BRAIN CIRCULATION: INTERNATIONAL STUDENT MOBILITY, 
EXPATRIATE RESEARCHERS, AND INTERNATIONAL RESEARCH COLLABORATION

A Dissertation in 
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by

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ABSTRACT

International student mobility is traditionally considered to result in “brain drain” from developing countries and “brain gain” for developed countries. More recently, many developing countries have attracted an increasing number of returning scientists, which is described as “brain circulation.” This relatively new concept, however, still downplays the role of individuals who do not return to their home countries and work in the host countries. Specifically, there is a lack of discussion on how expatriate researchers may contribute to their home countries through international research collaborations. Therefore, this dissertation focuses on bridging this apparent knowledge gap by integrating analyses of international student mobility, expatriate researchers and international research collaboration. First, I study the factors that influence the number of international students from origin countries to the United States. Second, descriptive analysis is conducted to illuminate the connection between foreign-born college graduates and foreign-born researchers in the United States. Finally, I examine the extent to which expatriate researchers contribute to their home countries through international research collaboration. The results reveal that student mobility to the United States has been mainly driven by the economy, the population for tertiary education, and the academic capacity of countries of origin. Further, there is a tight connection between the number of international students and expatriate researchers. Expatriate researchers are found to have a significant impact on the research collaboration between their home and host countries, implying an important form of brain circulation. However, not all countries can benefit from talent mobility. In particular, results suggest that countries with under-developed economy and education are unable to take advantage of their
expatriate researchers. Moreover, this study reveals different degrees of “homophily” between origin countries and the United States in international student mobility and research collaboration. Particularly, brain circulation in the form of research collaboration is more likely to happen between the United States and countries with similar academic capacity and development status. Therefore, developing countries need to make intentional efforts to advance their education and research capacity before they can significantly benefit from international student mobility and research collaboration.
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CHAPTER 1
INTRODUCTION

In the era of knowledge economy, a highly skilled labor force is valued and pursued by countries that seek fast economic growth and global competitiveness (Barro, 1991; Benhabib & Spiegel, 1994; Tremblay, 2005; Chapman & Chien, 2014). With increasing globalization in recent decades, the population of international students in higher education has grown at an unprecedented rate. Nevertheless, the majority of international students move lopsidedly from developing countries to developed countries. This pattern is often mentioned as “brain gain” and “brain drain” to juxtapose the win-lose status of countries in the competition for talent.

A few researchers propose that international student mobility is not necessarily a zero-sum game because developing countries can also benefit from the flow of international students both academically and economically (Cao, 1996; Wildavsky, 2010). The polarized view of brain gain and brain drain may inaccurately portray the consequences that international student mobility brings on developed and developing countries. As a result, researchers have advocated for a different set of phrases such as “brain exchange” and “brain circulation” to characterize the impact of student mobility from a long-term mutual perspective (Cao, 1996; Saxenian, 2002; Bhandari & Blumenthal, 2011). Still, there is a dearth of empirical studies on how and to what extent international student mobility contributes to the research and development in their home countries.

This dissertation aims to deepen our understanding of the antecedents that determine international student mobility and its influence on the research capacity of
countries of origin which have been considered as sufferers due to brain drain, particularly the developing countries. More specifically, this study will explore the factors governing international student mobility by integrating datasets from Institute of International Education (IIE) and other data related to country’s characteristics such as economy, demography, geography and other factors. Also, National Survey of College Graduates (NSCG) data will be utilized to describe foreign-born students who stay in the United States after graduation. NSCG data will also be aggregated with the Web of Science data (WOS) on research publications to examine the relationship between expatriate researchers and the research collaboration between their home countries and the United States. This will help further explain the mechanism of brain circulation in terms of how expatriate scientists may contribute to the research and development in their home countries.

**Background**

The primary driving force behind the international student mobility is the increasingly globalized and knowledge-based economy (Altbach & Teichler, 2001). Many students migrate to seek quality higher education, better employment opportunities and higher salaries from their experience of studying abroad (Wiers-Jenssen, 2007). Countries, research institutions, and companies also care about the inflows and outflows of the research workforce since the mobility can measure how effective they are in the global competition for talent (Chambers, Foulton, Handfield-Jones, Hankin & Michaels, 1998; Lawson, Fernandez-Zubieta, Kataishi & Toselli, 2015). For universities and research institutions, their international students, professors, courses, research capacity,
and even cross-border branch campuses are closely associated with their global competitiveness (Wildavsky, 2010). On the country level, developing countries aim to catch up with developed countries in their national economy by developing their capabilities in science and technology, to which academic exchange is considered an important approach. Meanwhile, developed countries hope to not only maintain the quality of higher education at home but also generate more revenue through dominating the market of international education and gain a valuable pool of skilled immigrants by recruiting talented international students (Hawthorne, 2008; Chapman & Chien, 2014).

Consequently, international student mobility is rapidly growing worldwide. The total number of international students around the globe increased by 65% between 2000 and 2010 and reached a total of 3.3 million in 2010 (Bhandari, Belyavina, & Gutierrez, 2011). In this huge, growing pie of international students’ population, countries make up very different shares. The United States received nearly 16.4% of the global total of international students which was 4.5 million in 2012, almost twice as many as the United Kingdom, the second top host country for international students (IIE, 2014). Also, among the top ten destination countries for U.S. students who study abroad, except for China, all others are developed countries. Due to the long-term, imbalanced flow of international students, countries that have more outbound than inbound students tend to lose highly skilled individuals, while the top host countries retain a large number of highly skilled immigrants who make contributions to their economic growth. This phenomenon is often referred to as “brain drain” and “brain gain” (Johnson & Regets, 1998; Findlay, 2011).

However, brain drain is not necessarily permanent for developing countries. First of all, the restriction of immigration policy and the highly competitive labor market in
host countries may push international students back to their home countries. In addition, many international students choose to return to their home countries after graduation due to different reasons, such as more career opportunities in developing countries, cultural affiliation and recognition, and being closer to family (Bhandari & Blumenthal, 2011; Franzoni, Scellato & Stephan, 2015). More importantly, some developing countries take measures to subvert their disadvantage in their status in the global network of student mobility. For example, China has provided attractive policy and financial support for universities to construct its own world-class research universities and has launched “Thousand Talents Plan” to recruit scientists and engineers overseas to join the research workforce in China. Saudi Arabia establishes research universities and collaborates with U.S. universities to set up branch campuses so as to enhance their attraction to domestic students (Wildavsky, 2010). Driven by such policies, a growing number of graduates and scholars return to their home countries and work in higher education and research fields.

