance reforms, the national government reduced its controlling grip on universities and granted them greater institutional autonomy. The most remarkable change came from reforms related to financial autonomy. The public universities, in particular, used to heavily rely on state appropriation were led to diversify their
financial resources mainly through engagement in commercial activities (for example, licensing the university-based technology and incubating the spin-off companies). The concept of the “entrepreneurial university” (Slaughter & Rhoades, 2004) became very fashionable during this period (Chang, 2006).

Between 1995 and 2005, the pace of higher education expansion was even more rapid than during previous decades. Within less than 10 years, the gross enrollment rate increased from less than 39% to approximately 82% or what Trow (2007) referred to as “universal” higher education. This expansion was accomplished mainly through of the upgrading of private junior colleges. During this period, almost all of the junior colleges that were established during the 1980s were transformed to full-fledged technological universities. These new technological universities were granted with the privilege to issue the bachelor degree and provide college-level courses. Some of them were even granted with the privilege to provide master and doctoral level education. By 2005, the Taiwanese system of higher education was comprised of 147 universities and colleges, while the number of junior colleges declined to 17.

The transition to universal higher education caused much chaos for the operation of Taiwanese higher education. Without a well-established coordination system, old and new universities were competing with each other for student resources, research funding, and any possible resources that could sustain them. The line between old universities and newly upgraded universities—in terms of course offering and mission of the schools—was blurred. As a result, the binary system that was created during the 1960s became less and less recognizable, leading to the blurred boundaries between types of HEI seen elsewhere.
2005-Present: Taiwan and the Emerging Global Model. Two driving forces were reshaping the landscape of higher education as Taiwan achieved universal tertiary enrollments. The first was a demand within the country for increased differentiation of the higher education system. The second came from the competitive pressures that accompanied the popularity of the World Class University ranking system (Tai, 2006; Song & Tai, 2007).

The combination of the two driving forces led the national government to adopt (for the first time) an institutionally-based competition to determine the allocation of state appropriations. The World Class University Project of 2006 was created to invest special funding for 10 years in a small group of research-intensive universities and to enhance their research capacity to compete globally. The Teaching Excellence Project of 2006 was another special funding project aimed to forge a group of teaching-oriented universities. In Taiwan’s context, the universities that participated in the World Class University Project were classified as “Research Universities.” On the other hand, the universities which received the funding from the Teaching Excellence Project were classified as “Teaching Universities.” It is unavoidable that these two institutional-based funding projects created a new way of conferring prestige or status that is accelerating competition among universities.

See Table 2 for a descriptive breakdown of the ways that Taiwan transitioned from elite to mass to universal higher education by creating HEIs and increasing student enrollments.
Table 2:

Number of Higher Education Institutes in Taiwan, 1950-2013

<table>
<thead>
<tr>
<th>Year</th>
<th>University Public</th>
<th>University Private</th>
<th>Independent College Public</th>
<th>Independent College Private</th>
<th>Junior College &amp; Teacher’s college Public</th>
<th>Junior College &amp; Teacher’s college Private</th>
<th>Tertiary Education</th>
<th>GER</th>
<th>NER</th>
</tr>
</thead>
<tbody>
<tr>
<td>1950</td>
<td>1</td>
<td>0</td>
<td>3</td>
<td>0</td>
<td>3</td>
<td>1</td>
<td>N/A</td>
<td></td>
<td>N/A</td>
</tr>
<tr>
<td>1955</td>
<td>3</td>
<td>1</td>
<td>3</td>
<td>3</td>
<td>4</td>
<td>1</td>
<td>N/A</td>
<td></td>
<td>N/A</td>
</tr>
<tr>
<td>1960</td>
<td>6</td>
<td>1</td>
<td>2</td>
<td>6</td>
<td>6</td>
<td>6</td>
<td>N/A</td>
<td></td>
<td>N/A</td>
</tr>
<tr>
<td>1965</td>
<td>8</td>
<td>2</td>
<td>1</td>
<td>10</td>
<td>15</td>
<td>20</td>
<td>N/A</td>
<td></td>
<td>N/A</td>
</tr>
<tr>
<td>1970</td>
<td>6</td>
<td>3</td>
<td>4</td>
<td>9</td>
<td>20</td>
<td>50</td>
<td>N/A</td>
<td></td>
<td>N/A</td>
</tr>
<tr>
<td>1975</td>
<td>6</td>
<td>3</td>
<td>7</td>
<td>9</td>
<td>20</td>
<td>56</td>
<td>15%</td>
<td>10%</td>
<td></td>
</tr>
<tr>
<td>1980</td>
<td>9</td>
<td>7</td>
<td>5</td>
<td>6</td>
<td>21</td>
<td>56</td>
<td>16%</td>
<td>11%</td>
<td></td>
</tr>
<tr>
<td>1985</td>
<td>9</td>
<td>7</td>
<td>6</td>
<td>6</td>
<td>21</td>
<td>56</td>
<td>21%</td>
<td>14%</td>
<td></td>
</tr>
<tr>
<td>1990</td>
<td>13</td>
<td>8</td>
<td>13</td>
<td>12</td>
<td>13</td>
<td>62</td>
<td>30%</td>
<td>19%</td>
<td></td>
</tr>
<tr>
<td>1995</td>
<td>16</td>
<td>8</td>
<td>18</td>
<td>18</td>
<td>16</td>
<td>58</td>
<td>39%</td>
<td>28%</td>
<td></td>
</tr>
<tr>
<td>2000</td>
<td>25</td>
<td>28</td>
<td>24</td>
<td>50</td>
<td>4</td>
<td>19</td>
<td>56%</td>
<td>39%</td>
<td></td>
</tr>
<tr>
<td>2005</td>
<td>41</td>
<td>48</td>
<td>10</td>
<td>46</td>
<td>3</td>
<td>14</td>
<td>82%</td>
<td>57%</td>
<td></td>
</tr>
<tr>
<td>2010</td>
<td>45</td>
<td>67</td>
<td>6</td>
<td>30</td>
<td>3</td>
<td>12</td>
<td>84%</td>
<td>67%</td>
<td></td>
</tr>
<tr>
<td>2013</td>
<td>47</td>
<td>75</td>
<td>3</td>
<td>22</td>
<td>2</td>
<td>12</td>
<td>84%</td>
<td>70%</td>
<td></td>
</tr>
</tbody>
</table>

Source: MOE (2016)

2.3.2 Governance Structure

Taiwan higher education is a centralized, mainly publicly-funded system. Ministry of Education influences the operation of universities through the legislation and the provision of funding. Before the education reform movement in the 1990s, the
public universities were strictly asked to follow the regulations and practices implemented in government agencies. In accordance with the legal framework, the public universities were treated as the branch of the central government. The faculty and staff working in the public universities were seen as public servants. Meanwhile, the public universities did not have an independent budgetary system. The budgetary systems of public universities were affiliated to the MOE.

For private universities, even if their personnel and financial operation were independent and not affiliated to MOE, their institutional autonomy was, to a large degree, constrained by this centralized system. This centralized system regulated the tuition level, the qualification of faculty and the cap of enrollment sizes. Besides, a national college entrance examination system coordinated the selection and placement of college students. This college entrance examination system deprived public and private universities’ privilege to select their prospective students. Universities could only passively enroll the students assigned through this national placement system.

This strictly centralized control system began loosening since the education reform in the 1990s. The education reform in the 1990s was the fruit of a series of political democratization. And, its impact spread over to K-12 education, teacher education, and higher education. Affected by the political democratization, the reform of institutional autonomy became the major issue in higher education field. The passage of University Act of 1994 positively responded to the demand of academic freedom and institutional autonomy. Regulations and administration practices were changed to redefine the governance relationship between universities and the central government. During the transition phase of shifting from old governance model to new one, some of the practices widely used in American higher education were transplanted.
First, in academic autonomy, the University Act of 1994 protected the academic freedom of university from the intervention of government. Since then, MOE was prohibited from interfering the courses arrangement at campus. Meanwhile, universities increased their autonomy on decision of opening or terminating academic programs. In addition, the organizational structure could be adjusted to accommodate the special tasks in universities. For example, the office of international cooperation was established to serve the international education. The office of technology transfer was created to promote the commercialization of research.

The second reform action focused on personnel autonomy. The reform changed the selection of the leadership in public universities from external political appointment to internal election. The presidents of public universities were no longer the appointed agents on behalf of government, but a general manager directly responsible for the accountability of universities. In addition, the hiring conditions of faculty and staff also changed. The University Act of 2000 granted public and private universities the authority to assess faculty’s performance periodically. If faculty failed the requirement criteria or did not receive the promotion within given years, the universities could lay off faculty. These practices eliminated the job security of faculty position and introduced the performance-based assessment into the academic working environment. As for the administration staff, the contract-based staffs replaced the public servants as the majority of administration staff. Very recently, some professional manager positions started being created to operate certain highly professional tasks. These new professional positions include the technology transfer manager in the office of technology transfer office and the institutional researcher in the office of institutional research.
The third reform action related to institutional autonomy was financial autonomy. The introduction of “School Fund System” granted the public universities the financial autonomy. School Fund System was designed to eliminate the rigorous financial and accounting system in public universities. The designated incentives mechanism embedded in the School Fund System was also expected to facilitate the revenues diversification in public universities.

School Fund System divided the financial revenue resources of public universities into two main categories under two parallel accounting systems. The one revenue resource was state appropriation; while the other was the self-earned revenues. The state appropriation was subsidized by MOE in the form of lump-sum grant budget. The amount of state appropriation was calculated based on a formula considering the number of students and staffs. As for self-earned revenue, the revenue came from the collection of tuition and fees as well as public universities’ involvement on contract research, outreach education, fundraising activities and commercialization of research finding, etc. The amount of state appropriation could barely cover the basic personnel and operation cost. If public universities want to conduct other aggressive strategical plan, they might need to rely on the self-earned revenue or special extra funding (i.e. the World Class University Project or the Teaching Excellence Project).

The last reform action was the corporatization of public universities. In 2004, influenced by the idea of neo-liberalism management, MOE attempted to push the policy of the corporatization of public universities. The corporatization of public universities aimed to transfer the public universities to autonomous entities and had public universities essentially and legally independent from the government system. However, the policy was pushed back due to the resistance at public universities.
Academics from the public universities feared that having a board of trustees own the superior authority over the university operation would hurt the academic freedom. They also concerned that this reform would lead to the privatization of public universities. Until now, the governance relationship between the public universities and the government is still entanglement.

2.3.3 Research Funding System

Taiwan’s national innovation system is constructed with three main performing sectors, which are the university sector, the industry and private sector and the public research institution sector. Among the three performing sectors, the industry and private sector takes the lead in terms of R&D expenditure. As showed in table 3, in 2010, the expenditure of industry and private sector spent on R&D is nearly 303 billion NTD, accounting for 73.1% of national R&D expenditure. According to the distribution of expenditure spent on three research activities, the industry and private sector strongly favors experimental development. It spends 79.7% of R&D expenditure on experimental development, while 0.4% on basic research and 19.8% on applied research (MOST, 2010).

Among three performing sectors, the scale of R&D expenditure spent by the university sector is relative small. In 2010, it only accounts for 11.8% of national R&D expenditure. The university sector mainly commits on basic research and applied research: 48% of R&D expenditure on basic research and 38.9% on applied research.
Table 3:
Taiwan’s R&D Expenditure on Research Activities, 2010 (in millions of NTD)

<table>
<thead>
<tr>
<th>Activities</th>
<th>University</th>
<th>Industry &amp; Private Sector</th>
<th>Public Research Institutions</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Amount</td>
<td>Share</td>
<td>Amount</td>
</tr>
<tr>
<td>Basic Research</td>
<td>23,868</td>
<td>48.7%</td>
<td>1,212</td>
</tr>
<tr>
<td>Applied Research</td>
<td>19,030</td>
<td>38.9%</td>
<td>59,972</td>
</tr>
<tr>
<td>Experimental Development</td>
<td>6,080</td>
<td>12.4%</td>
<td>241,401</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>48,978</strong></td>
<td></td>
<td><strong>302,887</strong></td>
</tr>
</tbody>
</table>

Source: MOST (2010)

The governmental funds are the primary source supporting the university-based research. As showed in Table 4, in 2010, the governmental funds accounts for 91.7% of R&D funds in the university sector; while the funds from the industry and private sector only accounts for 8.1%. The structure of R&D funds in the university sector implies that the university-based research is highly dependent on the governmental investment.
Among the government agencies supporting the university-based research, Ministry of Science and Technology is the leading contributor. Ministry of Science and Technology allocates the research funding through the project-based competition. Except for the special research funding projects with particular policy goals, the majority of funding projects are designed to provide faculty financial supports to conduct research works based on faculty’s personal research interests. Based on the scale of the research project, the faculty’s funding project can be divided into two main categories, which are the individual project and the integrated project, respectively. Under the funding scheme of the individual project, only one principal investigator could receive funds. Under the funding scheme of the integrated project, one leading principal investigator and several co-principal investigators work together, and each of listed participants shares the funds.

Every year, university-based researchers submit their research proposals. The results based on the peer review process would decide which proposals should be granted. This peer review process is used to guarantee the quality of granted proposal.
As showed in table 5, in 2010, the department of life science receives 2,253 applicants and approves 42.1% of cases; the department of nature science receives 1,602 applicants and approves 60.2% of cases; the department of engineering and technology receives 5,695 applicants and approves 50.2% of cases; the department of humanities and social science receives 3,863 applicants and approves 40.5% of cases (MOST, 2010).

Table 5:

<table>
<thead>
<tr>
<th>Department</th>
<th>Approval Case</th>
<th>Approval Rate</th>
<th>Funding Amount</th>
</tr>
</thead>
<tbody>
<tr>
<td>Life Science</td>
<td>2,253</td>
<td>42.1%</td>
<td>3,267</td>
</tr>
<tr>
<td>Nature Science</td>
<td>1,602</td>
<td>60.2%</td>
<td>2,802</td>
</tr>
<tr>
<td>Engineering and Technologies</td>
<td>5,695</td>
<td>50.2%</td>
<td>4,912</td>
</tr>
<tr>
<td>Humanities and Social Science</td>
<td>3,863</td>
<td>40.5%</td>
<td>1,888</td>
</tr>
</tbody>
</table>

Source: MOST (2010)

The distribution of MOST’s project-based research funding is highly concentrated. As showed in table 6, in 2010, 46.8% of funding is granted to the largest five recipient universities. They are National Taiwan University, National Cheng Kung University, National Chiao Tung University, National Tsing Hua University and National Central University. The remaining 53.2% is shared by the rest of 140 universities (MOST, 2010).
Table 6:
The Leading Universities Receiving Funding from MOST, 2010 (in millions of NTD)

<table>
<thead>
<tr>
<th>University</th>
<th>Amount</th>
<th>National Share</th>
</tr>
</thead>
<tbody>
<tr>
<td>National Taiwan University</td>
<td>2,233.21</td>
<td>18.7%</td>
</tr>
<tr>
<td>National Cheng Kung University</td>
<td>1,080.64</td>
<td>9.0%</td>
</tr>
<tr>
<td>National Chiao Tung University</td>
<td>791.17</td>
<td>6.6%</td>
</tr>
<tr>
<td>National Tsing Hua University</td>
<td>716.46</td>
<td>6.0%</td>
</tr>
<tr>
<td>National Central University</td>
<td>658.62</td>
<td>5.5%</td>
</tr>
<tr>
<td><strong>Top Five Total</strong></td>
<td><strong>5,480.10</strong></td>
<td><strong>46.8%</strong></td>
</tr>
<tr>
<td><strong>National Total</strong></td>
<td><strong>11,931.12</strong></td>
<td></td>
</tr>
</tbody>
</table>

Source: MOST (2010)

For the majority of universities, the funding from MOST is the main resource to support research activities. This is because the state appropriation from MOE is mainly used to cover the basic operation cost and staff salary. The funding from MOST can provide faculty an extra funding to recruit research assistants, purchase supplies, and conduct research. However, MOST’s project-based research funding has several weaknesses embedded in its funding scheme. These weaknesses indirectly facilitate the birth of the WCU Project.