Apart from the returning talent, outbound talent is regained in another way. As the knowledge-based economy gets increasingly globalized, the academic exchange can easily occur beyond space. Some developing countries efficiently utilize “diaspora knowledge networks” and use expatriate experts for development at home (Meyer & Brown, 2003; Recherche, 2006). Foreign-born professors in the United States cooperate with the researchers and institutions in their home countries without returning home (Tremblay, 2005). Data display that the number of collaborative publications between the United States and other countries grew fast, from 107,124 in 1975 to 405,793 in 2012 (Web of Science, 2013), which results from the increasing educational exchange, expanding expatriate knowledge networks and more convenient communication methods.
today. Therefore, rather than simply cause a brain drain, international student mobility may have brought a more mixed impact on the developing countries in recent years.

**Statement of the Problem**

Conceptually, there has been a good deal of discussion on terms regarding the flows of talent, such as “brain exchange,” “brain drain,” “brain gain,” and “brain waste.” “Brain exchange” implies a two-way flow of expertise between origin and destination. “Brain drain” or “brain gain” tend to be used where the net flow is heavily in one direction. “Brain waste,” however, refers to situations where the highly skilled migrate into employment that does not require the skills they own (Salt, 1997). Another term that appeared subsequently is “brain circulation,” which has not been consistently defined but usually is used to describe the fact that graduates or scholars abroad return to their home countries.

There is no consensus regarding the definition of “brain circulation”. Early studies had a limited view of circulation and only considered that people returning to their home country are the embodiment of brain circulation (Cao, 1996; Johnson & Regets, 1998). Very few researchers later expanded the meaning of brain circulation by applying it to cases where U.S.-educated, foreign-born engineers made connections with home countries and over time contributed to regional development in their home countries while working in the United States (Saxenian, 2002; Saxenian, 2005). However, the role of the invisible connection between expatriate talent and their home countries was not always mentioned as a type of brain circulation in most of the previous studies on this topic.
In general, the traditional concepts of brain drain and brain gain view the outcome of mobility in an oversimplified way—staying in the host country or returning to the home country, by emphasizing on the physical location of international students after graduation and considering the choice of stay or return as the end of mobility. The traditional concepts have their ground. They were appropriate two decades ago or earlier when cross-border communication and academic cooperation were inconvenient. It was difficult for students who studied abroad and did not return to establish a cooperative relationship with researchers in their home countries. Nowadays the increasingly frequent and tight global connection is changing this situation for many countries, which enables the fulfillment of "brain circulation" in an intangible form, and thus requires a better-defined "brain circulation." However, the discussion of "brain circulation" in this study does not serve the purpose of replacing the concept of "brain drain" because countries vary vastly in their development phases. Some countries still fall behind in economy and research and have not greatly benefited from international student mobility and collaboration, although globalization as a whole proceeds rapidly in recent decades. For disadvantaged countries, "brain drain" can better describe the adversity that they are facing. Thus, it can be arbitrary to generalize all countries using only one concept.

In this dissertation, "brain circulation" is considered to include three distinct but interconnected phenomena: 1) students flow from one country to another; 2) scientists return to home countries from abroad; 3) scientists do not return but work in host countries and may have a collaborative relationship with their home countries. These three categories are not mutually exclusive; instead, they stand for mobile talent who are at different stages of mobility and in different situations after graduation. Therefore, they
combined explain the rich content of “brain circulation” and can better summarize how international student mobility happens and how it can benefit both the home and host countries in the global knowledge economy. In previous studies, “brain drain” and “brain circulation” proposed by most researchers only cover the first two phenomena. When the group involved in the second phenomenon is much smaller than that in the first, it is considered to be “brain drain”; on the opposite, it is “brain circulation” (Cao, 1996; Johnson & Regets, 1998). Only a few researchers are found to view the third phenomenon as a part of brain circulation (Saxenian, 2002; Saxenian, 2005; Mahroum, Eldridge & Darr, 2006). This dissertation will have a systematic and complete view of brain circulation that integrates these three aspects, with an emphasis on the third.

About methodology, previous studies either adopt a qualitative approach by focusing on facts to illustrate “brain circulation” or conduct a limited descriptive data analysis due to the restriction of data. Although they have lent strong support to this study, their limitations have left some space for further exploration. Studies that utilize data on mobile researchers employ advanced statistical analysis contingent on their research questions, including gravity regression models, Poisson regression models, and negative binomial regression models (Van Bouwel & Veugelers, 2009; Franzoni, Scellato & Stephan, 2015; Fernandez-Zubieta, Guena & Lawson, 2015). Despite different research topics and data, they provide empirical experience for the selection of models in this study.

Based on proper quantitative analyses using data from a variety of sources, this study aims to settle the confusion in the use of “brain drain” and “brain circulation” and clarify the comprehensive meaning of "brain circulation." In particular, the study explores
the pattern of the relationship between country’s characteristics and international student mobility and examines how international students who stay abroad after graduation contribute to the research collaboration between their home and host countries.

This study is mainly guided by the following research questions:

1) How have characteristics of countries, such as economy, population, quality of higher education, geographic distance, language and polity type, influenced their student mobility into the United States?

2) How many foreign-born, U.S.-educated graduates have stayed in the United States after graduation? And how many of them are engaged in research activities in the United States?

3) To what extent have foreign-born, U.S.-educated researchers in the United States contributed to the research collaboration regarding academic publications between their home country and the United States?

**Significance of the Study**

Theoretically, brain circulation has not been clearly and adequately defined. This study aims to fill this gap and explore the concept of "brain circulation" by viewing international student mobility as a dynamic, long-term process rather than a static one. This study will examine whether “brain circulation” can properly describe the whole pattern of international student mobility and academic collaboration today. Also, international students are valuable human capital to both developing and developed countries (Benhabib & Spiegel, 1994). Thus, it is important to thoroughly understand the factors governing the flow of international students across borders and be cognizant of
the evolving nature of academic exchange among countries in the globalized knowledge-based economy.

Methodologically, brain circulation in the form of research collaboration between expatriate researchers and origin countries has not been under scrutiny using quantitative methods. Related studies focus on the group of mobile post-doctoral researchers or scientists who directly emigrate in their work rather than the population of international students who stay abroad after graduation (Fernandez-Zubieta, Guena & Lawson, 2015; Franzoni, Scellato & Stephan, 2015). This study will employ statistical models to check and quantify the influence of graduates who stay in the host country on the research production in their home country. With a significant result, brain circulation is likely to be confirmed; otherwise, brain circulation may not stand as a common pattern yet.

In practice, this study provides information for developing countries to examine their status in the global competition for talent. Researchers suggest that developing countries have different views of student mobility. Some countries consider student mobility a loss of talent; some others regard it more positively as “brain circulation” (Vincent-Lancrin, 2004). Since developing countries are not at the same pace of preventing or alleviating “brain drain,” not all developing countries are ready to gain benefits from brain circulation (Saxenian, 2005). Through the analysis of brain circulation, policy makers, university administrators, and researchers in developing countries, especially those in a brain drain situation, may find it helpful to know how their work may bring in more talent back home and how they can make use of the intellectual resources overseas for domestic development.
Moreover, researchers and policy makers in developed countries may understand better from this study how developing countries can benefit from global student mobility and stay abreast with developed countries in higher education. For developed countries, on the one hand, it is essential for them to keep their advantage in education and research worldwide by attracting foreign talent; on the other hand, their advantage may shrink as other countries benefit from the academic exchange. Therefore, they need to be informed of the change in the global market of higher education and come up with strategies to maintain their competitiveness in the global market.

Finally, for individuals such as scholars and students, this dissertation shows that higher education has been connected worldwide and that there is no strict national border in academia. It is important and helpful to have a global view of education and research because educational exchange and research collaborations may bring great progress and benefits to researchers, institutions, and even countries.

**Definition of Key Terms**

Countries have distinct definitions of “international students” which are specific to their national education systems for the purpose of data collection and the publication of enrollment statistics (Verbik & Lasanowski, 2007). International data from different sources, such as Organization for Economic Cooperation Development (OECD) and United National Education, Scientific and Cultural Organization Institute for Statistics (UIS), also identify “international students” in their own ways. This study utilizes the dataset from Institute of International Education (IIE) and therefore follows its definition
of international students, which refers to “non-immigrant international students in the United States on temporary visas at the postsecondary level” (IIE, 2013).

This study also mentions the notions of “developing countries” and “developed countries” frequently. According to World Bank, developed countries are those highly industrialized countries, and a developing country is one in which the majority lives on far less money and with far less basic services than the population in developed countries. For analytical purpose, developed countries are also called high-income countries, and developing countries can be classified into upper-middle-income countries, lower-middle-income countries, and low-income countries (World Bank, 2012).

Compared with developed countries, developing countries are a more heterogeneous group because they are at different phases of development. For example, middle-income countries have made significance efforts to be competitive in the global knowledge economy. As pointed out by World Bank, middle-income countries have made great strides in successfully entering the world economy and are creating better-paying jobs, better and more equitably available education and health services, and are investing in infrastructure improvements (World Bank, 2012). Thus, these countries tend to have more strengths in higher education and research and play a different role in international education exchange and research collaboration than lower-income developing countries.
CHAPTER 2
LITERATURE REVIEW

This study is built upon a rich volume of literature that focuses on three major topics. The first part focuses on the role of higher education and international students in the knowledge economy. Human capital is considered to be the core of knowledge economy, and this study advocates that international students are important human capital in the global knowledge economy. To understand what determines the mobility of international students between countries, the second part of literature review explores the characteristics of countries, such as economy, population, education, language, polity and geography. Finally, student mobility leads to uneven distribution of highly skilled talent because graduates can choose either staying in the host country or returning to their home country. Thus, the third part of literature review discusses the meaning of “brain drain” and “brain circulation” proposed by researchers who have taken different stances in previous studies.

International Students as Human Capital in the Knowledge Economy

Researchers share common views of what constitutes knowledge economy. The key component of the knowledge economy is considered to be a greater reliance on intellectual capabilities, particularly technical innovations and creative use of knowledge, than on physical inputs, such as cheap labors and natural resources (Porter, 1990; Powell & Snellman, 2004). Knowledge economy, therefore, is the use of knowledge to generate tangible and intangible values. Technology and in particular knowledge technology help to transform a part of human knowledge to machines, which further generates economic
values in various fields (Amidon, Formica & Mercier-Laurent, 2005). Moreover, human is viewed as a key to the development of knowledge economy (Guruz, 2008; Williams & Balaz, 2014). Unlike the industrial society in which technologies and industries are based on the results of scientific research and innovations and rely more on large-scale, mass-producing manufacturing, knowledge economy is characterized by information and communication technologies that heavily rely on human intelligence. Since human resource unevenly disperses and is freely mobile, the knowledge economy is also featured with being global. As knowledge, labor and other factors of production can be outsourced across borders, the transformation from an industrial to a knowledge economy has been accompanied by the emergence of a worldwide labor market and global networks for the production of both goods and services (Guruz, 2008).

As knowledge economy focuses on human and human’s creativity rather than physical resources, the development of a nation’s knowledge economy must rely on an educated and skilled population that can create, use and share knowledge. According to World Bank (2013), education and training are one of the critical requisites for a country to be able to fully participate in the knowledge economy. Researchers also have had an abundant discussion on the role of education and human capital in the knowledge economy. In general, economists consider education as the main measurement of human capital in quantitative analysis and have confirmed the positive influence of education on national economic growth (Barro, 2001; Hanushek & Kimko, 2000; Hanushek, Jamison, & Woessman, 2008). Although some other researchers do not find a significant relationship between human capital and economic growth, they detect a positive effect of human capital on factors that contribute to productivity (Benhabib & Spiegel, 1994).
The studies of human capital reveal the importance of education, particularly higher education, in building up human capital stock for a nation. When Kyriacou (1991) constructs the index of human capital stocks of a nation, he attributes a much higher coefficient to higher education (8.09 for higher education, 4.44 for primary and 2.66 for secondary education). Higher education is considered to be the most relevant to fostering highly skilled labor force that can produce or adopt advanced technology, while primary and secondary education is a necessary channel to higher education. Also, Salt (1997) points out that “highly skilled” is usually defined as having a tertiary educational qualification or its equivalent.

Similarly, many researchers put great emphasis on higher education and have fully recognized the importance of universities in the knowledge economy. For example, Geiger and Sa (2008) consider that universities have three traditional roles: teaching, research, and outreach. Universities are now increasingly viewed as a source of innovation for a growing economy. Particularly, research universities are expected to not only produce innovations but also transfer innovations to industry for technology-based economic development. In addition, universities are not only producers of research, but also a generator of human capital in the form of highly skilled labor that drives economic development (Etzkowitz & Leydesdorff, 2000; Schiller & Liefner, 2007; Abel & Deitz, 2011; Schaaper, 2014; Chapman & Chien, 2014).