First, for most of the projects subsidized by MOST, the amount of received funding is quite limited. This limited amount of funding received by these projects could barely afford the advanced laboratory equipment and supplies as well as the experienced post-doctorate researchers. As a result, the principle investigators are hard to target the research topics that could lead to the breakthrough discovery but demand the long-term financial commitment. Second, the competition among the
peers discourages the formation of the research center in the university. Since the scale of the project-based funding is small, there almost have no space to forge research consortium with multiple experienced researchers involved.

2.4 The World Class University Project (Phase I)

2.4.1 Competition Mechanism

Award selection of the WCU Project is based on the quality of the strategic plan submitted by applicant universities and their accumulated academic performances in the past. The selection process was divided into two parallel phases. First, two special task forces independently reviewed the strategic plan and the academic performance report. Finally, the summit committee made the final decision after comprehensively considering the recommendation reports from two special task forces.

For the quality of the strategic plan, the applicant universities were required to describe how they would use these funds to improve the quality of teaching and research, increase the academic reputation in global society, and strengthen the university-industry linkage. A special task group comprised of the presidents of foreign universities, leading scholars, industry leaders and senior governmental officials was in charge of reviewing these strategic plans.

As for the academic performance, three groups of indicators were used to assess the applicants’ research capacity. The first group is the teacher’s quality. The indicators in this group include the amount of faculty receiving the international academic award, the amount of faculty serving in the international leading research institute, and the amount of faculty serving in the international academic community. The second group is the academic publication. The indicators in this group include a number of papers published in the international journal, the amount of paper citation, and the amount of academic book published. The third group is the extent of the
university-industry linkage. The indicators in this group include the amount of private R&D investment on university-based research, the royalty revenue from licensing patents, and a number of patents received approval.

In addition to these quantized indicators, a group of leading scholars with global reputation was invited to provide review opinions for each applicant university. Their professional opinions were submitted to the decision committee with other review reports. Finally, the summit committee made a recommendation report and submitted this report to the Minister of Education for the approval. This recommendation report contained the candidate universities qualified for the funding and the allocation of funding among these qualified universities.

Initially, the WCU Project’s strategy was to concentrate support on one or two universities. Eventually, MOE decided to choose 11 universities from the 32 applicant universities and provide them with this university-wide funding. The top five recipients of the WCU Project funds were National Taiwan University, National Cheng Kung University, National Tsing Hua University, National Chiao Tung University and National Central University. Displayed in Table 7, the funds allocated to these five universities totally accounted for 75% of the WCU Project. In these leading WCU universities, the WCU Project accounted for about 15% to 23% of their annual operation budget. Once universities were granted, the funds would last five years from 2006 to 2010.
Table 7:
The WCU Project Funds on Top Five Leading Universities, 2010 (in millions of NTD)

<table>
<thead>
<tr>
<th>University</th>
<th>WCU Project</th>
<th>Total Budget</th>
<th>Share</th>
</tr>
</thead>
<tbody>
<tr>
<td>National Taiwan University</td>
<td>3,000</td>
<td>16,389</td>
<td>18%</td>
</tr>
<tr>
<td>National Cheng Kung University</td>
<td>1,700</td>
<td>7,989</td>
<td>21%</td>
</tr>
<tr>
<td>National Chiao Tung University</td>
<td>1,200</td>
<td>5,218</td>
<td>23%</td>
</tr>
<tr>
<td>National Tsing Hua University</td>
<td>900</td>
<td>5,646</td>
<td>16%</td>
</tr>
<tr>
<td>National Central University</td>
<td>700</td>
<td>4,629</td>
<td>15%</td>
</tr>
<tr>
<td><strong>Top Five Total</strong></td>
<td><strong>7,500</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>National Total</strong></td>
<td><strong>10,000</strong></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>


2.4.2 The Goals of the WCU Project

The WCU Project was a university-wide project, not a department-based or individual-based project. Once granted, the presidents of WCU universities had the superior power to decide the allocation of funding internally. Generally, these funds were used to improve the campus infrastructure, procure the advanced laboratory equipment and supplies, establish research centers, invest large-scale research projects, recruit distinguished scholars and offer the financial reward for the faculty’s research achievements.

Every year, these funds were allocated in the form of a block funding from MOE to WCU universities. This special design of appropriation aimed to increase the financial autonomy of WCU universities as much as possible. Meanwhile, as Ross (1973) described in the principal-agent dilemma, MOE was afraid of the abuse of the WCU Project funds by these selected WCU universities. Therefore, the WCU Project
developed a particular accountability system to ensure the progress of these WCU universities.

The WCU Project was aimed to transfer elite universities into world-class research universities. Affected by the popularity of global ranking, the accountability system of the WCU Project was in aligning with the indicators used in the ranking system and weighted the research performance. The goals of the WCU Project are listed as following (MOE, 2005):

1. Transfer universities into World Class Universities
2. Establish leading research center
3. Increase the research impact and research capacity
4. Recruit distinguished scholars and nurture creative researchers for the future
5. Facilitate the international cooperation and university-industry collaboration

To monitor the progress, a set of quantitative performance indicators were used for performance assessment. They were listed as below (MOE, 2005):

1. The number of faculty receiving international academic awards
2. The number of faculty serving as international journal editors
3. The number of papers published in international journal
4. The amount of paper citation
5. The amount of patents
6. The amount of industrial R&D investment

As mentioned above, the selection of performance indicators was affected by the global ranking system (i.e. Academic Ranking of World Class University, QS World University Ranking). This was because the World Class University is an abstract concept, and there had no clear criterion to judge whether these selected universities have reached the status of “World Class Universities”. As a result, the performance
indicators developed by the existing ranking institutes were quickly adopted to fill this vacancy. The weaknesses of these ranking systems were apparently. They overvalued the research performance and neglected the teaching and other mission of higher education. Shewan & Coats (2012) argued that the fanaticism of believing in ranking has led to misconduct and dishonesty in higher education. But, prior to 2005 when the WCU Project was in discussion, these phenomena did not emerge and did not catch too much attention.

2.4.3 Incentive Mechanism

The incentives created by the WCU Project were served to motivate and change the behaviors of universities and faculty working in this environment. For WCU universities, there were at least two incentives derived from the Project WCU. The first was a fiscal incentive. The WCU Project provided a remarkable funding resource to support these universities’ operation. And, because the WCU Project was an extra funding in addition to the annual state appropriation, with this extra resource these WCU universities could initiate the projects that previously were not able to realize.

For faculty working in these WCU universities, the fiscal incentive was very attractive. The WCU Project provided sizable and stable funding for WCU universities to support research. The scale of each award for an individual group was much larger than that of other project-based research funding from MOST. In addition, every WCU University began to develop a new reward system to motivate the growth of personal research achievements. These rewards include the salaries and the promotion. It ended up that the faculty who has outstanding performance in research would enjoy more resources and higher recognition.

The second incentive was institutional reputation. The universities had to win the competition for being selected as WCU universities, as a result, the WCU Project
turned itself as a signal system. Once universities won the title of “WCU universities”, their capacity in research and quality in teaching were assumed by the public to be superior to the rest of universities. Such signal effect created varied benefits for WCU universities such as, fundraising, establishing student exchange program, and recruiting talented students and new faculty. It is noteworthy that the institutional reputation not only had an impact on the selected WCU universities. For the rest of non-selected universities, because of its nature of the winner-take-all, the reputational incentives also drive them to accommodate this emergence of differentiation of the institutional status.

2.5 Chapter Summary and Reflection

In this chapter, this study summarizes the global and local context giving the birth to the WCU Project. This study argues that the birth of the WCU Project is attributed to several driving forces. From the perspective of science policy, the WCU Project was created to complement the weakness of existing research funding system; while in the higher education policy, the WCU Project was aimed to facilitate the classification of higher education. The design and content of the WCU Project integrated many contemporary thoughts. These included the use of performance-based budget allocation and the appreciation of the value of research universities on economic growth. More profoundly, argued by this study, MOE was shifting its funding principle from the approach of even distribution to the institutional-based competition. What the impacts brought by the introduction of the competition in the higher education is at the center of the investigation conducted by this study.
Chapter 3: Theoretical Framework

3.1 Introduction

This chapter is aimed to summarize the main theoretical arguments that are relevant to the research questions investigated by this study. In this chapter, this study proposes an alternative approach opposite to the traditional lens that the injection of the additional R&D funds can increase the scientific production of those chosen universities. This argument is based on the organization theory proposing that the competitive pressure derived from the funding competition like the WCU Project can stimulate the behavior changes in those universities exposed to the competitive environment. This study also introduces three hypotheses used to predict how the injection of public R&D funds would affect the private R&D funds.

3.2 The Effect of the Injection of Extra R&D funds on Scientific Production

3.2.1 Divergence or Convergence

Divergence. There have two competing approaches with respect to how the injection of additional R&D funds like “University Excellence Initiative” would affect the growth of scientific production. The first approach, most popular as well, assumes that the injection of extra R&D funds can bolster the growth of scientific production in those chosen universities, making them grow faster than their other domestic counterparts. This assumption is based on the empirical studies indicating the association between the availability of R&D funds and the scientific production.

Since 1970, the determinants of research productivity in universities have been the interest of empirical studies in the research policy area. Among the various predictors of research productivity, R&D funds, and faculty size are carefully
investigated (Shin, 2009). The first and perhaps foremost determinant in the production equation is the availability of R&D funds.

Wood (1990) pointed out that for scientists engaged in theoretical work, R&D funds may not be considered to be of major importance as long as computer facilitates are readily available. However, for the majority in STEM departments, the availability, amount, and continuation of R&D funds are very important in facilitating research. R&D funds could be used to recruit additional scientists, to support PhD students, to maintain the operation of laboratories and to procure equipment and supplies. These components are essential to conducting the research activities.

The importance of R&D funds for the establishment of World Class University is also well documented in Salmi (2009)’s report. He argued that the definition of world class universities can essentially be attributed to three complementary sets of factors at play in top universities: (1) a high concentration of talents, (2) abundant resources to offer a rich learning environment and to conduct advanced research, and (3) favorable governance features that encourage strategic vision, innovation, and flexibility that enable institutions to make decisions and to manage resources without being encumbered by bureaucracy.

The realization of first two factors is heavily reliant on the availability of R&D funds. In today’s globalization of science, the competition between the brain drain and the brain gain is raising another round of arms race among countries. The provision of scholarship for talent students and well package of compensations for “Star” scientists have been widely used by universities as strategic actions to build up their research capacity. Plus, in the era of big science, the cutting-edge research demands an investment of high-end laboratory equipment that sometimes the cost is far from affordable by any individual university (Rosenzweig & Turlington, 1982).
The importance of R&D funds for the establishment of World Class University is also well documented in Salmi (2009)’s report. He argued that the definition of world class universities can essentially be attributed to three complementary sets of factors at play in top universities: (1) a high concentration of talents, (2) abundant resources to offer a rich learning environment and to conduct advanced research, and (3) favorable governance features that encourage strategic vision, innovation, and flexibility that enable institutions to make decisions and to manage resources without being encumbered by bureaucracy.

These realities in global competition justify the efforts of policymakers to break the rule of even distribution and concentrate extra R&D funds on a small group of universities with the potential to be excellent. The empirical studies provide shreds of evidence to support this argument. In the late 20th century, China and South Korea were two Asia countries taking a lead on the investment of World Class University through their “University Excellence Initiative”. The policy effects in these two countries were carefully investigated by empirical studies.

Seong et al. (2008) studied the policy impact of BK21 in South Korea on scientific production of chosen universities. They used the absolute number of publications as the outcome variable, concluding that the BK21 had resulted in the growth of scientific publications of South Korean research universities. The chosen universities grew faster than those unchosen universities. Shin (2009)’s study also reached the same conclusion and found the BK21 had an impact on the chosen universities, making these universities grew faster after the policy intervention.

In China, the same conclusion is reached as well. Zhang et al. (2013) studied the policy effect derived from the 985 Project on the growth of scientific publications of Chinese research universities. They used the natural logarithm of the number of
publications in their estimation equations as outcome variables, concluding that a significant growth of scientific publications in 985 universities can be attributed to the policy intervention.

**Convergence.** Whether the growth of scientific publications in the chosen universities would necessarily go faster than their non-chosen counterparts? Integrated insights from the organization theory, this study proposes an alternative approach opposite to the approach proposing the presence of divergence. This study posits that the non-chosen universities, particularly for those in the edge to admission, could increase their scientific publications even rapidly than their chosen counterparts. This argument is based on the organizational theories and the findings derived from the empirical studies introduced below.

From the theoretical perspective, Bowen (1980) pointed out that universities tend to spend all of the resources they raise in pursuit of the excellence, prestige, and influence. James (1990) also claimed that if universities only have one goal, it would be “prestige maximization”. The most profoundly change brought by the WCU Project to Taiwan higher education is the stratification of higher education. Since the WCU Project starts, MOE entitles the group of chosen universities as “World Class Universities” in all of the official documents.

The label of “Excellence” attached to WCU universities and “Non-Excellence” to Non-WCU universities facilitates the formation of stratification of higher education. The differentiation of prestige among universities due to the stratification creates a reputation ladder for universities to compete. Harwood (2010) argued that under this circumstance the most avid status-seeking institutions are in the middle of the ladder where staffs are particularly desperate to be recognized by their “superiors”. They are
more eagerly to differentiate themselves from their counterparts which belong to the same ladder.

The second thread of theoretical perspective is from the resources dependence theory (Pfeffer & Salancik, 2003). Argued by Pfeffer & Salancik (2003), universities are subject to the external agents that control their resources. The governmental agents who control critical resources can easily impose preferred values and practices by linking compliance with resource allocation. The strategies and actions of universities are constrained by external pressures since their survival is dependent upon their responsiveness to external demands and expectations (Horta et al., 2008).

In Taiwan context, both public and private universities heavily rely on governmental appropriation and subsidies for institutional operation. For any university, losing the big amount of grant like the WCU Project would slow down the pace of development and eventually put the university in a relative disadvantage status. This coercive power accompanying with the provision of the WCU Project left the universities a very few space to avoid this competition.

Not only the theoretical arguments, the findings derived from the empirical studies addressing the policy effect also provide some evidences leading this study to explore another possibility. The first example is Seong et al. (2008)’s study. Although they found that the BK21 has an impact on the chosen universities, they also found that if the outcome variable was replaced with the natural logarithm of the number of publications, the divergence among three groups of universities disappeared.

In Zhang et al. (2013)’s study, they found that among those 985 universities, the rate of growth in publications by lower tier 985 universities exceeded that of China’s two most highly regarded universities. Given the lower tier universities receiving less R&D funds than those two highly regarded 985 universities, this study assumes that
the growth of scientific publications in lower tier 985 universities was driven by other factors beyond the money, such as the environmental change because of the policy implementation.

While evaluating the BK21 of South Korea, Seong et al. (2008)’s findings based on the interview implied this possibility. Two representatives of universities that won Phase II but not Phase I funding said that their initial failure led to structural reform, thus matching an aim that MOE officials intended for the program. Representatives of these universities said their institutions changed significantly as a result of the BK21 program, with increased recognition of the importance of top talent and lower tolerance for mediocre performers. These changes were a result of the competitive system established by the program.

Based on the theoretical framework, this study pictures these two different approaches in Figure 2, visualizing the trend of scientific productions before and after the policy intervention that two competitive approaches propose, respectively. The graph on the left-hand side reveals the argument made by the traditional approach, indicating the chosen universities would increase their scientific production more rapidly than non-chosen universities after the policy intervention. The graph on the right hand side reveals the argument that the non-chosen universities would even grow rapidly while their chosen universities continually grow.
3.2.2 Production Function

In addition to the hypothesis addressing the policy effect in the possible directions, this study utilizes the Cobb-Douglas production function which can appropriate reflect the relationship between the input and output in R&D production environment. The Cobb-Douglas production function is particularly designed to represent the technological relationship between the amounts of two or more inputs and the amount of output that can be produced by those inputs (Cobb, & Douglas, 1928).

In aligning with the Cobb-Douglas production function, this study investigates the inputs that need to be considered in the university-based research setting. These inputs include a number of R&D funds and the number of faculties. Since the importance of R&D funds on the scientific production has been addressed in the previous section, this study only addresses the impact of faculty size on scientific production.