As the knowledge economy is a global competition and universities are closely tied to it, universities themselves are increasingly involved in a global race. Universities yearn for a higher position in world university rankings through building up their graduate education, research capacity and publications in academic journals. The focus of
their race is essentially competing for students and faculty worldwide because people are the core drive for research and innovations (Wildavsky, 2010; Chapman & Chien, 2014).

Researchers have an adequate discussion on the reasons of attracting international talent. From an economic perspective, Williams (2009) contends that international human mobility is an interweaving of labor, knowledge and material capital. Moreover, Florida (2008) points out that one key factor to U.S. economic growth miracle is its openness to new ideas, which has allowed it to harness the creative energies of its people. To stay innovative, the United States must continue to attract the world’s brightest minds, because innovation and economic growth always follow where talents go. He advocates that students are a leading indicator of global talent flows and the countries which attract them have an advantage retaining them. However, U.S. visa and immigration policies restrict the entering of students, scientists, and professionals to the United States and harm the development of research projects or enterprises in the country. Therefore, he suggests that the United States should rebuild the creative infrastructure by reforming immigration policies and investing generously in research and development to retain talent and tap into more people’s creative capabilities.

Suter and Jandl (2008) summarize some more specific reasons as to why countries should attract international students. First, educational exchange enhances the political and economic relations with sending countries. Second, host countries and institutions make profits from students’ tuition and living expenses. Third, the quality of education in host countries improves because international students contribute to knowledge creation and innovation. Fourth, domestic students benefit from studying in an international environment. Finally, student mobility may relieve the shortage of labor force in the job
market and help prevent a demographic decline in host countries. Additionally, they suggest that universities play an important role in the selection of immigrants by recruiting international students, which is well supported by many other studies, as elaborated below.

International students influence host countries in various ways based on a few empirical analyses. First, international students change the demographic composition of students and academic programs in the host country. For example, Freeman, Jin and Shen (2004) reveal the extent to which international students have made up the share among doctoral recipients in the United States. They utilize data from the Survey of Earned Doctorates by National Science Foundation and find the demographic origins of new U.S.-trained science and engineering Ph.D.s changed markedly from the late 1960s to the early 2000s. In 1966, 77% of science and engineering doctoral graduates were U.S.-born and 23% were foreign-born. In 2000, 61% of the graduates were U.S.-born, and 39% were foreign-born. Also, most of the growth in Ph.D.s was in less prestigious, smaller doctorate programs, and there was a huge growth in the number of foreign bachelor's graduates obtaining U.S. doctoral degrees over time. Moreover, Gaule and Piacentine (2013) explain how international students contribute to the innovation of the host country by exemplifying that doctoral students in chemistry from China to the United States are found to have higher performance in research compared with native students.

Not only the United States, other western countries and non-English-speaking countries are also energetic recruiters of foreign talent, especially top graduate students, and they also benefit from hosting international students (Wildavsky, 2010). The reason is not always tuition revenues, but more because of their contribution to the research
enterprise. From interviews with academic directors in universities, Wildavsky (2010) reveals that university is one of the biggest contributors to knowledge and that in higher education sector, increasingly most of the work is done by researchers and their teams—and their teams are doctoral students.

Further, international students contribute to the mobility of highly skilled labor force to the host country. Dreher and Poutvaara (2011) confirm that there is a positive relationship between international students and migration into the United States. They use panel data of immigrants from 78 countries of origin from 1971 to 2001 and examine the impact of the inflow of international students to the United States on migration patterns over the whole period. They find that the stock of international students is an important predictor of subsequent migration. The estimated results show that for every 10 percent increase in the number of international students the immigration to the United States increases by a maximum of 0.94 percent. Since international students, in general, are well-educated and highly skilled, their study suggests that student flows result in a significant brain gain for the United States.

International students also contribute to host countries through exerting influence on other participants in higher education. Peterson, Briggs, Dreasher, Horner and Nelson (1999) underscore the benefits brought by international students to the U.S. campus and students in addition to their tuition and living expenses. First of all, international students as teaching assistants guarantee the supply of courses required by U.S. students who otherwise would have delayed graduation, because U.S. college graduates often choose lucrative jobs in industry instead of advanced studies and teaching assistants would be scarce if it were not for international students. Also, international students on campus,
although proposing new challenges, enable faculty and student affairs staff to change and improve their teaching and research or administrative support to students. Moreover, the interaction between international students and native students can educate Americans about intercultural issues and help them become more competitive with global views in labor market. Finally, U.S.-educated international alumni remain a close economic and political relationship with the United States after returning to their countries, and their favor for U.S. goods and services even helps create many new American jobs annually.

In summary, international students do not only work as a potential highly skilled labor force in the form of scientists and engineers, but also affect campus climate and American students who constitute the domestic human capital, and build up global networking for U.S. universities and government. Therefore, international students are human capital that contains an immeasurable value.

Factors Influencing International Student Mobility

International students do not flow randomly. Researchers have used demand-and-supply and push-and-pull models to examine factors that influence their mobility. These two approaches differ in that the former considers economic factors while the latter adopts a more comprehensive perspective. In addition, demand-and-supply models usually rely on individual-level survey data that emphasize on individual motivation and choices, while push-and-pull models utilize both individual-level data and country-level data in the analysis of student flows among countries (Mazzarol & Soutar, 2002; Bouwel & Veugelers, 2009).

Economic Perspective
Some researchers investigate student mobility from the economic lens and view studying abroad as a market behavior that is affected by both demand and supply factors. The demand-side theories focus on the need of students, while the supply-side theories emphasize on the preferences of colleges and universities. Although most studies consider both demand and supply theories, demand-side factors often overshadow supply-side factors.

On the demand side, the focus has been on individual motivation. Researchers adopt the human capital theory to explain studying abroad as a choice made by students and their families: international students pursue better education to increase their human capital in the hope of gaining a higher economic return.