Faculty size is another critical component which could be have an impact on research productivity. Kyvik (1995) identified several arguments in favor of larger
faculty size for research productivity. First, larger faculty size can better facilitate collaborative research groups. In larger universities, there are more likely to be several faculties with similar research interests, which might increase cooperation and collaboration for joint research products. Second, larger universities are more likely to attract high-quality researchers. Finally, larger universities may have greater amounts of resources with more degrees of freedom in their use. In Jordan et al. (1988) study, they found the positive relationship between academic departmental size and publication in the American university.

Even though the advantage along with the large faculty size seems obvious, the research findings derived from empirical studies are mixed. In Jordan et al. (1988) study, they proved the positive relationship between academic departmental size and publication in the American University. However, Dundar and Lewis (1998) argued that in a large size of universities, research performance can be hampered due to increasing difficulty in communication and more formal rules and routines that may hinder initiatives and innovativeness. Martin and Skea (1992) used British university for study and found that no relationship between size and productivity in the natural science fields.

Martin and Skea (1992) provided a reasonable explanation to help understand why faculty size would have such inconsistent effect on research productivity. They noticed that if the faculty were able to share some of the same research equipment or interact closely with each other, the departmental size does have a positive relationship with research productivity. Following this rationale, this study argues that the universities with large faculty size do have the advantage that the universities with small size do not have. But, the faculty size is not a decisive factor. It still required a
good colleagueship to facilitate so-called as “intellectual synergy”. Otherwise, the faculty size is just a number.

3.3 The Effect of Public R&D funds on Private R&D funds

3.3.1 Crowding-In or Crowding-Out Effect

Early on, researchers were interested in the effect of the public R&D funds on the private R&D funds. Spurred by the work of Blank and Stigler (1957), empirical studies were undertaken to investigate how the public R&D funds influence the level of private R&D investment. Scholars have been debated whether the public research funding could efficiently spur private research funding or just offset it. Until recently, the conclusion is still far from being reached. Two opposite arguments: “crowding-in” and “crowding-out” effect are still waiting to be explored. This section addresses the definition of two opposite effects and summarizes the key findings derived from empirical studies.

Crowding-In Effect. What is the crowding-in effect? Rose-Ackermar (1981), Sugden (1982) and Segal and Weisbrod (1998) posited that the private R&D investment would increase with the increase in the public funding. This scenario was named as “crowding-in effect.” Why would public R &D funding stimulate private R&D investment? And how could public R &D funding affect industrial behaviors to invest? Several different perspectives and explanations are proposed for this question.

The first thread of argument is because of “Matthew effect” (Merton, 1968). Seong et al. (2008) argued that if government grant is seen a signal of high-quality work for a group, it would attract other funding flow, which makes the research institutions more powerful candidates for other funding. Payne (2001) also emphasized the message delivered through review system conducted by the government funding agencies. Payne (2001) stated that the accessibility of
information is crucial for the industrial investment decision. The government has resources to audit a research institution to ensure that grants are used for their intended purposes. Given the rigorous grant process most funding agencies use before awarding a grant, private sectors might use the granting result as an indicator of the reliability of research institution. Therefore, a positive correlation between private and public R&D investment could be predicted.

The second thread of literature argued that the cost-sharing drives the industrial R&D investment. This rationale is based on the belief that the market failure leads the private sector to underinvest in R&D (Arrow, 1962). Therefore, the government support of R&D is the correction of the market failure in the production of scientific and technological knowledge. The R&D subsidy can be viewed as lowering the private cost of the project. Receiving the subsidy may turn an unprofitable project into a profitable one to be pursued by the firm. Or it may speed up the completion of a project already underway. The learning and know-how gained in the subsidized project can also spill-over to other current and future projects thereby enhancing their prospects of success. For all these reasons, the public R&D subsidy can stimulate current and future private R&D expenditures (Lach, 2002).

**Crowding-Out Effect.** The public R&D funding does not necessarily result in the growth of private R&D funding. It might even cause the decrease of private R&D funding. The empirical evidences suggest that some substitution between private and public R&D does indeed occur. In the U.S., Wallsten (2000) showed that a subset of publicly traded, young, technological intensive firms, reduced their R&D spending in the years following the award of a Small Business Innovation Research Grants. Busom (2000) found that in about 30% of the Spanish firms in her sample, public funding fully crowds out private financed R&D. This substitution relationship was
called as the crowding-out effect (Seong et al. 2008, David and Hall, 2000). Two perspectives are proposed to answer why the crowding-out effect occurs.

The first is because of the “excessive concertation.” Lach (2002) argued that one way to rationalize the possibility of crowding out is attributed to government’s funding preference. Government bureaucrats are under strong pressure to avoid the appearance of “wasting” public funds. Therefore, government funding agencies may tend to fund projects with higher success probabilities and with clearly identifiable results, for example, projects that are likely to have high private rates of return (Lach, 2002). These projects could have been financed by the firm either from internal or external funds, suggesting that the R&D subsidies are in fact superfluous and may be crowding out private R&D resources. Using data on Israeli manufacturing firm in the 1990s, Lach (2002) found the evidence suggesting that the R&D subsidies granted by the Ministry of Industry and Trade greatly stimulated company financed R&D expenditures for small firms but had a negative effect on the R&D of large firms.

The second argument is because of “incentive transfer.” Seong et al. (2008) posited that research group receiving a huge amount of public R&D funding might spend less time and have less incentive seeking other funding. It might cause the funding project, BK21 of South Korea for example, crowds out other potential funding which originally would flow into universities. In Payne’s (2001)’ empirical study, the relationship between federal research funding and private donations varied across the different types of colleges and universities. In research universities, increasing federal research funding increased private support; but in non-research universities, increasing federal research funding was associated with decreased private support.
3.3.2 Making Industry University Partnerships Work

Regardless the crowding-in effect or the crowding-out effect, these two arguments are based on a simple assumption, which is the injection of the public investment, certainly, can change the interest of the private sector on university-based research. This simplified linear association between the public investment and the private investment received many critiques from the theoretical as well as the practical perspective.

From the theoretical perspectives, Leyden and Link (1991) argued that over past decades, researchers have investigated the government’s role in stimulating private sector innovation, but they did not provide a convincing theoretical framework to explain why the complementary relationship exists. Leyden and Link (1991) further pointed out that past empirical studies ignored the role of infratechnology and knowledge sharing. Thus, past empirical studies have left the wrong impression that the observed complementarity between governmental R&D and private R&D funding is a predetermined outcome of the R&D process.

In Leyden and Link (1991)’s argument, the observed complementarity is the result of technological complementarity. The governmental R&D funding itself cannot result in the growth of industrial R&D funding. If there has no technical connection in the innovation chain, the complementarity relationship between governmental R&D and private R&D funding would not efficiently sustain.

Geiger (2012)’s study also pointed out that the availability of the public investment is not the only parameter on predicting the growth of private investment in the university-based research. Geiger (2012) studied the development of American research universities and concluded that long-term and trusting relationship between universities and industries required many efforts to establish. This sort of the trusting
relationship is the driving force forging the foundation of research collaboration (Edmondson et al, 2012).

From the practical perspective, the move to strengthen the links between university and industry unavoidably would encounter difficulties. Universities and industrial firms have different objectives, different incentive schemes, and different approaches to research that will not be bridged by mere rhetoric (Rosenzweig & Turlington, 1982). The evolvement of policy instruments in the US that aims to improve the linkage provides many references.

Before the 1970s, the university-industry relations were still relatively weak. Since then, the US federal agencies made efforts to improve them (Baer, 1978). Among these efforts, the funding schemes of the newly developed projects were mainly focused on forging the formation of knowledge-sharing between the universities and the private sector. The Cooperative Research Programs initiated by NSF is one of example.

Under the funding scheme of the Cooperative Research Program, the part of the cost of a university research project was provided by the private sector; while the remaining costs were paid for by a government agency and the university itself. One of the successful cases in the Cooperative Research Program is the Processing Research Institute at Carnegie-Mellon University (Baer, 1978).

In 1971, the Processing Research Institute (PRI) at Carnegie-Mellon University used cooperative research projects to develop a master of engineering program oriented toward the processing industries. This program involved graduate students in problem-oriented research directly relevant to industrial needs. Baer (1978) pointed out that the federal contributions to PRI research projects did not simply substitute for the funds the companies would have spent on research in their own laboratories and
not at Carnegie-Mellon. The PRI program represents a direct effort to use federal funds as a catalyst to reorient university engineering studies toward industrial interests.

The model of the Cooperative Research Program has profound influences even on today’s science policy. The 7th Framework Program for Research and Technological Development (hereafter, the FP7) initiated by the European Commission during 2007 to 2013 is a remarkable example. Under its funding scheme, the FP7 is a co-financing project, which means that the European Commission does not purchase research services by placing contracts and paying a price. Rather, the FP7 gives grants to projects, thus contributing a certain percentage to the overall costs.

The collaborative projects of the FP7 are focused research projects with clearly defined scientific and technological objectives and specific expected results (such as developing new knowledge or technology to improve European Competitiveness). They are carried out by consortia made up of participants from different countries, and from industry and academia (European Commission, 2007). This sophisticated arrangement orients the R&D funds to the project that the scientific community and the industrial side appreciate its value. More profoundly, this arrangement makes the researchers from the different sectors engage into the course of innovation that further raises the possibility of knowledge sharing.

The second example that represents the US agencies’ efforts on strengthening academia-industry ties is the creation of research consortia with well-defined applied research objectives. This consortium is called as University-Industry Research Consortia. In the university-industry research consortia, a group of experts in the field defines the key research needs, solicits proposals from both university and industry
groups, selects the best proposals for funding, and coordinates the reporting and publication of results (Baer, 1978; Geiger & Sá, 2008).

Informal meetings of members to discuss their ongoing work have been instrumental in the success of research consortia (Baer, 1978). An example of such a consortium in the non-military field is that organized by Clemson University to conduct research on fabric flammability with support from the experimental technology incentives program of the department of commerce. This consortium includes three universities, a nonprofit laboratory, a government laboratory, and four private firms. It serves as a vehicle to speed the commercialization process from laboratory research to demonstration to subsequent diffusion. As the Cooperative Research Program, besides the financial supports provided by the governmental agency, a productive University-Industry Research Consortia needs the long-term commitments from university and industry. Under this partnership, the consortium is oriented toward the achievement of a specific goal.

3.4 Chapter Summary and Reflection

In this chapter, this study investigates the theoretical arguments and empirical studies with respect to how the injection of additional R&D funds can affect the scientific productivity and receiving private R&D funds. The results derived from the literature review show that the policy effect could have any possibility. The scientific production in the chosen universities could be stimulated because of the injection of additional resource. However, the non-chosen universities could also be encouraged by the competitive pressure and produced more scientific production.

As for the impact of the injection of public R&D funds on the private R&D investment in the university-based research, pre-existing literature argued that the private R&D funds in chosen universities could either increase or decrease following
the policy intervention. However, the recent investigations on the university-industry cooperation show that without technological complementarity the public R&D funds might not have any impact on the private R&D funds.

The Table 8 summarizes the main arguments and research finding discussed in the chapter of the literature review. These arguments could be helpful for this study to explore what might occur and possible rationales behind any observed scenario.

Table 8:

Summary of Research Finding from the Empirical Studies

<table>
<thead>
<tr>
<th>Topic#1: The Effect of the Injection of Extra R&amp;D funds on Scientific Production</th>
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<tbody>
<tr>
<td>Approach</td>
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<tr>
<td>----------</td>
</tr>
<tr>
<td>Divergence</td>
</tr>
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<td>Convergence</td>
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</tbody>
</table>

<table>
<thead>
<tr>
<th>Topic#2: The Effect of Public R&amp;D funds on Private R&amp;D funds</th>
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<tbody>
<tr>
<td>Approach</td>
</tr>
<tr>
<td>----------</td>
</tr>
<tr>
<td>Crowding-In</td>
</tr>
<tr>
<td>Crowding-Out</td>
</tr>
<tr>
<td>No Effect</td>
</tr>
</tbody>
</table>

Note: (+) positive; (-) negative; (*) not straightforward
Chapter 4: Research Methodology and Design

4.1 Introduction

This chapter outlines the methodological framework and approach used to conduct the research. A quantitative and qualitative mixed research method is used for this study. A quasi-experiment design and interviews are the instruments used to explore the causality among the implementation of the WCU project and the policy effects. This chapter describes the research design, the data collection method, procedure, and the data analysis techniques that are used as well as the reasons that the particular methods are chosen. This chapter also addresses the issues of reliability and validity. Finally, this chapter concludes with a discussion of ethical considerations.

4.2 Research Approach: A Mixed-method Research

Research integrating quantitative and qualitative methods has been increasing in recent years, especially in the social and behavioral sciences (Bryman, 2006; Collins, Onwyegbuzie & Sutton, 2006). Using mixed research methods can help the researcher not only avoid some disadvantage of qualitative methods such as limited scope, participants’ bias, time-consuming, and so on but can also improve the validity of the data, and gain more information beyond the scope of quantitative data analysis (Collins, Onwyegbuzie & Sutton, 2006). In this study, both of the quantitative and the qualitative approach would together assist in capturing the policy effect and exploring how universities and individual faculty react to the implementation of the WCU project.

4.3 Quantitative Research Approach

Quantitative research explains phenomena by collecting numerical data that are analyzed using mathematically based methods (Johnson et al., 2004). It is a very
popular option in social science research. But, because the random assignment is almost impossible to be deployed in the real word setting, making a causal inference is almost impossible. To deal with this problem, several quasi-experimental design techniques are developed to overcome the endogenous issue and make the causal inference possible.

The quasi-experimental design is one that looks a bit like an experimental design but lacks the key ingredient—random assignment. In Trochim’s (2000) opinion, the quasi-experimental design often appears to be inferior to the randomized experiment. But, with the implementation of appropriate statistical models, the quasi-experimental design can generate the approximate effect of causal inferences which only experimental design can claim. This feature also makes the quasi-experimental design more easily and frequently implemented than randomized experiment design in social science topics.

As in other public policy fields, the stakeholders of higher education are demanding clear evidences to prove what have been achieved by the implementation of specific policies. The advancement of statistical techniques in the quasi-experimental design has been made in recent years, but these are only starting to gain attention in higher education (Bowman et al., 2014). This study is aware of this demand and chooses to use Difference-in-Differences design to examine the policy effects.

The following section will introduce the key components used to construct the statistic model. These sections include the group composition, the data collection methods, and the estimating equations proposed for the hypothesis testing.
4.3.1 Group Composition

For any policy effect analysis like this study, the comparability among different comparison groups is always a crucial issue in terms of the validity of research findings. Ideally, the best strategy is to randomly select a group of universities to the treatment group and another group of universities to the comparison group. Randomization is optimal for evaluation because any difference among the groups after the delivery of the WCU project funding could be attributed to the policy intervention.

However, in many public policy contexts, randomization may be impossible and undesirable. Seong et al. (2008), in their study to assess the effect of BK 21 on science production, suggested that the group of universities applying for funding but not receiving it may serve as a good comparison group. This argument is based on an assumption, which is the intention on competition of non-chosen universities differentiates the non-chosen universities from the rest of universities that did not join the competition.

The practice Seong et al. (2008) used to construct the comparison group could only choose the universities with strong intention to become research universities. But, the research performance in this comparison group might not be good enough to be comparable to the universities in the treatment group. Improved from Seong et al.’s (2008) work, this study applies a two-stage selection procedure to construct the comparison group of universities with strong competition intention and comparable research performance. The detail is presented as the following.

Stage One: Research Performance. Research performance in most universities worldwide is determined by the number of published articles in internationally referred journals and conference proceedings, which are the channels for the
dissemination of research and development activities among researchers. Therefore, publishing a paper is an indication of success in advancing the frontiers of knowledge. As a result, it is also an important criterion for academic promotion and academic award (Brooks & German, 1983).

This study uses the number of published articles in internationally referred journals as the indicator to measure the research performance of each Taiwanese university. To generate the indicator for the following investigation, this study extracts the raw data from “Science Citation Index dataset” produced by Thomas Reuters Company. “Science Citation Index dataset” records each paper author’s affiliation information, containing the name of affiliation, the location of the affiliation, and the academic subject which the published paper belongs to. This study accesses this raw data spanning from 1980 to 2012 and extracts the indicators from here.