Higher education increases individuals’ economic value by offering better job opportunities and earnings. For example, Brewer, Eide and Enrenberg (1999) find that the opportunity of well-paid employment is significantly associated with the institutions that students attend. Zhang (2005) tests the effects of different measures of college quality but to find that no matter what measures are used, the effect of college quality on graduates’ earnings is generally positive and significant. Hoekstra (2009) suggests that attending the most selective state university causes earnings to be about 20% higher for white males. As the public has widely accepted the notion that quality of higher education matters for individual success, students and their parents seek better higher education to gain advantages in the labor market. When high-quality higher education can only be obtained across the borders, students and foreign institutions of higher education respectively constitute the demand and supply sides of the international business.
Van Bouwel and Veugelers (2009) provide a discussion of the close link between students’ college choice and quality of higher education from the human capital perspective. Based on earlier studies on the relationship between quality of higher education and return, they suggest that in human capital perspective, individuals consider education as an investment decision which directly increases their human capital. Students prefer to attend a high-quality institution if any possible higher costs, even those incurred by studying abroad, are compensated by higher returns through future earnings and employment opportunities. They examine the student mobility within Europe and prove that quality of higher education has a positive and significant effect on the size and direction of flows of undergraduate students exchanged among 31 European countries. They also suggest that the quality of education in the destination country is especially important for students from countries with a low score on quality indicators.

The job market also has a certain impact on students’ decision of studying abroad. Rosenzweig (2006) examines how global wage differences influence international student flows. He utilizes data from New Immigrant Survey Pilot (NISP) and Immigration and Naturalization Service (now USCIS) which provide the home-country earnings for a sample of new U.S. legal immigrants and their demographic information, along with data from Occupational Wages around the World (OWW). The results show that the price of skill in origin countries has a significant and negative impact on the number of students who have become permanent resident aliens in the United States in 2004. He argues that students migrate to get well-paid employment when the earnings for skilled work decrease in their home countries. When economic conditions are not good,
and there is overloaded competition in the domestic job market, students tend to flee from their countries.

Based on rational considerations, many students choose to study in another country. It also turns out that studying abroad pays off. Williams and Balaz (2008) look at Slovakian students who studied in the United Kingdom and later returned to their home country and analyze their motivation and acquisition of human capital. They find that the students’ evaluations of their experience are highly positive, with substantial numbers reporting improvements in their job and income. Their study emphasizes on specific competencies acquired by students and highlights the value attached to language competence, learning, attitudinal and interpersonal as well as networking skills. The increase of human capital, particularly in foreign language skills and social capital, which occurred due to overseas educational experience, is suggested to be a major reason for students to make the decision of studying abroad.

On the supply side, the financial interest of the government and universities in destination countries is thought to play an important role. Findlay (2011) examines changing characteristics of international student mobility and differentiate between social demand theories (social and cultural capital) and supply-side theories (financial interest of suppliers of elite higher education). He emphasizes that the primary concern of studying demand-supply theories is to understand that in a globally competitive higher education sector, it is not only the demand side that is important but also the supply side that matters. Institutions that sell international credentials have an opportunity not only to raise significant financial capital in the process but also to profit from the embodied cultural capital that students bring with them from their countries of origin. Thus, Findlay
(2011) maintains that supply-side theorization is needed, and supply-side theories should consider that the mobility of international students is strongly shaped by the financial interest of suppliers. By examining data from U.K. Higher Education Statistics Agency, he finds that the growth of the number of international students in the United Kingdom in the past decade has been greatly driven by the Prime Minister’s Initiative on International Education commenced in 1999. This Initiative aims to double the number of international students in the United Kingdom so as to feed more money into universities in the country through increasing tuition revenues and to open up opportunities to more young people at home without increasing taxes.

Previous studies from the economic perspective suggest that studying abroad is firstly driven by individuals’ pursuit of a higher return to education. Particularly, the quality of higher education is the most relevant factor that motivates students to study abroad, because it is critical for the formation of individual’s human capital which is greatly valued in labor market. Meanwhile, the enrollment of international students is boosted or restricted by suppliers of higher education who decide the educational opportunities for international students to a great extent. However, since demand-supply theories adopt economic lens which focuses on human behavior and motivation, the related studies are mainly based on survey data rather than country-level data.

**Comprehensive Perspectives**

Other studies that simulate international student mobility using push-and-pull model have a more macro view of factors governing the mobility pattern. They suggest that the flow of international students is not only driven by individuals’ or institutional pursuit of economic benefits, but also shaped by national characteristics, such as
economy, demography, education, language and polity, of both host and origin countries (Agarwal & Winkler, 1985; McMahon, 1992; Mazzarol & Soutar, 2002; Van Bouwel & Veugelers, 2009).

Agarwal and Winkler (1985) study the demand for U.S. education among international students from 15 low-income or middle-income countries by using data from 1954 to 1973. They find that the number of international students has increased dramatically since 1954, largely because the eligible populations in non-industrialized countries have increased. However, the proportion of international students among U.S. student population has decreased because of the rising cost of U.S. higher education and more higher education opportunities in the countries of origin. Their study discovers that the change in international student mobility can be a mixed result of the changing population, economic, and educational factors of both home and host countries.

Similarly, McMahon (1992) examines the flow of students from 18 developing countries to developed countries during the 1960s and 1970s. By estimating both push and pull statistical models, he assesses how economic factors, educational variables, and political conditions determine international mobility pattern. The estimated “push” model suggests that outbound student flow is affected by the level of economic wealth, the involvement of the developing country in the global economy, the emphasis on education, and the level of educational opportunities in the home country. The “pull” model shows that student flow is also influenced by concentration of trade with the host country, relative strength of higher education in the host country compared with the home country, the host country’s political interest in the home country through international
financial assistance, and the host country’s support to foreign students through scholarship.

Mazzarol and Soutar (2002) investigate the factors that determine international students’ choice of host country using individual-level data. They utilize data collected from surveys conducted in Indonesia, Taiwan, India and China during the period from 1996 to 2000. They identify factors that motivate students to study abroad, regardless of which country the students are from. According to their finding, economic and social forces within the home country serve to “push” students abroad. A perception that overseas study is better than a local one, local educational opportunity, a desire to better know the “West” and an intention to migrate after graduation will make students choose to study internationally. However, the decision of choosing the host country depends on the reputation or profile of the host country, knowledge about the host country, parental influence or friends’ recommendations, cost of studying abroad, and local environment in the host country. The choice of a particular host institution is more influenced by the quality and reputation of the institution, student’s linkage and knowledge of the institution, and whether the institution is willing to accept students’ qualifications. The advantage of their study is that they have first-hand survey data which enable them to study individuals’ motivation for choosing a host country and even a host institution. They provide an insight into the pattern of international student mobility by analyzing the role of various characteristics of home and host countries.