How to count the number of published papers produced in each affiliation is an issue needed to be solved appropriately. In today’s science, it is common and even becomes popular to have multiple authors working on the same paper. They might either come from the same affiliation or different affiliations. This study uses the individual institution as the measurement unit instead of individual faculty. Therefore, the ignorance of multiple authors from the same affiliation would result in the inflation of estimation.

To solve this problem, this study applies the “whole counts”, a standard calculation procedure used in the bibliometric literature. The “whole count” indicates the number of publications attributed to authors from a given affiliation in which each publication lists at least one author affiliation from that affiliation no matter how many authors from that affiliation contributed to the article. For example, if two
authors affiliated to National Taiwan University, and one author affiliated to National TsingHua University (three authors in one article) worked on the same article, National Taiwan University and National TsingHua University get one publication record, respectively.

This study uses the “whole count” strategy and calculates the number of published papers produced in each Taiwan University from 2000 to 2012. Then, this study sums the number of published papers for each university from the year of 2000 to 2004. The reason choosing the total amount of published papers in this time duration as the criteria is because MOE used the same criteria as one of the indicators to decide which applicant university should be taken into consideration for funding. This practice can ensure the composition of groups in this study, to the maximize extent, could be in aligned with the selection of award in the WCU Project. As a result, this study chooses top 40 universities with most scientific publications in all 145 universities.

Stage Two: Participation of Competition. The WCU Project is a university-wide project. MOE used the open competition to decide which universities should be chosen as WCU universities. In 2005, MOE totally received 32 applications and eventually only chose 11 universities as WCU universities. After matching the list of 40 universities with most scientific publications from 2000 to 2004 with the list of application universities, this study finally chooses 10 chosen universities and 14 non-chosen universities, and assigns them to the treatment group and the comparison group, respectively.

Table 9 shows the composition of two groups; while Figure 3 visualizes the impact of the WCU Project on the total amount of governmental R&D funds received by two groups during this period.
Table 9:

The Composition of Two Groups

<table>
<thead>
<tr>
<th>Group</th>
<th>Applicants</th>
<th>In Study</th>
</tr>
</thead>
<tbody>
<tr>
<td>WCU Universities</td>
<td>11</td>
<td>10</td>
</tr>
<tr>
<td>Non-WCU Universities</td>
<td>21</td>
<td>14</td>
</tr>
<tr>
<td>Total</td>
<td>32</td>
<td>24</td>
</tr>
</tbody>
</table>

Figure 3:

The Amount of Gov. R&D Funds in STEM fields by Two Groups, 2001 to 2010

Note: R&D funds adjusted in 2011 constant dollars

Source: MOST (2013). the National Science and Technology Activities Survey
4.3.2 Data Sources

In accordance with the Cobb-Douglas production function, there are at least three data components, which should be included in the dataset. They are human capital, financial capital and the scientific production. In the university setting, the human capital usually refers to the number of faculties, who are work force of university to conduct the research. The financial capital usually refers to the research funding granted to the research project or university.

As for the scientific production, knowledge is delivered in several different forms. Books, published papers, conference papers, patents and even consultant activities could be counted as research production. In alignment with the explicit goals of the WCU Project, this study chooses two indicators: the scientific publications and the private R&D investment.

The scientific publications have long history been recognized as the leading indicator of scientific production. Publishing a paper in the scientific journals often directly represents the author’s contribution to knowledge creation. In the university setting, the faculty’s performance on the scientific publications plays a decisive role in the course of their career path. In the global ranking system, the institutional performance on the scientific publications to the certain degree dominates the result of the ranking as well.

Compared to the scientific publications, using the private R&D investment as a measurement indicator to represent the scientific production is a relatively new practice. Although it is new, in the scientific accountability system the importance of the private R&D investments as a measurement indicator would continue increasing. This is because, in the era of the knowledge economy, the society expects to see the fruit of the knowledge creation can have more impacts on the economic growth.
The private sector uses the R&D investment to show their appreciation on the research capacity of the university-based researchers whom they collaborate with. Through R&D investment, the private sector acquires the expertise and knowledge of the university-based researchers, and even obtains the priority to commercialize the technology derived from this joined effort. If the scientific publication could be treated as the recognition from the scientific community, the private R & D investment likes a voting behavior demonstrating the appreciation from the private sector. The following paragraphs further introduce how these datasets are collected.

The Amount of Faculty in STEM fields. In order to generate the variable reflecting the amount of faculty in STEM fields, this study uses the data from the Digest of Education Statistics, an annual report published by the Taiwan Ministry of Education.

The Digest of Education Statistics does not provide the total amount of faculty in STEM fields specifically. Instead, it provides the amount of faculty registered in each academic department of the University from 1972 to 2014. To aggregate the amount of faculty in STEM fields from the structure of raw data, this study first identifies which academic departments should belong to STEM fields based on the discipline classification system developed by MOE. Then, based on the classification result, this study aggregates the amount of faculty in STEM fields for each university. In the classification of this study, the discipline of science, technology, engineering, agriculture, and medicine are included in the STEM fields. The discipline of education, humanity, and arts, social science, business management, law, and service are excluded.

The Number of Published Papers in STEM fields. To calculate how many published papers produced in each university, this study uses the “Science Citation
Index Dataset” created by Thomas Reuters Company. Science Citation Index Dataset is one of leading dataset recording the scientific publication around the world. Its raw data contains each author’s affiliation information in each published paper collected in Science Citation Index. In 2012, the SPHERE project sponsored by the Qatar Foundation purchased this raw data with time coverage from 1980 to 2012. As part of SPHERE project, this study obtains the privilege to use this data.

However, since it is in the most primitive data format, it requires additional efforts to clean it up before meaningful indicators could be generated. There have two issues needed to be carefully addressed. The first issue is the variation of the institutional name. From 2001 to 2012, certain Taiwanese universities experienced consolidation or rename. To ensure the data consistency across the time, this study unifies the name of each higher education institution over this period. Besides, in practice, the author claims his/her affiliation in various formats: some in full name; while some in abbreviation. Thus, this study standardizes these various names as well and assigns these different expressions to the affiliation that it should be.

The second issue is how to count the paper if there are multiple authors from the same university or from different universities. The way implemented by this study is the “whole count” strategy. The idea of “whole count” strategy is that each affiliation gets equal credit for one paper without considering whether the author is first author or second author. This practice is implemented in several international organization reports (UK Royal Society, 2011) and become an acceptable practice.

The Amount of R&D Funds in STEM fields. To generate the variables reflecting the composition and size of research funding in STEM fields, this study used the data extracted from “the National Science and Technology Activities
Survey”, an annual survey conducted by the Taiwan Ministry of Science and Technology (formerly known as National Science Council).

Taiwan government started “the National Science and Technology Activities Survey” since 1981. To ensure the comparability of indicators, this survey follows the standard and data framework implemented in OECD Science, Technology and Industry Outlook. Every year, MOST conduct this survey by delivering a questionnaire to universities, research institutions, public companies and private companies. While receiving this questionnaire, each survey unit is asked to list the name of research projects, a number of funds and its resources (public or private).

As introduced in previous sections, the dataset used by this study merges from multiple sources. After integration of these multiple data sources, a panel data at the institutional level with the time period ranging from 2001 to 2012 is created. Table 10 shows the measurable indicators designed for following data analysis. And, Table 11 presents the descriptive statistics for these analysis variables.
Table 10: The Definition of Dependent and Independent Variables

<table>
<thead>
<tr>
<th>Dimensions</th>
<th>Data Sources</th>
<th>Variable Name</th>
<th>Indicators</th>
</tr>
</thead>
<tbody>
<tr>
<td>Financial Capital</td>
<td>Gov._R&amp;Dfunds</td>
<td># of Gov. R&amp;D funds</td>
<td></td>
</tr>
<tr>
<td></td>
<td>MOST</td>
<td>Private_R&amp;Dfunds # of Private R&amp;D funds</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>R&amp;D_funds     # of R&amp;D funds</td>
<td></td>
</tr>
<tr>
<td>Human Capital</td>
<td>MOE</td>
<td>Faculty       # of faculty in STEM fields</td>
<td></td>
</tr>
<tr>
<td>Competition</td>
<td>MOE</td>
<td>WCU University 1=WCU University;</td>
<td></td>
</tr>
<tr>
<td>Participation</td>
<td></td>
<td>Non-WCU University 0=Non-WCU University</td>
<td></td>
</tr>
<tr>
<td></td>
<td>SCI</td>
<td>Scientific # of published papers in STEM</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Publications fields</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>1st tier journal # of published papers in STEM</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>fields in the 1st tier journal</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>2nd tier journal # of published papers in STEM</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>fields in the 2nd tier journal</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>3rd tier journal # of published papers in STEM</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>fields in the 3rd tier journal</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>4th tier journal # of published papers in STEM</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>fields in the 4th tier journal</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>5th tier journal # of published papers in STEM</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>fields in the 5th tier journal</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Overseas # of published papers in STEM</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Co-Authorship fields with Overseas Authors</td>
<td></td>
</tr>
</tbody>
</table>
Table 11:
Means and Standard Deviations for Analysis Variables

<table>
<thead>
<tr>
<th>Group</th>
<th>WCU (10)</th>
<th>Non-WCU (14)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Baseline (2001-05)</td>
<td>Baseline (2001-05)</td>
</tr>
<tr>
<td></td>
<td>Mean</td>
<td>SD</td>
</tr>
<tr>
<td>IVs</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Faculty</td>
<td>489</td>
<td>304</td>
</tr>
<tr>
<td>R&amp;D funds</td>
<td>1,728</td>
<td>1,544</td>
</tr>
<tr>
<td>Gov. R&amp;D funds</td>
<td>1,622</td>
<td>1,438</td>
</tr>
<tr>
<td>DVs#1: Scientific Publications</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total Publications</td>
<td>906</td>
<td>641</td>
</tr>
<tr>
<td>1st tier journal</td>
<td>359</td>
<td>290</td>
</tr>
<tr>
<td>2nd tier journal</td>
<td>205</td>
<td>149</td>
</tr>
<tr>
<td>3rd tier journal</td>
<td>125</td>
<td>79</td>
</tr>
<tr>
<td>4th tier journal</td>
<td>94</td>
<td>57</td>
</tr>
<tr>
<td>5th tier journal</td>
<td>62</td>
<td>47</td>
</tr>
<tr>
<td>DV#2: Private R&amp;D funds</td>
<td></td>
<td></td>
</tr>
<tr>
<td>One-Year Lagged</td>
<td>117</td>
<td>137</td>
</tr>
</tbody>
</table>

Note: R&D funds adjusted in 2011 constant millions NTD

Source: own calculations based on WOS, MOST, and MOE
4.3.3 Method and Estimating Equation

An appropriate technique for data analysis should reflect the features of data structure and sufficiently serve the purpose of capturing the policy effects derived from the implementation of a new policy. This study performs Difference-in-Differences (DD) analyses with both institution effects and year effects fixed and the covariates controlled. This arrangement can help to capture the average treatment effect attributed to the policy intervention after controlling covariate variables.

In addition, this study is also aware of that the injection of extra R&D funds may only have impacts after some time has elapsed. The timing of policy effect is the issue worthy of carefully addressing. The decision made here with respect to how long the policy effect would really take effect is relatively arbitrary. To appropriately deal with this issue, this study refers to the practices adopted by the previous empirical studies (Seong et al., 2008; Shin, 2009; Zhang et al., 2013).

In this study, the growth of scientific publications and the growth of private R&D funds are two dependent results derived from the implementation of the WCU Project. First, when considering the impact of the WCU Project on the growth of scientific productions, based on an assumption that the research often takes at least one year to finish and another year to publish the results, this study chooses to regress a given year’s publications on the previous two years of independent variables.

Second, when examining the “crowding-in effect” or “crowding-out effect”, if the private R&D funds is going to be attracted by the WCU Project, this study would observe that the cash flow of private R&D funds would increase in the next coming year. Conversely, if the private R&D funds would be crowded out, the impact might also be observed in the next following year. Based on this assumption, this study
chooses to regress a given year’s private R&D funds on the previous one year of independent variables.

Given the variation of the purchase power in different years, the amount of funds is adjusted based on the price index of 2011. The research design may be most clearly explained by discussing the following ordinary least squares regression (refer to formula 4.1 and formula 4.2).

In accordance with the Cobb-Douglas production function, the proposed estimation equation and variables with their definitions used for the following data analyses are as follows:

“Divergence or Convergence”

\[ y_{it+2} = \alpha_0 + \beta (WCU_i \times Post) + \delta_i + \theta_t + Z_{it}'\xi + \mu_{it} \]  
(formula 4.1)

where \( y_{it+2} \) is log number of publication for institution i in year t+2; \( WCU_i \) is a binary variable indicating whether an institution is part of the WCU group; \( Post \) is a dummy variable indicating the period of 2006-2010; \( \delta_i \) is a set of institutional fixed effects, while \( \theta_t \) is a set of year fixed effects; \( Z_{it} \) contains a set of covariates for institution i in year t. These covariates include:

\( \ln(R&D_{ij}) \): The R&D funds expended by school j in year i. The variable is the natural log of university’s R&D funds in STEM fields each year.

\( \ln(Faculty_{ij}) \): The full-time faculty registered in school j in year i. The variable is the natural log of university’s faculty’ size in STEM fields each year.
“Crowding-in or Crowding-out Effect?”

\[ y_{it+1} = \alpha_0 + \beta (WCU_i \times Post) + \delta_i + \theta_t + Z_{it}'\xi + \mu_{it} \]

(formula 4.2)

where \( y_{it+1} \) is log amount of the private R&D funds expended by institution \( i \) in year \( t+1 \); \( WCU_i \) is a binary variable indicating whether an institution is part of the WCU group; \( Post \) is a dummy variable indicating the period of 2006-2010; \( \delta_i \) is a set of institutional fixed effects, while \( \theta_t \) is a set of year fixed effects; \( Z_{it} \) contains a set of covariates for institution \( i \) in year \( t \). These covariates include:

- \( \ln(Public\_funds_{ij}) \): The Public R&D funds expended by school \( j \) in year \( i \). The variable is the natural log of university’s Public R&D funds in STEM fields each year.
- \( \ln(Faculty_{ij}) \): The full-time faculty registered in school \( j \) in year \( i \). The variable is the natural log of university’s faculty’ size in STEM fields each year.
4.4 Qualitative Research Approach

The following section explains the data collection methods used for the qualitative analysis in this study.

4.4.1 Method of Data Collection: Interview

Qualitative interview techniques usually refer to in-depth forms of interviewing with the goal of exploring and elucidating specific research questions by allowing the interaction between interviewees and interviewer to shape the data collected (Mason, 1996). While the quantitative analysis proves the presence of the policy effects, the data collected from the qualitative interview further explores and elucidates what caused the final consequence.

To ensure the representativeness of interviewees, this study sends invitations to senior administrators working for MOE, WCU universities, and Non-WCU universities. Eventually, this study successfully interviews five senior administrators who had involved in the WCU Project at the national policy level and the institutional leadership level. Table 12 shows the number of interviewees and their representation.

The interviewees are asked to recall their memories about: “What internal policy changes have occurred in your universities in response to the implementation of the WCU Project?” This open question orients the interviewees to generally describe how their universities reacted to the policy change. The specifically questions are asked during the course of interviews. These questions are aimed to encourage the interviewees to clarify their descriptions and provide more details about what has happened.
Table 12:
The Composition of Interviewees

<table>
<thead>
<tr>
<th>Participants Representation</th>
<th>Number of Interviewees</th>
<th>Pseudonym</th>
</tr>
</thead>
<tbody>
<tr>
<td>WCU universities</td>
<td>2</td>
<td>Ann, Cheng</td>
</tr>
<tr>
<td>Non-WCU universities</td>
<td>2</td>
<td>Wang, Lee</td>
</tr>
<tr>
<td>Ministry of Education</td>
<td>1</td>
<td>Chen</td>
</tr>
<tr>
<td>Total</td>
<td>5</td>
<td></td>
</tr>
</tbody>
</table>

4.4.2 Data Analysis and Storage

Qualitative data analysis is an interpretive task, with interpretations actively constructed through social processes (Ezzy, 2013). The process of qualitative data analysis is not linear and clear. It is a progression and ongoing process rather than a stage of the research process or a one-time event (Erlandson et al., 1993). In this study, qualitative data analysis lasts for three months from the invitation requests to final write-up of the study. During this time, there are two distinct stages of analysis: data generation and collection, and ongoing analysis throughout the study.

The interview was audio recorded after having interviewees’ consent. If participants requested that the interview should not be recorded, the handwritten notes capturing the main points raised were used as interview notes. All audio and handwritten recorded was transcribed.

4.4.3 Ethical Consideration

This study involves collecting participants’ perspectives and personal experiences, which makes ethical issues inescapable. This study received the approval of the Pennsylvania State University for Ethics in Human Subject Research (IRB). Confidentiality, privacy, and voluntariness are important ethical considerations in this
study. All data that are collected in this project is kept confidential. No individual or workplace could be identifiable by name or description in the final thesis.

4.5 Chapter Summary

This chapter presents the methods used to generate data (creating a comprehensive panel data by merging multiple data resources and conducting interviews) and the methods of data analysis. In quantitative analysis part, the rationale to comprise two groups and the equations proposed to test the policy effects are addressed and described, respectively. In qualitative analysis part, the rationale to select the participants and proposed questions are also introduced.
Chapter 5: Research Findings

5.1 Introduction

This chapter presents the research findings derived from the quantitative and qualitative analysis. The first section explores the causality between the impact of the WCU Project on the growth rate of scientific publications. The second section explores the causality between the impact of the WCU Project and the growth rate of private R&D funds. The third section summarizes how the implementation of the WCU Project affected the behavior of WCU universities and Non-WCU universities.

5.2 Divergence or Convergence

In accordance with the traditional approach, the injection of extra R&D funds like the WCU Project could cause the occurrence of divergence in the growth rate of scientific publications between chosen and non-chosen universities. However, informed by the organization theory, this study proposes a competing approach arguing that non-chosen universities could be motivated to mimic their chosen counterparts. In this sense, the convergence in the growth rate of scientific publications between two groups of universities could happen. In the following sections, this study presents the result of examination of the validity of this hypothesis.

5.2.1 The Growth Rate of Total Scientific Publications

The investigation of the presence of causality is conducted in two steps: (1) the visualization of longitudinal development in WCU universities and Non-WCU universities; (2) the confirmation of the causality between the policy intervention and expected outcomes by performing Difference-in-Differences analysis.

Table 13 presents a number of scientific publications produced in the higher education sector during the period of 2001 to 2010. During this period, the number of
scientific publications produced in the higher education sector increased from 12,191 in 2001 to 34,413 in 2010, posting an increase of 182% or an annual rate of 11%. For WCU universities and Non-WCU universities, both groups increased their scientific publications as well. During this time period, WCU universities increased their scientific publications from 7,116 in 2001 to 17,231 in 2010, posting an increase of 142%. The growth of Non-WCU universities was more apparently. The number of scientific publications produced in Non-WCU universities increased from 2,358 to 7,336, posting an increase of 211%.

Table 13:

The Number of Scientific Publications, 2001 to 2010

<table>
<thead>
<tr>
<th>Year</th>
<th>HEIs Total</th>
<th>WCU (10)</th>
<th>Non-WCU (14)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Number</td>
<td>Share</td>
<td>Number</td>
</tr>
<tr>
<td>2001</td>
<td>12,191</td>
<td>7,116</td>
<td>58.37%</td>
</tr>
<tr>
<td>2002</td>
<td>13,875</td>
<td>7,939</td>
<td>57.22%</td>
</tr>
<tr>
<td>2003</td>
<td>15,833</td>
<td>8,700</td>
<td>54.95%</td>
</tr>
<tr>
<td>2004</td>
<td>18,901</td>
<td>10,194</td>
<td>53.93%</td>
</tr>
<tr>
<td>2005</td>
<td>21,300</td>
<td>11,368</td>
<td>53.37%</td>
</tr>
<tr>
<td>2006</td>
<td>24,778</td>
<td>12,984</td>
<td>52.40%</td>
</tr>
<tr>
<td>2007</td>
<td>27,286</td>
<td>13,983</td>
<td>51.25%</td>
</tr>
<tr>
<td>2008</td>
<td>30,140</td>
<td>15,292</td>
<td>50.74%</td>
</tr>
<tr>
<td>2009</td>
<td>33,912</td>
<td>17,009</td>
<td>50.16%</td>
</tr>
<tr>
<td>2010</td>
<td>34,413</td>
<td>17,231</td>
<td>50.07%</td>
</tr>
</tbody>
</table>

Overall Change (%) | 182 | 142 | 211
The investigation of the growth of scientific publications based on the absolute value provides an intuitive impression with respect to the longitudinal development. However, since two groups had different starting points, the application of absolute value for the comparison could not appropriately reveal the growth rate of two groups. In this sense, this study replaces the absolute value with the logged value to investigate the growth rate of two groups during this time period. Table 14 presents the logged value of scientific publications in two groups. Figure 4 portrays the developments of logged values to exemplify the exponential growth trajectory of WCU universities and Non-WCU universities.

Table 14:
The Average Logged Value of Total Scientific Publications, by Groups

<table>
<thead>
<tr>
<th>Year</th>
<th>WCU</th>
<th>Non-WCU</th>
<th>Difference</th>
</tr>
</thead>
<tbody>
<tr>
<td>2001</td>
<td>6.39</td>
<td>5.03</td>
<td>1.36</td>
</tr>
<tr>
<td>2002</td>
<td>6.50</td>
<td>5.18</td>
<td>1.31</td>
</tr>
<tr>
<td>2003</td>
<td>6.59</td>
<td>5.31</td>
<td>1.27</td>
</tr>
<tr>
<td>2004</td>
<td>6.75</td>
<td>5.47</td>
<td>1.28</td>
</tr>
<tr>
<td>2005</td>
<td>6.88</td>
<td>5.57</td>
<td>1.31</td>
</tr>
<tr>
<td>2006</td>
<td>7.01</td>
<td>5.75</td>
<td>1.26</td>
</tr>
<tr>
<td>2007</td>
<td>7.10</td>
<td>5.87</td>
<td>1.23</td>
</tr>
<tr>
<td>2008</td>
<td>7.19</td>
<td>5.96</td>
<td>1.24</td>
</tr>
<tr>
<td>2009</td>
<td>7.31</td>
<td>6.08</td>
<td>1.23</td>
</tr>
<tr>
<td>2010</td>
<td>7.33</td>
<td>6.12</td>
<td>1.21</td>
</tr>
</tbody>
</table>
In Figure 4, the navy-blue solid line and red long dash line indicates the average logged value of WCU universities and Non-WCU universities, respectively. And, the blue dot line connecting the points indicates the longitudinal differences between two groups spanning from 2001 to 2010.

From the visualization, several preliminary observations reveal. First, both of WCU universities and Non-WCU universities showed an upward trajectory during this time period. This scenario indicates that not only WCU universities steadily increased their scientific publications, but also Non-WCU universities increased. Since interested in the causality between the policy intervention and the expected outcomes, this study focuses on the change in the growth rate between two groups during the transition period of 2005 to 2006.

While focusing on the transition period of 2005 to 2006, this study finds that while WCU universities steadily increased their scientific publications (logged value increased from 6.88 in 2005 to 7.01 in 2006), Non-WCU universities increased slightly rapidly (logged value increased from 5.57 in 2005 to 5.75 in 2006). Referring to the blue dot line, during the transition period of 2005 to 2006, there had a slight drop in the difference between two groups (logged value decreased from 1.31 in 2005 to 1.26 in 2006). After 2006, the differences over following years between two groups had no apparent changes.

Based on the observations from the visualization, no intuitive finding indicates that the injection of extra R&D funds caused the divergence in the growth rate of scientific publications between two groups. The trajectory between two groups was parallel after the policy intervention.
To confirm the observations from the visualization, this study employs the difference-in-differences estimation to verify the presence of causality. The DDs and the corresponding standard errors, which account for serial correlations within each institution over time, are shown in Table 15.

In Table 15, the negative coefficient of DDs suggests that the average Non-WCU universities outperformed the average WCU universities in terms of the growth rate of total scientific publications by approximately 8.4%. In other words, while entering the follow-up period, the growth rate of scientific publications in Non-WCU universities increased faster by 8.4% compared to WCU universities. But, this change is minor and insignificant.
Table 15:

DD results for WCU’s Impact on the Growth Rate of Scientific Publications

<table>
<thead>
<tr>
<th>Dependent Variable</th>
<th>Log(Scientific Publications)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Coefficient</td>
</tr>
<tr>
<td>Post</td>
<td>0.810***</td>
</tr>
<tr>
<td>WCU*Post</td>
<td>-0.084</td>
</tr>
<tr>
<td>log(funding)</td>
<td>0.244*</td>
</tr>
<tr>
<td>log(faculty)</td>
<td>0.496</td>
</tr>
<tr>
<td>Constant</td>
<td>1.322</td>
</tr>
</tbody>
</table>

Institution fixed effects: Yes
Year fixed effects: Yes
R-Square: 87%
Observations: 240
Institutions: 24

\( t \) statistics in parentheses

* \( p < 0.10 \), ** \( p < 0.05 \), *** \( p < 0.01 \)

The investigation of the growth rate of total scientific publications in two groups suggests that the traditional approach of proposing the divergence between chosen and non-chosen universities following the injection of extra R&D funds did not occur. Based on the findings derived from the data visualization in Figure 3 and statistical verification in Table 15, the longitudinal trajectory between two groups in the context of the WCU Project was parallel, though not converging.
5.2.2 The Growth Rate of Scientific Publications in 1st Tier Journal

The investigation of the growth rate of total scientific publications did not confirm the occurrence of either divergence or convergence caused by the policy intervention. Nevertheless, it is too early to claim that the hypothesis this study proposes was rejected. This study argues that the previous empirical studies that did not sophistically divide the scientific publications into different groups based on the quality of journals could conceal the possible policy effect.

This assumption is based on the reality that in most of the countries, the non-chosen universities were in relatively small operational size compared to their chosen counterparts. It is also true in Taiwan context (refer to Table 11 of Chapter 4). If the argument, “maximum of prestige”, deriving from the organization theory is correct, this study should be able to see that Non-WCU universities strategically focused their energies on the most influential research works instead of spread over their limited efforts to other less influential research ones.

Based on this assumption, this study divides the scientific publications into five different tier groups and investigates the causality between the policy intervention and these expected outcomes. Table 16 first presents the average difference at logged value of scientific publications across different tier journals between two groups during these ten years. And, Figure 5 and Figure 6 together visualize the longitudinal trajectories of two groups in different tier groups.
Among these five different tier groups, the change in the 1st tier journal reveals a clear association with the policy intervention. Showed in column 1 of Table 16, during the baseline period (2001-05), the differences between WCU universities and Non-WCU universities at logged levels were very stable, ranging from 1.60 to 1.64. During the transition period of 2005 to 2006, the difference decreased from 1.62 in 2005 to 1.51 in 2006. During the follow-up period (2006-10), the difference between two groups continually reduced. By 2010, the difference between two groups reduced to 1.43.

Figure 5 presents this transformative change. First, both of WCU universities and Non-WCU universities showed an upward trajectory during this time period. This
scenario indicates that both groups increased their growth rate of scientific publications in the 1st tier journal. During the baseline period, the trajectory of WCU universities was parallel with the trajectory of Non-WCU universities. The blue dot line designed to indicate the difference between two groups was quite flat. The transformative change appeared during the transition period of 2005 to 2006 and followed by 2007.

In 2006 and 2007, two consequent years, the differences between two groups decreased, shrinking the difference from 1.62 in 2005 to 1.51 in 2006 followed by 1.45 in 2007. During the follow-up period, except for a slight rebound observed in 2008 (logged value=1.51), the shrinking difference between two groups was quite apparently. This scenario is indicating the emergence of convergence between two groups on producing the highest prestige scientific publications.
Figure 5:
Logged Levels of Scientific Publications in the 1st Tier Journal: Averages for universities in the WCU group and the Non-WCU group
To confirm the observations based on the visualization, this study once again employs Difference-in-Differences to exam the causality. Table 17 presents the DDs and the corresponding standard errors. The DDs result shows that the difference change in the 1st tier journal between two groups reached the statistically significant level. The negative coefficient of -0.165 in DDs indicates that the average Non-WCU universities outperformed the average WCU universities by a factor of 1.65 with respect to the increase in logged levels of scientific publications in the 1st tier journal. And, this observed change in the 1st tier journal can be attributed to the policy intervention. In other words, on average, the growth rate of the scientific publications
in the 1\textsuperscript{st} tier journal of Non-WCU universities grew faster by 16.5\% compared to WCU universities because of the implementation of the WCU Project.

Table 17:

Heterogeneity of the Effects of WCU on Scientific Publications

<table>
<thead>
<tr>
<th>DV(logged)</th>
<th>(1)</th>
<th>(2)</th>
<th>(3)</th>
<th>(4)</th>
<th>(5)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>1\textsuperscript{st} Tier</td>
<td>2\textsuperscript{nd} Tier</td>
<td>3\textsuperscript{rd} Tier</td>
<td>4\textsuperscript{th} Tier</td>
<td>5\textsuperscript{th} Tier</td>
</tr>
<tr>
<td>Post</td>
<td>1.148***</td>
<td>0.920***</td>
<td>0.321**</td>
<td>0.609***</td>
<td>0.331**</td>
</tr>
<tr>
<td></td>
<td>(7.81)</td>
<td>(7.55)</td>
<td>(3.30)</td>
<td>(3.77)</td>
<td>(2.82)</td>
</tr>
<tr>
<td>WCU*Post</td>
<td>-0.165*</td>
<td>-0.097</td>
<td>-0.040</td>
<td>-0.115</td>
<td>-0.168</td>
</tr>
<tr>
<td></td>
<td>(-1.82)</td>
<td>(-0.99)</td>
<td>(-0.65)</td>
<td>(-1.10)</td>
<td>(-1.31)</td>
</tr>
<tr>
<td>ln(funding)</td>
<td>0.280</td>
<td>0.0617</td>
<td>0.231**</td>
<td>0.433</td>
<td>0.791**</td>
</tr>
<tr>
<td></td>
<td>(1.36)</td>
<td>(0.48)</td>
<td>(3.36)</td>
<td>(1.98)</td>
<td>(3.28)</td>
</tr>
<tr>
<td>ln(faculty)</td>
<td>0.319</td>
<td>0.324</td>
<td>1.159*</td>
<td>0.441</td>
<td>0.237</td>
</tr>
<tr>
<td></td>
<td>(0.54)</td>
<td>(0.71)</td>
<td>(2.34)</td>
<td>(1.01)</td>
<td>(0.57)</td>
</tr>
<tr>
<td>Institution fixed effects</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>Year fixed effects</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>Constant</td>
<td>0.855</td>
<td>1.937</td>
<td>-4.009</td>
<td>-1.606</td>
<td>-3.271</td>
</tr>
<tr>
<td></td>
<td>(0.30)</td>
<td>(0.78)</td>
<td>(-1.35)</td>
<td>(-0.76)</td>
<td>(-1.50)</td>
</tr>
<tr>
<td>R-Square</td>
<td>0.76</td>
<td>0.59</td>
<td>0.83</td>
<td>0.79</td>
<td>0.69</td>
</tr>
<tr>
<td>Observations</td>
<td>240</td>
<td>240</td>
<td>240</td>
<td>240</td>
<td>240</td>
</tr>
</tbody>
</table>

*p < 0.10, **p < 0.05, ***p < 0.01

\textit{t} statistics in parentheses
Table 18 presents the ratio between WCU universities and Non-WCU universities in terms of a number of scientific publications in the 1st tier journal. During the baseline period, the ratio between WCU universities and Non-WCU universities was about 8 versus 2. And this ratio was stable. Since 2006, the ratio started changing every year and continually favored Non-WCU universities side. By 2010, the ratio between WCU universities and Non-WCU universities became 7.4 versus 2.6.