Although many researchers agree on that the characteristics of both home and host countries can affect student mobility, only a few of them have differentiated the unequal weights of determinants. Franzoni, Scellato & Stephan (2015) conduct a survey
among student who went abroad for Ph.D. study in a selection of 16 developed and developing countries, and they ask them about factors underlying their decision to study abroad. They find that labor market for scientists and visa policies in the host country play the most important role, while the policies and resources in the home country seem unimportant and neutral. Furthermore, by checking the bi-directed flow of students between countries, Perkins and Neumayer (2014) find that the characteristics of destination countries are always significant predictors or have larger coefficients compared with origin countries, including GDP, the student population at tertiary level, and the number of top universities.

To sum up, researchers have explored a variety of factors that may affect student mobility, and they have depicted a general pattern. However, they also vary in certain aspects because they study different groups of students based on different data. Some use individual-level data; others use country-level data. It is probably hard to get completely consistent results when the contexts of research are so changeable. This study integrates comprehensive country-level data sets which are not identical with those used in previous studies and only involves one destination country. Therefore, the results of this study are expected to be only consistent with previous studies in general but different in details.

**Measurement of Factors**

Based on the findings of previous studies, a number of factors indicating country’s characteristics can be identified as important ones that “push” or “pull” students to move across borders. Sorting out how these factors are measured in most studies will be helpful for conducting the quantitative analysis in this study.
**Economy.** Factors explaining international talent mobility have been predominantly economic (Harvey, 2014). Two types of economic factors are usually examined in push-pull models. First, the economic power of a nation can be gauged by the annual gross domestic product (GDP) per capita which works a gross measure of economic activity (McMahon, 1992; Perkins & Neumayer, 2011), or GDP per capita ratio of destination to origin countries which reflects the economic gap between countries (Perkins & Neumayer, 2011; Wei, 2013). Higher-income countries are found to receive more international students than lower-income countries, and a larger gap between the average income of origin and destination countries is considered to deter the outflows of students from origin countries (Perkins & Neumayer, 2011). Second, an economic factor indicating international or bilateral relation is a valid measurement for the economic connection between countries and found to be a significant predictor of international student flow, such as exports and imports relative to GDP, and trade volumes in goods (McMahon, 1992; Wei, 2013).

**Population.** The total population of host and origin countries is considered as an important indicator because the number of migrants between two countries is found to be proportional to the population in either country (Rodríguez González, Bustillo Mesanza, & Mariel, 2010). In other studies, the student population at the tertiary level rather than the whole population in the host and origin countries is used and proved to be a significant predictor as well (Van Bouwel & Veugelers, 2009; Perkins & Neumayer, 2011).

**Educational opportunity.** For origin countries, the enrollment ratio in tertiary education is mostly used to indicate their educational opportunities (McMahon, 1992;
Mazzarol & Soutar, 2002; Van Bouwel & Veugelers, 2009). Some researchers also consider the percentage of gross national product (GNP) allocated to education which reflects a country’s emphasis on education because, with less attention on education by a country, students tend to seek better educational opportunities abroad (McMahon, 1992). For host countries, the average amount of tuition of higher education is included to examine how the price influences international students' demand. Also, some researchers use higher educational expenditure per student to indicate the level of financial investment in higher education, which, however, does not show a significant effect on international student mobility (Van Bouwel & Veugelers, 2009). In another study, purchasing power parity is used to measure the related costs in the host country, and GDP per capita growth rate of the host country is used to indicate the demand for labor which brings favorable policies to attract international students (Wei, 2013). In general, smaller chance of attending higher education in home countries pushes students to study abroad, while higher cost of studying abroad cuts down the number of international students.

**Quality of higher education.** There are several ways to measure the quality of a country’s higher education. One measurement is citations received by a country’s scientific publications (Van Bouwel & Veugelers, 2009). Quality of higher education can also be indicated by the number of universities a country has among the top 200 universities in the Academic Ranking of World Universities (ARWU, also known as Shanghai Ranking) which is largely based on research capacity, or the number of universities a country has among the top 200 universities in the World University Ranking (WUR) by Times Higher Education which emphasizes more on teaching quality (Van Bouwel & Veugelers, 2009; Perkins & Neumayer, 2011). Van Bouwel and
Veugelers (2009) find that the quality of higher education in the host country, measured by either citation or ARWU, proves to significantly and positively attract the flow of international students; however, WUR does not yield significant results because the ranking is skewed in favor of British institutions. Other measures include “student-teacher ratio” and “higher education expenditure as percentage of GDP” which indicate the abundance of faculty resource, financial resource, and quality of higher education in destination countries. “Higher education enrollment rate in the host country” reflects the possible attention paid by the host country to domestic students and negligence to international students. Furthermore, “number of patents approved in the host country” indicates the level of information technology development in the host country (Wei, 2012).

**Geography.** In most cases, geographic factors are measured by the physical distance between the capital cities of two countries (Van Bouwel & Veugelers, 2009; Rodríguez González, Bustillo Mesanza, & Mariel, 2010; Perkins & Neumayer, 2011). Other geographic factors, such as whether two countries share a border, and the region where the host or home countries are located, are also considered by some researchers (Van Bouwel & Veugelers, 2009).

**Language.** As language is considered a barrier for studying abroad, it is often included in push-and-pull models. Some researchers measure it by whether two countries share a common language and find it significant (Van Bouwel & Veugelers, 2009; Perkins & Neumayer, 2011). However, Perkins and Neumayer (2011) also include in their model a binary variable indicating whether English is the first language in the destination country but find it insignificant.
Polity. Researchers have very different ways to measure the political factor in their push-pull models. McMahon (1992) uses receipt of U.S. foreign assistance by the origin countries to indicate the diplomatic linkage between the two countries, which is below significance level. Van Bouwel and Veugelers (2009) categorize countries by their membership in the European Union: EU member, new EU member, and non-EU member, which barely show any significant result. Perkins and Neumayer (2011) measure the political status of a country by using a scale from -10 (the most autocratic) to 10 (the most democratic) created by Polity IV project, and they find a role for political regime type in student mobility. They suggest that students from developing countries are more likely to go to more autocratic destinations and students from developed countries prefer more democratic ones.

Most previous studies of push-pull models examine the mutual flow on the country level within regions or worldwide. This dissertation differs from previous macro-level studies by focusing on the relationship between a specific host country (the United States) and multiple origin countries and utilizing a series of more up-to-date data. Given the discussions and findings from previous studies, this study also includes factors indicating economic, demographic, geographic, educational, and linguistic characteristics of countries in the empirical models and examines how they affect the flow of international students into the United States.