Table 18:
Share of SCIE Publications in 1st tier journals

<table>
<thead>
<tr>
<th>Year</th>
<th>Total</th>
<th>WCU</th>
<th>Non-WCU</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Number</td>
<td>Share</td>
</tr>
<tr>
<td>2001</td>
<td>3,230</td>
<td>2,611</td>
<td>80.84%</td>
</tr>
<tr>
<td>2002</td>
<td>3,678</td>
<td>2,921</td>
<td>79.42%</td>
</tr>
<tr>
<td>2003</td>
<td>4,383</td>
<td>3,524</td>
<td>80.40%</td>
</tr>
<tr>
<td>2004</td>
<td>5,274</td>
<td>4,224</td>
<td>80.09%</td>
</tr>
<tr>
<td>2005</td>
<td>5,829</td>
<td>4,687</td>
<td>80.41%</td>
</tr>
<tr>
<td>2006</td>
<td>6,706</td>
<td>5,288</td>
<td>78.85%</td>
</tr>
<tr>
<td>2007</td>
<td>7,407</td>
<td>5,711</td>
<td>77.10%</td>
</tr>
<tr>
<td>2008</td>
<td>8,410</td>
<td>6,451</td>
<td>76.71%</td>
</tr>
<tr>
<td>2009</td>
<td>10,421</td>
<td>7,777</td>
<td>74.63%</td>
</tr>
<tr>
<td>2010</td>
<td>11,000</td>
<td>8,114</td>
<td>73.76%</td>
</tr>
</tbody>
</table>

The findings derived from this section confirm the hypotheses proposed by this study in two aspects. First, Non-WCU universities did strategically focus their efforts
on the most prestige journals. In accordance with the DDs results, the policy intervention did not create a significant impact on the other tiers of journal except for the 1st tier. The growth rate of scientific publications in the 1st tier journal in Non-WCU universities is the only one aspect sensitive to the policy intervention. The transformative change in Non-WCU universities shrunk the differences between two groups on the aspect of the production of the most prestige scientific papers. The observed and confirmed emergence of convergence between two groups was caused by the implementation of the WCU Project.

Second, the neglect of the differential quality of scientific publications could result in the biased estimation of the potential policy effect. In this study, the analysis using the total amount of scientific publications as the outcome variable reaches a conclusion different from the conclusion based on the number of scientific publications in the 1st tier journal. The divergent findings based on the different designs of outcome variables shows it is necessary to consider the varied impact of the policy on the different level of research activities.

5.2.3 The Growth Rate of Overseas Co-Authorship

In today’s globalization of science, the importance of cross-national collaboration in research is increasing. The empirical studies (Narin, 1991; Wagner et al., 2001) even indicated that the strength in the cross-national research collaboration is a good predictor for future excellence. In this sense, this study further explores whether the extent of cross-national research partnership was affected by the policy intervention.

Table 19 first presents the average difference at logged value of scientific publications between two groups during these ten years. And, Figure 7 portrays the developments of logged levels of the amount of scientific publications derived from
cross-national co-authorship to exemplify the exponential growth trajectory of WCU universities and Non-WCU universities.

Table 19:
Average difference at logged levels

<table>
<thead>
<tr>
<th>Year</th>
<th>WCU</th>
<th>Non-WCU</th>
<th>Difference</th>
</tr>
</thead>
<tbody>
<tr>
<td>2001</td>
<td>4.40</td>
<td>2.90</td>
<td>1.50</td>
</tr>
<tr>
<td>2002</td>
<td>4.55</td>
<td>3.05</td>
<td>1.50</td>
</tr>
<tr>
<td>2003</td>
<td>4.68</td>
<td>3.12</td>
<td>1.56</td>
</tr>
<tr>
<td>2004</td>
<td>4.83</td>
<td>3.28</td>
<td>1.56</td>
</tr>
<tr>
<td>2005</td>
<td>5.06</td>
<td>3.48</td>
<td>1.59</td>
</tr>
<tr>
<td>2006</td>
<td>5.27</td>
<td>3.72</td>
<td>1.55</td>
</tr>
<tr>
<td>2007</td>
<td>5.37</td>
<td>3.92</td>
<td>1.45</td>
</tr>
<tr>
<td>2008</td>
<td>5.60</td>
<td>4.11</td>
<td>1.49</td>
</tr>
<tr>
<td>2009</td>
<td>5.69</td>
<td>4.26</td>
<td>1.42</td>
</tr>
<tr>
<td>2010</td>
<td>5.81</td>
<td>4.40</td>
<td>1.41</td>
</tr>
</tbody>
</table>

Showed in Figure 7, both of WCU universities and Non-WCU universities experienced an upward trajectory during this time period. This scenario indicates that the growth rate of international co-authorship in both of two groups increased. To explore the possible causality caused by the implementation of the WCU Project, this study investigates the change before and after the policy intervention.

During the baseline period, the differences between WCU universities and Non-WCU universities at logged levels were slightly expanded, increasing from 1.50 in 2001 to 1.59 in 2005. Unlike the transformative change shown in Figure 5, there
had no clear drop appearing during the transition of 2005 to 2006 presented in Figure 7.

During the transition period of 2005 to 2006, while WCU universities steadily increased their international co-authorship (logged value increased from 5.06 in 2005 to 5.27 in 2006), Non-WCU universities increased as well (logged value increased from 3.48 in 2005 to 3.72 in 2006). During this period the differences between two groups reduced 0.04, decreasing from 1.59 in 2005 to 1.55 in 2006. After 2006, except for a slight rebound in 2008 (logged value=1.49), the differences between two groups over the following years continued decreasing. Yet, the extent of decrease in the differences between two groups is not dramatically.
Figure 7:
Logged levels of Scientific Publications with Overseas Co-Authorship: Average for universities in the WCU group and the Non-WCU group

Table 20 presents the DDs estimates and the corresponding standard errors, which account for serial correlations within each institution over time. The DDs of -0.08 indicates that the difference in the growth rate between two groups across two periods was shrinking. In other words, on average, compared to the baseline period, Non-WCU universities grew faster than their WCU counterparts in terms of international co-authorship. However, since the result of DDs is not statistically significant, there is no compelling evidence to claim the observed shrinking is driven by the policy intervention.
Table 20:

DD results for WCU’s Impact on the Growth Rate of Intl. Co-Authorship Scientific Publications

<table>
<thead>
<tr>
<th>Dependent Variable</th>
<th>Log(Intl. Co-Authorship)</th>
<th>Coefficient</th>
<th>t-value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Post</td>
<td></td>
<td>1.305***</td>
<td>7.68</td>
</tr>
<tr>
<td>WCU*Post</td>
<td></td>
<td>-0.088</td>
<td>-0.91</td>
</tr>
<tr>
<td>log(funding)</td>
<td></td>
<td>0.241</td>
<td>1.43</td>
</tr>
<tr>
<td>log(faculty)</td>
<td></td>
<td>0.250</td>
<td>0.45</td>
</tr>
<tr>
<td>Constant</td>
<td></td>
<td>0.640</td>
<td>0.23</td>
</tr>
</tbody>
</table>

Institution fixed effects: Yes
Year fixed effects: Yes
R-Square: 66%
Observations: 240
Institutions: 24

* t statistics in parentheses

* p < 0.10, ** p < 0.05, *** p < 0.01
5.3 Crowding-in Effect or Crowding-out Effect

In accordance with the theoretical arguments, because of Matthew effect (Merton, 1968) or cost sharing effect (Arrow, 1962) the injection of public R&D funds can drive the increase of private R&D funds. On the other hands, because of excessive concentration (Lach, 2000) or incentive transfer (Seong et al, 2008) the injection of public R&D funds also could cause the decrease in private R&D funds.

Except for the previous two competing arguments, because the private R&D investment is based on the long-term and trusting relationship among partner institutions that is hard to be achieved in the short-term period (Leyden & Link, 1991; Geiger, 2012), the injection of public R&D funds could cause no any impact on a number of private R&D funds. In alignment with this argument, the public R&D could have an impact only if the policy instrument is well-design to facilitate the linkage between the university and the private sector.

Based on these varied perspectives, this section is aimed to investigate which argument can precisely predict the impact resulting from the implementation of the WCU Project in Taiwan context.

5.3.1 The Growth Rate of Private R&D Funds

Like the growth rate of scientific publications, the investigation of the growth rate of private R&D funds also needs to define the policy lagged effect. In alignment with the goals set by the WCU Project, this study focuses on the short-term effect of the policy rather than the long-term return on public R&D investment. On the basis of this, this study follows the practice of previous empirical studies (David et al., 2000; González & Pazó, 2008) and chooses one-year lagged effect for the following analysis.
Table 21 presents the absolute amount of private R&D funds received by WCU universities and Non-WCU universities during the first decade of 21st century. In the perspective of longitudinal development, both of WCU universities and Non-WCU universities increased their private R&D funds. Referring to Table 21, in 2001, 10 WCU universities totally received 940.29 million NTD dollars, accounting for 70.74% of private R&D funds used in university-based research nationally (referring to Table 24). During this decade, the total amount of WCU universities receiving stably increased except for a slight recession in 2004 and 2006. By 2010, WCU universities totally received 1,947.97 million NTD dollars from private R&D funds for university-based research. The overall change between 2001 and 2010 is 107%.

For Non-WCU universities, in 2001, 14 universities totally received 176.44 million NTD dollars, accounting for 13.27% of private R&D funds used in university-based research (referring to Table 24). During this decade, except for an extreme jump in 2004 the total amount that Non-WCU universities received increased stably. By 2010, Non-WCU universities totally received 817.53 million NTD dollars from private R&D funds for university-based research. The overall change between 2001 and 2010 is even more dramatically, reaching 363%.
### Table 21:

Amount of Private R&D Funds by Groups, 2001 to 2010 (in millions of NTD)

<table>
<thead>
<tr>
<th>Year</th>
<th>One-Year Lagged WCU</th>
<th>Non-WCU</th>
</tr>
</thead>
<tbody>
<tr>
<td>2001</td>
<td>940.29</td>
<td>176.44</td>
</tr>
<tr>
<td>2002</td>
<td>1,025.73</td>
<td>263.46</td>
</tr>
<tr>
<td>2003</td>
<td>1,219.17</td>
<td>316.65</td>
</tr>
<tr>
<td>2004</td>
<td>1,195.00</td>
<td>456.06</td>
</tr>
<tr>
<td>2005</td>
<td>1,497.28</td>
<td>339.68</td>
</tr>
<tr>
<td>2006</td>
<td>1,343.25</td>
<td>340.69</td>
</tr>
<tr>
<td>2007</td>
<td>1,434.57</td>
<td>414.88</td>
</tr>
<tr>
<td>2008</td>
<td>1,664.77</td>
<td>572.58</td>
</tr>
<tr>
<td>2009</td>
<td>1,794.16</td>
<td>674.29</td>
</tr>
<tr>
<td>2010</td>
<td>1,947.97</td>
<td>817.53</td>
</tr>
</tbody>
</table>

Overall Change

- 107% 363%

*Note: In 2011 constant dollars*

Since WCU universities and Non-WCU universities had different starting bases, the application of absolute amount for the comparison could not appropriately reveal the growth rate of two groups. In this sense, this study replaces the absolute amount with the logged value to investigate the growth rate of two groups during this time period. Table 22 presents the logged value of private R&D funds received by two groups and Figure 8 visualizes the longitudinal trajectory.
Table 22:
Logged level of Private R&D Funds by Groups, 2001 to 2010

<table>
<thead>
<tr>
<th>Year</th>
<th>One-Year Lagged</th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>WCU</td>
<td>Non-WCU</td>
<td>Diff.</td>
</tr>
<tr>
<td>2001</td>
<td>4.12</td>
<td>2.08</td>
<td>2.04</td>
</tr>
<tr>
<td>2002</td>
<td>4.35</td>
<td>2.73</td>
<td>1.62</td>
</tr>
<tr>
<td>2003</td>
<td>4.48</td>
<td>2.78</td>
<td>1.69</td>
</tr>
<tr>
<td>2004</td>
<td>4.42</td>
<td>3.02</td>
<td>1.40</td>
</tr>
<tr>
<td>2005</td>
<td>4.47</td>
<td>2.75</td>
<td>1.72</td>
</tr>
<tr>
<td>2006</td>
<td>4.38</td>
<td>2.81</td>
<td>1.57</td>
</tr>
<tr>
<td>2007</td>
<td>4.55</td>
<td>2.96</td>
<td>1.59</td>
</tr>
<tr>
<td>2008</td>
<td>4.63</td>
<td>3.27</td>
<td>1.36</td>
</tr>
<tr>
<td>2009</td>
<td>4.74</td>
<td>3.41</td>
<td>1.33</td>
</tr>
<tr>
<td>2010</td>
<td>4.81</td>
<td>3.54</td>
<td>1.27</td>
</tr>
</tbody>
</table>

In Figure 8, the blue solid line and red long dash line presents the average amount of private R&D funds at logged level in WCU group and Non-WCU group, respectively. The added green dash line presents the annual difference between two groups, which helps to visualize the possible causality between the policy implementation and the expected outcome.

Table 22 and Figure 8 together show several noteworthy scenarios. First, the longitudinal trajectory based on the logged level of private R&D funds shows that the growth rate of private R&D funds in WCU universities during these ten years was increasing but at a very slow pace (logged value increased from 4.12 in 2001 to 4.81 in 2010). In contrast, Non-WCU universities grew much faster (logged value
increased from 2.08 in 2001 to 3.54 in 2010). The differences between two groups were reduced from 2.04 in 2001 to 1.27 in 2010. In general, over the first decade of 21st century, the growth rate of Non-WCU universities in the private R&D funds on average increased much faster than WCU universities.

To explore the possible causality caused by the policy intervention, this study divides these ten years into the baseline period and the follow-up period, investigating the change in the growth rate of private R&D funds before and after the policy intervention.

During the baseline period, the differences between WCU universities and Non-WCU universities at logged levels had been reduced, decreasing from 2.04 in 2001 to 1.72 in 2005. During the transition period of 2005 to 2006, there had a clear drop, decreasing from 1.72 in 2005 to 1.57 in 2006. Entering the follow-up period, the differences continually shrunk, decreasing from 1.57 in 2006 to 1.27 in 2010.

Based on the visualization of the growth trend in WCU universities presented in Figure 8, this study finds neither the crowding-in effect nor the crowding-out effect occurred following the policy intervention. However, between WCU universities and Non-WCU universities, there is a shrinking trend observed during the follow-up period. It indicates that the growth rate of Non-WCU universities on obtaining private R&D funds grew faster than WCU universities during the follow-up period. It indicates that after the policy intervention, Non-WCU universities were increasing their share on the private R&D market.
Figure 8:
Logged levels of Private R&D Funds: Average for universities in the WCU group and the Non-WCU group (One-Year Lagged)

To confirm this observation, the DD is employed to exam the average treatment effect on treated caused by the implementation of the WCU Project. The DDs and the corresponding standard errors are shown in Table 23. In Table 23, the negative coefficient of DDs suggests that the average Non-WCU universities outperformed the average WCU universities in terms of the growth rate of total private R&D funds by a factor of 3, statistical significance at 95% of confidence interval. This indicates that during the follow-up period the growth rate of total private R&D funds obtained by Non-WCU universities on average increased faster by 30% compared to WCU universities.
Table 23:

DD results for WCU’s Impact on the Private R&D Funds

<table>
<thead>
<tr>
<th>Dependent Variable</th>
<th>One-Year Lagged</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Coefficient</td>
</tr>
<tr>
<td>Post</td>
<td>0.678</td>
</tr>
<tr>
<td>WCU*Post</td>
<td>-0.309**</td>
</tr>
<tr>
<td>log(public_funding)</td>
<td>0.940***</td>
</tr>
<tr>
<td>log(faculty)</td>
<td>0.040</td>
</tr>
<tr>
<td>Constant</td>
<td>-2.803</td>
</tr>
</tbody>
</table>

Institution fixed effects: Yes  
Year fixed effects: Yes  
R-Squared: 52%  
Observations: 240  
Institutions: 24

$t$ statistics in parentheses  
* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

5.3.2 Changes in National Shares of Private R&D Funds

The results derived from the DD estimate implies that on average the growth rate of private R&D funds received in the group of Non-WCU universities increased faster than the group of WCU universities. But, based on the current evidence, it could be insufficient to argue that the group of WCU universities had experienced the crowding-out effect during the period of policy implementation.

In accordance with the longitudinal trajectory of the two groups in the aspect of obtaining the private R&D funds (refer to Table 24), it might be much more precisely
to say that while the group of WCU universities is securing their private R&D funds, the group of Non-WCU universities is gaining more from this market. Based on this observation, the following question should be: if the group of WCU universities did not lose their private R&D funds to the group of Non-WCU universities, where did the group of Non-WCU universities obtain those additional funds? In this section, this study uses the concept of the national share in the private R&D funds (Geiger & Feller, 1995) to explore the answer.

Geiger & Feller (1995) proposed that the most concise way to gauge a university’s participation in the research economy, and especially to measure change, is by its percentage share of total expenditures for academic R&D. This approach can obviate the confusion inherent in using current or constant dollars, percentage changes, or changes in rank. This study employs this approach, investigating the change in the share of private R&D funds of WCU universities, Non-WCU universities and a group of universities that are neither WCU universities nor Non-WCU universities. This study calls the third group of universities as the rest of universities.

Showed in Table 24, at the very beginning of the first decade of 21st century, the private R&D funds spent on university-based research were overwhelmingly taken by the group of WCU universities. In 2001, the group of WCU universities accounted for 70.74% of private R&D funds nationally. After 2001, the scenario that the group of WCU universities monopolized the private R&D funds began to change.

From 2001 to 2004, the group of WCU universities continually lost their national share to the group of Non-WCU universities and the rest of universities. In 2002, the group of WCU universities lost 8.18% of a national share compared to the previous year. The rest of universities took 5.39%, while the group of Non-WCU universities took the rest of 2.80%. In 2004, the group of Non-WCU universities replaced the rest
of universities as the biggest beneficiary of the WCU group’s lost in national share. By 2005, the group of WCU universities stopped losing its national share and increased its national share by 6.96%. And, this time, the group of Non-WCU universities became the biggest loser in the national share. The group of Non-WCU universities totally contributed 6.51% of its national share to the group of WCU universities, while the rest of universities contributed to the group of WCU universities another 0.45%.

Referring to the composition change of the national share before the WCU Project, two driving forces were changing the landscape of the national share. The first is the expansion of higher education. Since the 1990s, Taiwan higher education experienced a series of higher education expansion. Although the sizes of these new universities were relatively small compared to the old universities, the amount of these new universities was big. As shown in Table 24, these new universities were increasing their national share in private R&D funds until 2007.

The second is the significant impact brought by the scattered projects with the big private R&D funds. Different from the scientific publications, a number of private R&D funds that universities can receive are subject to the special preference of the private sector. For the small market like Taiwan, the scattered projects with big industrial endorsement flowing to certain universities could suddenly change the composition of the national share, as observed in 2004 of Non-WCU universities and in 2005 of WCU universities.

Compared to the period during 2001 to 2005, the development trajectory in the WCU group and the Non-WCU group became relatively stable after 2006. First, the group of WCU universities stabilized its national share and accounted for average 52% of national share. This scenario implies that the growth rate in the WCU group
generally was going along with national growth. On the other hand, the Non-WCU group experienced a clear continual upward trajectory. The national share that the Non-WCU group took increased from 13.96% in 2006 to 21.81% in 2010. This implies that the Non-WCU group was taking more national share. While investigating the change of national share, this study finds that the most of the share increase in the group of Non-WCU universities came from the loss of the group of the rest of universities in the private R&D funds.

Table 24:
Share of Private R&D Funds by Groups, 2001 to 2010 (One-Year Lagged)

<table>
<thead>
<tr>
<th></th>
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<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>2001</td>
<td>1,329.22</td>
<td>70.74%</td>
<td></td>
<td>13.27%</td>
<td></td>
<td>16.0%</td>
<td></td>
</tr>
<tr>
<td>2002</td>
<td>1,639.59</td>
<td>62.56%</td>
<td>-8.18%</td>
<td>16.07%</td>
<td>2.80%</td>
<td>21.4%</td>
<td>5.39%</td>
</tr>
<tr>
<td>2003</td>
<td>2,043.53</td>
<td>59.66%</td>
<td>-2.90%</td>
<td>15.50%</td>
<td>-0.57%</td>
<td>24.8%</td>
<td>3.47%</td>
</tr>
<tr>
<td>2004</td>
<td>2,285.77</td>
<td>52.28%</td>
<td>-7.38%</td>
<td>19.95%</td>
<td>4.45%</td>
<td>27.8%</td>
<td>2.92%</td>
</tr>
<tr>
<td>2005</td>
<td>2,527.48</td>
<td>59.24%</td>
<td>6.96%</td>
<td>13.44%</td>
<td>-6.51%</td>
<td>27.3%</td>
<td>-0.45%</td>
</tr>
<tr>
<td>2006</td>
<td>2,440.94</td>
<td>55.03%</td>
<td>-4.21%</td>
<td>13.96%</td>
<td>0.52%</td>
<td>31.0%</td>
<td>3.69%</td>
</tr>
<tr>
<td>2007</td>
<td>2,819.52</td>
<td>50.88%</td>
<td>-4.15%</td>
<td>14.71%</td>
<td>0.75%</td>
<td>34.4%</td>
<td>3.39%</td>
</tr>
<tr>
<td>2008</td>
<td>3,164.36</td>
<td>52.61%</td>
<td>1.73%</td>
<td>18.10%</td>
<td>3.39%</td>
<td>29.3%</td>
<td>-5.11%</td>
</tr>
<tr>
<td>2009</td>
<td>3,454.29</td>
<td>51.94%</td>
<td>-0.67%</td>
<td>19.52%</td>
<td>1.42%</td>
<td>28.5%</td>
<td>-0.76%</td>
</tr>
<tr>
<td>2010</td>
<td>3,748.26</td>
<td>51.97%</td>
<td>0.03%</td>
<td>21.81%</td>
<td>2.29%</td>
<td>26.2%</td>
<td>-2.32%</td>
</tr>
</tbody>
</table>
Who was leading the increase in the group of Non-WCU universities? The investigation of the distribution of change in the national share at the institutional level can help to identify which university had experienced the transformative change. To investigate the change in the national share at the institutional level during this period, this study divides this decade into the baseline period (2001-05) and the follow-up period (2006-10) for the following analysis.

Shown in Figure 9, the y-axis indicates the percentage change of the national share of private R&D funds from the baseline period to the follow-up period, while the x-axis indicates the percentage of the national share of private R&D funds during the follow-up period. Each dot represents an individual institution.

Figure 9 reveals two noteworthy scenarios. First, for the group of WCU universities, the distribution of percentage change in share is relatively concentrated compared to the group of Non-WCU universities. For the group of WCU universities, the range of percentage change is from 12.0% to -43.8%. For the group of Non-WCU universities, the range is much scattered, spanning from 95.8% to -59.1%.

Second, except for a university, the majority of WCU universities lost their private R&D share. Among 14 Non-WCU universities, five universities had experienced a transformative increase. For these universities with increasing institutional shares, their leading academic fields include the electric information and communication, biomedical science, oceanography and material science. Since these academic fields were not exclusive to the WCU group or the Non-WCU group, the academic fields should not be the decisive factor causing the observed change. One of the tentative explanations for this is the intention of the individual institution to find another financial resource to compensate their loss in the WCU Project. In general, this study finds that more Non-WCU universities were willing to cut into this market.
Before proceeding to the qualitative analysis, this study wraps up the main findings from the quantitative analysis. First, there is no compelling evidence to support the argument made by the traditional approach that the injection of extra R&D funds would lead to the divergence on the production of scientific publications between the group of WCU universities and the group of Non-WCU universities. This study shows that in Taiwan context the trajectories of two groups on the growth of scientific publications were parallel.

Second, this study finds a compelling evidence to support that the group of Non-WCU universities strategically increased their scientific publications in the highest prestige journal. This finding supports the alternative assumption proposed by this study that the university excellence initiative adopting the competition in its
selection process would lead to the convergence between the group of chosen universities and the group of non-chosen universities.

Third, the study finds that after the policy implementation the group of Non-WCU universities on average outperformed the group of WCU universities in terms of the growth rate of the private R&D funds. Yet, the occurrence of this scenario should not be attributed to the loss of the group of WCU universities in the private R&D funds, which theoretically refers to the crowding-out effect. Instead, in accordance with the change in the national share of the private R&D funds, this study shows that the additional private R&D funds obtained in the group of Non-WCU universities after the policy implementation mainly came from the loss of the group of the rest of universities.

This scenario implies that there had no direct impact resulting from the policy implementation on the group of WCU universities. However, the policy itself, in an unexpectedly way, was motivating the group of Non-WCU universities to aggressively compete with the rest of universities. The result of competition among the group of Non-WCU universities and the rest of universities brought the group of Non-WCU universities the additional financial resource to build up their capacity.
5.4 Paths to Transform

Why did the implementation of the WCU Project result in the convergence instead of divergence in the production of the highest prestige journals between two groups? And, why were Non-WCU universities motivated to obtain more private R&D funds? Three themes derived from the interviewing with 5 participants provide a part of explanations. These themes include (1) the varied extent of perception on competitive pressure; (2) the transformative change of Non-WCU universities’ commitments to research and (3) the unfavorable governance structure facing WCU universities. To maintain the confidentiality this study promised participants, this study reports the findings in the following using pseudonyms and without identifying any person’s specific position within the university.

5.4.1 The Varied Extent of Perception of Competitive Pressure

The WCU Project could result in the formation of the institutional-based competition among universities; however, not all of the universities perceived the competitive pressure in the same way as well as at the same level. Compared to WCU universities with a historical good reputation, Non-WCU universities were more desperate to prove their excellence through winning the WCU Project.

The interview shows this difference. Two participants from Non-WCU universities reports that their universities felt strong competitive pressure because of the implementation of the WCU Project. Wang, from a Non-WCU university, explained how the competitive pressure was created in the context of his university.

Wang said that the competitive pressure his university received was mainly from the competition with another two Non-WCU universities. These two Non-WCU universities and his university had very high degree of homogeneity in terms of the composition of academic disciplines. Before the WCU Project announced, this
extreme homogeneity had forced these three Non-WCU universities to compete the same group of faculty, students, and R&D funds.

The implementation of the WCU Project further intensified this competition. Because the public tended to believe that the education quality in WCU universities is superior to Non-WCU universities. Wang’s university was worried that if these two competitors won the status of the WCU University before his university did in next competition, his university would become less attractive to prospective students and other important resources. His response described how his university reacted to their first failure in the competition.

Even though our university did not win the WCU Project, this time, we did not just give up. We knew that MOE is going to have another competition five years later. Therefore, we had to be well prepared before the next competition coming. Otherwise, we could be at risk of being defeated by other two Non-WCU universities. This is the result that we really want to avoid at that time. (Wang)

Lee, another participant from a Non-WCU university, described another sort of the competitive pressure facing his university.

The county my university was located had a WCU university. The location of this WCU university was very close to my university. Because of the geographic location, these two universities were competing for the same student group. When the result of competition showed that my university lost the WCU Project and another one university won, my university felt a strong sense of anxiety. In
the following years, we all were striving for the next opportunity and preparing to prove our capacity. (Lee)

The unexpected reactions that the WCU Project brought to Non-WCU universities were also well perceived of by Chen, a senior officer in MOE.

The original idea of implementation of the WCU Project is to assign a certain amount of universities to become so-called “research-intensive universities” and support them dedicated to the research. The rest of unchosen universities were supported by another project encouraging these universities toward so-called “teaching-oriented universities.” However, I was aware of that some teaching-oriented universities, especially those ones were at the edge in admission to the WCU Project showed very strong intentions to come back for competition. This is not in our expectation. (Chen)

Why did not WCU universities perceive the competitive pressure as strong as Non-WCU universities? The response of Ann, from a WCU university, provided an explanation.

My university had several research fields that were well established and already had global reputations before the WCU Project started. In the local context, the research capacity of other competitors was not strong enough to challenge our leading status in these fields. Our pressure was mainly from our performances in the university ranking and this is the goal that MOE expected my university to achieve. (Ann)
Both of the participants from WCU universities and Non-WCU universities report the emergence of competitive pressure. However, WCU universities and Non-WCU universities perceived the competitive pressure in a very different way. The threats and consequences of failure facing Non-WCU universities could have direct impacts on the operation of the university in the domestic market, which the result is more visible and tangible.

Conversely, the pressure that WCU universities were dealing with is not as visible and tangible as Non-WCU universities were facing. Although WCU universities were concerned with their performances on the global ranking, the reality is they would not really lose their prospective students even if they did not make a transformative progress on the ranking performance. They would still be the first choice of the talented domestic students because of their historical reputation.

This study argues that just because of this fundamental difference between WCU universities and Non-WCU universities in terms of the consequence of the competition, Non-WCU universities were more aggressively than their WCU counterparts to commit the necessarily transformative change.

5.4.2 The Transformative Changes of Institutional Commitment to Research

Geiger (1996) stated that if there is a single factor that stands foremost in the enhancement of research competitiveness, it would be institutional commitment. This study argues that the transformative change in the scientific production of the highest prestigious journal observed in Non-WCU universities confirms this statement.

In this study, two participants from Non-WCU universities reported that the institutional commitments of their universities were dramatically changed to
accommodate the emergence of competitive pressure. Wang described how the leadership of his university decided to change their institutional commitments.

Before MOE initiated the WCU Project, the leadership was quite hesitated to endorse money to support the improvement of research infrastructure. After all, for a private university like my university, the research expenditure is a luxury investment and hard to collect the economic return. However, the WCU Project and the message delivered by its implementation quickly convinced the leadership to believe that improvement of research capacity is a necessary strategy to remain our competitiveness in the market. (Wang)

Lee pointed out how the transformative change of the institutional commitment to research reshaped the way his colleagues conducted research and stimulated their research productivity.

By the eve of the WCU Project, my university had just finished a wave of faculty’s turnover and substitution. Many junior faculties, educated in US research universities, were willing and eager to build up their research capacity. But, limited by the size of R&D funds each research project obtained and the lack of organized research units, most of the research works could only be conducted in the personal laboratory. Because the WCU Project emphasized the formation of research clusters and targeted on the cutting-edge research, our leadership quickly embraced these practices. We provided new research spaces and start-up funds to enlarge the scale of research topics with the potential to be
The involvement of the leadership in the formation of organized research groups became very actively and aggressively. (Lee)

The transformative change of institutional commitment to research observed in Non-WCU universities was not apparently in WCU universities. This is not saying that WCU universities did not commit efforts as much as Non-WCU universities did. Compared to Non-WCU universities, the commitments made by WCU universities is less transformative. Ann’s description helps to explain this scenario.

In my university, many research fields had been well established before the WCU Project. These research fields were already led by distinguished scholars, employing high standards while operating these research works. The injection of WCU Project funds provided these fields monetary support to expand the scale of research and explore other research directions. We also tried to build new fields based on our strengths. But, it seems not so successful. It required a lot of efforts for my university to build up the partnership with external research institutes. It was not only about the money but the long-term collaboration. (Ann)

Cheng’s explanation also helps to understand why the WCU Project did not bring the transformative change on the WCU universities.

Before the WCU Project, the research capacity of my university had been well recognized. We already had some remarkable achievements in certain cutting-edge research fields. With the financial support from the WCU Project,
we encouraged our faculty to continually focus on the cutting-edge research and invested on these prospective projects. (Cheng)

The reason why these WCU universities were chosen is that of their research performances, accumulated before the policy implementation. In these WCU universities, the institutional commitment to research had been well entrenched in their culture prior to the implementation of WCU Project. Unless WCU universities commit any further significant change beyond their running system; otherwise, it is hard to see any leap-jump transformation.

Unexpectedly, the emergence of competitive pressure stimulated the leadership of Non-WCU universities and motivated them to actively engage in the formation of new campus culture. The formation of the organized research units effectively integrated the research capacity of individual faculty and raised the efficiency of scientific production at the institutional level. This new production method was not new for WCU universities, though, but it brought a substantial change for Non-WCU universities.