Influence of International Student Mobility on Countries

What international student mobility brings to the host or home countries is the most concerning question for policy makers and researchers in many countries. Once
international students complete their degrees in the host country, they make their decision of returning to their home country or staying in the host country based on a variety of factors, such as personal or family reasons, quality of life, job opportunities or career prospects, outstanding faculty, and prestige of institutions (Franzoni, Scellato & Stephan, 2015; Appelt, van Beuzekom, Galindo-Rueda, de Pinho, 2015; Veugelers & Van Bouwel, 2015). Students from the same country may be affected by identical factors and behave in a similar pattern. Therefore, individuals’ choice collectively can bring about a pronounced impact on their home country.

“Brain Gain” and “Brain Drain”

Traditionally, researchers hold a relatively extreme view of the consequence of international student mobility. Findlay (2011) puts it in a straightforward way that international student migration, like other forms of knowledge migration, is not a neutral process, but one that may benefit someone while others may be disempowered at the same time. This point of view is well supported by many studies.

To begin with, international students from developing countries have a high rate of intention of looking for a job or settling down in the host country. As cited by Baas (2006), Australian governmental statistics show that 33% of international students who completed their study in 2003 in Australia obtained permanent residence, and the countries of origin with the highest acquisition rates of permanent residence were: Pakistan (67%), Bangladesh (71%), India (73%) and Nepal (77%), which are all South Asian countries. Baas (2006) explores the motivations of students from India and suggests that their main objective is to obtain a permanent residence visa in Australia and they tailor their choice of course and university with this end in mind.
Moreover, foreign-born students who stay after graduation are found to make contributions to host countries, particularly in research. Levin and Stephan (1999) find that foreign-born population in the United States has a larger proportion of highly productive scientists than the native population. Fernandez-Zubieta, Guena and Lawson (2015) also discover that foreign-born researchers have better performance and more extensive international collaborations than native returnees from abroad and native researchers who have never experienced mobility.

Therefore, many host countries recognize the value of mobile human capital and promote the retention of the highly skilled individuals. Suter and Jandl (2008) provide a comparative analysis of admission and retention policies towards international students in selected industrialized countries, including Australia, Canada, the United Kingdom, and the United States. Their analysis of migration policies of these four countries suggests that attracting and retaining international students has become a major policy goal. The statistics show that Australia almost doubled its number of permanents resident permits granted to international students in 2005 than in 2003. Also, U.S. visa and immigration policies have allowed a large number of talent to stay in its territory. For example, students from China and India who obtain Ph.D. in science and engineering had the highest retention rate in the United States, which were 90% and 86% respectively in 2003. Even for a long-term estimate, 58% of international students who received their Ph.D. in science and engineering in 1993 still lived in the United States in 2003.

A high stay rate of highly skilled talent, especially in the science and technology fields, means great gain for the host countries, which, however, may mean low return rate for the origin countries. Thus, some researchers argue that the loss of highly skilled talent
harms the welfare of developing countries. Wong and Yip (1999) examine the effects of brain drain on economic growth, education, and income distribution. Their analysis shows that brain drain has a detrimental effect on the economic growth rate and generally hurts the non-emigrants by reducing the wage rate of the unskilled workers. Although brain drain may improve the wage rate of the skilled workers who otherwise can migrate for better pay, it still hurts all who are left behind, including future generations, because of the drop in national income. Thus, brain drain also harms the human capital accumulation of origin countries. To prohibit brain drain, they suggest that the government of origin countries can choose to spend more on education and increase the educator-student ratio to lessen the detrimental growth effects of brain drain.

In addition, some researchers investigate the possible nuances of brain drain for different countries. Beine, Docquier and Rapoport (2008) examine the impact of migration on human capital formation in developing countries by using data on emigration rates by education level in 127 countries. They find a positive effect of skilled migration on the gross human capital formation through returning human capital and investment in education at home. Countries combining relatively low levels of human capital and low skilled emigration rates are likely to have a net positive effect; however, more countries lose talent due to emigration more than they gain from the human capital formation. They suggest that the situation of many small countries in Sub-Saharan Africa and Central America is extremely worrisome, while the main globalizers such as China, India, and Brazil, all seem to experience evident gain.

To sum up, there are proper reasons why researchers contend that international student mobility results in brain drain or gain; however, their analyses are restricted to the
discussion of the effect of student outflow on economic growth rather than on other aspects of a nation, such as education and research. In academic fields, the benefit of international student mobility to both home and host countries cannot be sufficiently measured by economic indicators. Moreover, the consequence of student mobility may take a long time to embody in certain aspects, before people can clearly see if it is “drain” or “gain” for the origin or host countries.

The “Brain Circulation” Concept

“Brain Circulation” is a relatively new concept without an agreed definition among researchers. The concept was first posited by Xiaonan Cao (1996) who depicts talent mobility as a multiple-directed system in which talents can move freely between organizations for many times in their lifetime and acquire marketable expertise and international experience that can be tapped into by all countries involved. Cao (1996) has a different view from the traditional “brain gain” which considers that global human resource is divided and the direction of mobility is only one-way. Instead, he describes it as a dynamic, long-time process. However, his argument is still based on the mobility of people in the geographic dimension. In comparison, this study agrees with him on viewing student mobility as an open and integrated system with multiple directions but further considers intangible circulation that is not reliant on geographic mobility.

Among a few studies that allude to this term, “brain circulation” has different meanings. This study summarizes from these studies that there are two types of brain circulation: “return” and “diaspora.” Either through the return of talent to their home country or diaspora knowledge networks overseas, brain circulation does not automatically happen. It relies on certain conditions, especially policy efforts and
communication convenience (Meyer et al., 1997; Mahroum, Eldridge & Darr, 2006; Meyer & Wattiaux, 2006).

“Return” is a very self-explanatory concept of how brain circulation works. The return of talent directly benefits the origin countries, because they bring back advanced knowledge and skills and they become a part of the education, science and innovation system of their home country. Johnson and Regets (1998) suggest that in 1995 almost half of the foreign doctoral recipients in science and engineering in the United States have left for their home countries after completing their graduate degrees, and some others left after a few years of teaching or industrial experiences in the United States, which is considered as brain circulation for their home countries.