5.4.3 The Unfavorable Governance Facing WCU Universities

The main weakness embedded in the traditional approach is its over-optimistic on the impact of monetary on scientific production. The traditional approach ignores that the injection of only one element (physical capital) could be both wasteful and disappointing if the university governance has not been modernization.

Robert & Louis (2015) studied the “University Excellence Initiative” in French higher education system and concluded that the remaining bureaucratic model of university governance should be held accountable for the insignificant improvement of its research universities on the ranking performance. Aghion et al. (2010)’s
comparative study of European and US universities also argued that the governance was, along with funding, the main determinant of world class universities.

In this study, two participants also reported that the unfavorable governance could be one of the reasons preventing the occurrence of transformative change in WCU universities. Chen described the obstacles facing WCU universities as below.

*Originally, MOE attempted to release the affiliation of national universities with the government that can allow these universities to operate in line with the new personnel and accounting system independent from the government line. MOE believed that this reform attempt can improve the efficiency of national universities’ operation. However, the reform attempt was postponed. During the whole period of implementation of the WCU Project, these extra R&D funds were still subject to the rules, conventions, and requirements applied to government agencies. The leadership of these WCU universities had been troubled by this rigorous system and suffered by its inflexibility. (Chen)*

The unfavorable governance also prevented WCU universities from realizing their strategic plans and from concentrating efforts on the breakthrough projects. Ann pointed out the dilemma that the leadership of his university was facing when allocating the additional funds.

*The budgetary allocation of this extra R&D funds was always a challenging task. Saying that the leadership was considering increasing financial commitments on certain research fields, at this moment, other fields would come and argue that they also demand more investment on their projects. For most of the time, this*
extra R&D funds would be spread over to all the fields equally. After these politics compromise, it always ended up with that the leadership had no sufficient resources to realize the strategic plans that could lead to a breakthrough development. (Ann)

The cores of the favorable governance include the complete institutional autonomy (Salmi, 2009) and the efficient leadership (Aghion et al., 2008). The former indicates that universities can manage their resources with agility and quickly respond to the demands of a rapidly changing global market; while the latter indicates that the dynamic reforms taking into account long-term institutional interests can be decided upon without undue delay. Unfortunately, during the period of the WCU Project both of these two aspects were not addressed effectively. Even today, the unfavorable governance in the higher education system is still a pending agenda.
Chapter 6: Conclusions and Policy Implications

6.1 Conclusions

6.1.1 Competition, Autonomy and Scientific Publications

The findings derived from this study are profoundly in the theoretical and the practical aspects. In the theoretical aspect, using Difference-in-Differences design, this study shows the implementation of the “University Excellence Initiative” like the WCU Project did not necessarily cause the divergence on the growth of scientific production between chosen universities and non-chosen universities. This study further proves that when the measurement variables are divided into different quantile groups based on the quality of journals, the convergence on the growth of scientific production in the most prestigious journal between two groups are observed and confirmed following the policy intervention.

In accordance with the findings derived from the interview, the transformative change observed in non-chosen universities can be attributed to the competitive pressure resulting from the implementation of the WCU Project. The emergence of stratification of higher education due to the WCU Project created the competitive pressure. And, this competitive pressure forced non-chosen universities to reshape their institutional commitments toward research. Noteworthy, their transformative change not only reflected on the change of institutional missions. Specifically, these rising universities emulated the actions adopted by WCU universities before the policy intervention and employed these actions to increase their efficiency of science production. The actions employed by these non-chosen universities during this period include the formation of research clusters, the increasing expectation for faculty’s research performance and the provision of start-up funds.
The diffusion effect of the WCU Project and the changed behaviors confirmed and observed in non-chosen universities adds the evidence to the arguments proposed by the organization theory (Bowen, 1980; James, 1990; Harwood, 2010). The revenue theory of costs (Bowen, 1980) pointed out that the dominant goals of HEIs are educational excellence, prestige, and influence. In higher education, the quality of education is always hard to be measured. However, the World Class University Project confers the chosen group of universities with the title of “Excellence”. As a result, the World Class University Project itself becomes an official signal system facilitating the differentiation of the quality in education.

Weisbrod et al. (2008) pointed out that the prestige like “Excellence” attached to the chosen universities can bring unique advantages for universities to select students with more institutionally desirable characteristics. In the higher education market, this advantage becomes even more apparently as the higher education system faces an imbalance between supply and demand. That is, when higher education becomes universal education, in order to ensure their competitiveness in the market, universities have little choice but to differentiate themselves from other universities.

Harwood (2010) argued that under this circumstance, the most avid status-seeking institutions would be in the middle of the status ladder, where administrators are particularly desperate to be recognized by their “superiors.” Academic leaders at mid-tier institutions are more eager to differentiate themselves from their counterparts. In this study, the non-chosen universities were those at the edge to admission to the chosen group of universities. The institutional changes after policy intervention described by the interviewees serving in the non-chosen universities precisely matched the Harwood (2010)’s prediction.
If the transformative change observed in non-chosen universities is unexpected, the absence of leap-jump change observed in chosen universities following the policy intervention is not following policymakers’ expectations either. However, in accordance with the growing literature investigating the association between the university's governance and science production, the observations in chosen universities should not be so shocking. While “University Excellence Initiative” became the primary strategy in those countries involving in the establishment of the research universities, Salmi (2009) warned that in addition to the abundant resource devoted to universities, the favorable governance features that encourage strategic vision, innovation, and flexibility that enable institutions to make decisions and to manage resources without being encumbered by bureaucracy is also a decisive factor for the development of World Class University.

Aghion et al. (2010)’s empirical study further supports this argument. They studied European and American universities and concluded that the degree of university’s autonomy is positively associated with its research production. They further argued that a combination of autonomy and competition makes universities more productive. Robert and Louis (2015) studied French research universities and reached a similar conclusion. They reported that in French research universities, university presidents are constrained by the interventionism of the government—with its many decrees, regulations, and procedures that hamstring their management of the careers of university professors and researchers. Robert and Louis (2015) argued that the unfavorable governance structure in French research universities compromised the impacts that the provision of additional funds can generate.

What Robert and Louis (2015)’s observations in French research universities to the certain degree are happening in Taiwanese research universities as well. In
accordance with the findings derived from the interviewees, the inflexibility encumbered by bureaucracy deters any individual institution which sincerely desires to innovate. Moreover, the currently unfavorable governance makes leadership job consists more of mediation than of action.

6.1.2 Policy Design, Public R&D funds and the Private R&D funds

The findings derived from this study find no compelling evidence to show neither the crowding-in nor the crowding-out effect occurred in WCU universities. However, this study finds that Non-WCU universities were driven by the WCU Project to increase the growth rate in the private R&D funds. The group of Non-WCU universities performed more actively in terms of cutting into this market compared to their counterpart in the group of WCU universities.

This study argues that the design of the WCU project should be held accountable for the lack of transformative change in the group of WCU universities. The WCU Project was a hundred percent government-financed project. There has no requirement for applicant universities to provide the matching funding collected from the private sector or the institution itself. While reviewing the research capacity and the development plan, the university’s capacity on the basic research obtained more emphasis during the selection process. To the certain degree, the WCU Project itself was focused on the research capacity in the basic research. Only very few attentions were given to the formation of university-industry cooperation in the selected institution. As a result, the WCU universities lacked a strong incentive to conduct any structural reform.

The lack of strong incentive in WCU universities to change reflected on two concrete aspects. First, in WCU universities the review criteria used for the decision of faculty promotion was still heavily relied on faculty’s research publications rather
than their impact on the technological advance. The awarding system designed for faculty had been receiving a plenty of criticism from the society because it encouraged faculty to choose the research topics that are welcome by the international scientific community instead of helping the local industry to deal with the technological problems. Second, in WCU universities the supporting system at the campus level to facilitate the university-industry cooperation was still relatively fledgling. Most of the technology transfer offices (TTO) in universities were comprised of administrative staffs instead of professional technology managers. The cultural conflict between the technology managers and researchers always resulted in the high turnover rate of those newly recruited managers. Until today, WCU universities are hesitated to invest the formation of technology transfer offices to support the linkage between academy and industry.

To wrap up, although the WCU Project envisioned the injection of public R&D funds can increase the private R&D funds, the growth rate of private R&D funds in WCU universities did not increase as the expectation of policymakers. This study argues that this result was due to the loose connection between the goals of policy and the design of the policy instrument. The assumption of the linear association between the public investment and the private investment underestimates the complexity of university-industry cooperation. While the policy down to the campus level, the unchanged campus culture, as well as the lack of strong supporting system, deterred the possible transformative change.

On the other aspect, the unexpected growth observed in the group of Non-WCU universities in the private R&D market is also noteworthy. This study contributes the occurrence of this scenario to the spillover effect caused by the emergence of competition. As mentioned in the previous section, the competition resulting from the
implementation of WCU Project drove the group of Non-WCU universities to see the accumulation on the research performance as the prime strategy to build up the reputation of good quality. The change of institutional commitment was motivating this group of universities to compete for alternative R&D funding resources and bolster their research capacity. This argument is supported by the longitudinal trajectory indicating that most of the share increasing in the group of Non-WCU universities came from the loss of the group non-research-intensive universities (referring to Table 24 of Chapter 5). In this sense, the effect on the implementation of WCU Project on the landscape change in the private R&D funds did not necessarily bring a direct impact on the group of WCU universities but in an indirect way have an impact on the group of Non-WCU universities.

6.2 Policy Implications

6.2.1 The Value of Open Competition on Research Capacity

In the practical aspect, this study provides a concrete evidence to show the value of open competition. The process of competition itself facilitated the transformation of Non-WCU universities and stimulated their growths on scientific production. For the nation, the rising and flourishing of these new competitors can be helpful to keep leading universities staying alerted on the one hand. On the other hand, such continually intellectual competition between universities is necessary for the sake of maintaining the dynamics of the national innovation system.

The policymakers involved in the formation of University Excellence Initiative always struggle with the decision on the amount of chosen institutions to receive this special funds. For the US, where concentrates most of the research universities in the world, the number of research universities is also a chronic question. In 1960, the US President’s Science Advisory Committee Report (1960) called for doubling the
number of research universities from between 15 and 20 in 1960 to 30 and 40 in 1983. Rosenzweig and Turlington (1982) pointed to “perhaps fifty to seventy-five in all” research universities. By 1992, the US President’s Council of Advisors on Science and Technology proposed, in its “Renewing the Promise: Research-Intensive Universities and the Nation”, that American should have 175 universities within this category.

Regardless which number should be, what the rest of world really should learn from the US’ experience is its incentive structures that include the key influences of competition and emulation between institutions and academic faculty, all of which are framed by resource appropriation modes that are responsive to market influences (Aghion et al, 2010; Robert & Louis, 2015). In endeavoring to fulfill their multiple missions, US research universities succeed in assembling levels of resources per graduate student and per professor that are higher than anything we have observed for comparable institutions elsewhere in the world.

Competition is a treadmill that can increase in speed and steepness over time. Increased efforts to acquire the right factors or combination of factors by universities are necessary to maintain their status in the face of actions by dominant institutions and new entrants. Such competition for financial resources within and between universities is contributed to the success in US research universities (Feller, 1996; Geiger, 2004).

Since there has no magic formula to say how many research universities should be appropriate for a nation, this study suggests that instead of concerning the amount of research universities, having a well-designed competition mechanism that stimulates the intellectual competition should worth policymaker’s more attentions.
6.2.2 Sustainability of Higher Education

While this study points out the benefits brought by the competition, the by-products accompanying with the intensified competition for research funds and prestige should receive equal attention. Among these by-products, the phenomenon of “academic drift” (Riesman, 1956) requires policymaker’s most attentions. Academic drift is a consequence of increasingly shared values or attempts by non-research universities to increase their structural and programmatic similarity to research universities. The mimetic behavior for aspiring institutions that wish to become research universities is also diminishing the diversity of higher education (Morphew, 2009). Salmi (2017) further warned that the potential “adverse consequences” that “University Excellence Initiative” could have on teaching quality and student diversity.

Higher education is a complex integrated system with multiple facets. The narrow range of criteria used in today’s university ranking created a distorted vision of educational success and fail to capture the essential elements of an education (OECD, 2012). It also leads the higher education to fail to response the demands from students with varied academic preparation and educational expectations. The society would start losing their confidences on higher education if the university cannot well prepare their graduates for the future labor market.

In this sense, scholars repeatedly argued that government should dedicate more efforts to the construction of higher education system that encompass a wide range of good quality and well-articulated tertiary education institutions with distinctive missions (Salmi, 2015). The good classification of the higher education system is able to meet collectively the great variety of individual, community and national needs that characterize dynamic economies and healthy societies.
The strategy to balance the mission of higher education on research and education is clear; however, the path leading to the goal is still vague. In the scientific community, the criteria and the reviewing process designed to distinguish the quality of research have been well developed. However, the collegiate learning assessment that is aimed to reflect the progress of students’ learning is still under development. The lack of well-articulated accountability with respect to the student learning outcome inevitably prevents the society from appreciating the efforts made by any individual institution to help student success. The existence of this shortcoming deters the formation of the incentive mechanism in the higher education market that could drive the part of universities to build on their reputation based on the provision of a good college education.

This study argues that the competition itself should not be blamed for causing the “academic drift”. The introduction of the competition can break the organizational inertia inherent in the centralized controlling system. For policymakers in the higher education, this study suggests that while considering the policy instruments aimed to realize the classification of higher education, beyond the financial incentives or mandatory orders, the transparency of educational quality should require the most of attentions and efforts collectively contributed by the whole system. The value system that appreciates and rewards the efforts on facilitating students’ learning could only be build up while the comparable information is accessible to all stakeholders.

6.2.3 The Reform of Favorable Governance

Salmi (2009) argued that the success in the US higher education should be attributed not only to its wealth but also to its relative independence from the state, the competitive spirit that encompasses every aspect of it, and its ability to make academic work and production relevant and useful to society. In Aghion et al.
(2010)’s comparative study of European and US universities, they also argued that the governance was, along with funding, the main determinant of world class universities.

Through investigating the WCU Project, this study supports this argument by showing that without favorable governance the funds could not be used in their best way. The expected effects driven by the provision of additional funds on the beneficiary universities could be compromised during the process of bureaucracy.

Compared to the creation of new funding resource and the introduction of the competitive environment, the reform of governance structure is a more challenging task. The reform of governance always involves the redefinition and redistribution of stakeholders' influential powers. The existing power structure is always representing a collective belief in a community with respect to how the university should be governed. Therefore, it is not surprising to see the attempt on the reform the governance continually receives resistance from the stakeholders who are having the superior power.

Based on the findings from the interview there have at least two aspects demanding the effective actions with respect to the reform of governance structure in Taiwan’ context. The first is the incorporatization of leading national universities. Like Germany and French universities, the national universities in Taiwan are government entities constrained by civil service employment rules and rigid management controls. Under the legal framework, it is almost impossible to pay higher salaries to reward the most productive academics or to attract world-class researchers. The establishment of the research building and the procurement of the leading-edge facilitates always take a very long period to complete.

More profoundly, under this conservative campus culture, the spirit of entrepreneurship and innovation is hard to flourish. As reported by the interviewees in
this study, the funds that could be used to concentrate on several ambitious projects eventually were mainly spent on the expansion of the originally well built-up projects. This is a relatively safe choice but also deters the occurrence of any transformational change.

The second is the reorganization of the decision entity at the leadership level. Today, the national universities in Taiwan still follow so-called “republic of faculty” model for their decision-making structure. The republic of faculty model means the academic staffs run the institution, and external people have very few and limited influential powers on the decision (Sultana, 2012). Under this decision-making model, the decision entity tends to protect faculty’s interests instead of best serving its customers. This approach eventually would lead universities to less responsive to the change of external environment and fail to respond accordingly. Aghion et al. (2008) argued that “having significant outside representation on the board can ensure that dynamic reforms taking into account long-term institutional interests can be decided upon without undue delay.” For the advance of Taiwan research universities, if the reformation of decision entity at campus level once again is added to the policy agenda, creating a board of trustees with the influential involvement of external representatives deserves policymakers’ more serious considerations and real actions.
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