Velema (2012) advocates that returning scientists, due to their connection to foreign institutions, can facilitate knowledge exchange and international scientific cooperation projects between two locations. However, by looking into the data on returning migrants in Taiwanese academic community, he argues that the impact of returning scientists is not only dependent on the absorptive capacity and the local social, cultural, and institutional contexts in the country of origin, but also contingent on the nature and quality of the contexts in which they acquired their international education and labor experience. His opinion further implies that brain circulation does not happen without careful plan and effort. Policy makers should be sensitive to where potential highly skilled immigrants are encouraged to go to and where returning scientists come back from so that highly skilled labor migration can result in a beneficial impact on the scientific community at home.
Furthermore, Wagner, Leydesdorff and Bornmann (2014) reveal a positive effect of return scientists on their home country’s research. They examine data on journal information from Web of Science between 2000 and 2012 and find that China and the United States have become each other’s top one collaborator in scientific research. During the early 2000s, the number of coauthored papers between Chinese and U.S. researchers showed significant growth, and Chinese scientists claim first-authorship much more frequently than their U.S. counterparts in 2012. One of the reasons for this growth is that Chinese scientists who have been studying and living in the United States are encouraged to go back to China and they are likely to co-publish utilizing their academic connection with U.S. researchers and institutions.

“Diaspora” is more invisible compared with “return.” Meyer et al. (1997) indicate that many developing countries are considering their highly-qualified citizens overseas as potential resources for national development and design policies to ensure the return of their expatriated talented group. By conducting a survey among more than 1,000 Columbians in 43 countries, they find that three-fourths intend to return home and live in Columbia, which shows that emigration is not necessarily permanent but temporary. In addition to the return option, Columbia applies a second approach—the diaspora option, which is to establish the connection of intellectual abroad to the scientific, technological and cultural programs at home through Internet, local associations, and joint projects between diaspora and the home community members. The researchers suggest that a population of expatriate individuals does not automatically constitute a diaspora but becomes one when members are in communication, have a collective autonomy, and shared goals and activities. They also emphasize on the role of electronic communication
methods in constructing the diaspora network, which supports the point that is held by this dissertation that brain circulation can be more easily realized by expatriate researchers than before because of more convenient communication today.

Mahroum, Eldridge and Darr (2006) also point out that the emigration of knowledge workers has been traditionally viewed as a loss for the source countries and a net gain for the receiving countries; however, they focus on how source countries might benefit from their diaspora by turning “brain drain” into “brain gain.” They suggest that knowledge and technology can transfer through the physical return of skilled emigrants, targeted visits of highly skilled emigrants to their home country such as visiting scientist programs in some developing countries, and digital knowledge networks without physical relocation. They also specify different ways that source countries can benefit, such as international remittances and investments. For example, the highest remittance receiving countries are also those with the largest group of students overseas. Moreover, expatriates are relatively more likely to invest in their own country of origin. Therefore, in a network of worker and financial flows, the relationship between home and host countries does not have to be a relationship between losers and winners.

In addition, Saxenia (2005) finds a diaspora network among the highly-skilled workers in Silicon Valley. She discovers that many U.S.-educated, foreign-born engineers who are mostly from China and India tap low-cost skills in their home countries and over time contribute to highly localized processes of entrepreneurial experimentation and upgrading. She suggests that they transform developing opportunities for formerly peripheral regions as they build up professional and business
connections to their home countries, and this process is more akin to brain circulation than to brain drain for the origin countries.

Although a growing number of researchers take the perspective of brain circulation, its mechanism is still under-researched and needs more discussion and empirical analysis. Meyer and Wattiaux (2006) contend that diaspora knowledge network has deeply changed the way highly skilled mobility used to be looked at by converting the traditional “brain drain” flow into a “brain gain” of expatriates’ skills circulation. By reviewing previous empirical studies of diaspora knowledge network, they find there is an increasing amount of evidence of the existence and prosperity of diaspora knowledge network. Especially during recent years, more research utilizes a systematically searching through the Internet and definitely proves the ongoing activities of numerous diaspora knowledge network. More features and mechanisms of these networks are explained; however, recent research heavily relies on identifying diaspora knowledge network on the Internet, with a risk of neglecting others that cannot be found via the Internet. Therefore, they suggest that studying diaspora knowledge network needs new tools, methodology, and concepts to explore theoretical as well as empirical issues. This is also one of the purposes of this dissertation: to study the influence of diaspora knowledge network through quantitative analysis with support from relevant data on actual activities performed by expatriate researchers.

Although “brain circulation” is not uniquely identified, previous studies over time have shaped the core of this concept, that is, the mobility of talent can contribute to their country of origin in two main ways, particularly through returning talent or diaspora knowledge network.
Brain Circulation in Different Countries

For origin countries, brain circulation happens when returning or expatriate scientists contribute to the research and development in their home countries, especially when they can compensate for what the country has lost due to the outbound mobility of talent who have no connection with home country anymore, although complete disconnection rarely happens in the global era. Overall, scientific teams have been proved to play an increasingly important role in the production of knowledge across all fields and collaborations are dispersed geographically since the cost of collaboration has sharply declined. Through collaboration, researchers are likely to produce more and higher-impact research (Adams, Black, Clemmons & Stephan, 2005; Wuchty, Jones & Uzzi, 2007). Nevertheless, countries have unequal research capacity and population of native, returning and expatriate researchers. Those with more access to the global higher education and research system are more likely to build up an international collaborative relationship with other countries (Freeman & Huang, 2015). Therefore, the degree of brain circulation should vary by country.

To begin with, domestic researchers, returnees, and expatriate researchers are found to have different academic performance. For example, by examining data of 16 developed and developing countries, Franzoni, Scellato and Stephan (2015) find that returnees to most industrialized countries, such as the United States, Japan, and western European countries exhibit comparable performance to their compatriots who remained abroad in 2011, while returnees to Brazil, India, and Italy on average do not perform as well as those who stayed abroad. They advocate that it is because developed countries are more likely to draw the best talent back and can provide better conditions for research.
Their finding further suggests that developing countries that are more vulnerable to brain drain may still lose more than what they gain since their best talent choose not to return even when returnees outnumber expatriate researchers.

It seems difficult to accurately conclude whether a country has benefited from student mobility and brain circulation; thus, some researchers do not take an absolute stance in their discussion of the consequences of student mobility. According to them, there is no identical pattern for all countries, and the impact of international talent mobility is conditional by countries. For example, Johnson and Regets (1998) explore if the international mobility of scientists and engineers to the United States is a brain drain or brain circulation for origin countries. They examine the data of National Science Foundation Survey of Earned Doctorates in 1995 by analyzing the rates of doctoral recipients who plan to stay in the United States by their country of origins. They suggest that for China and India the pattern is considered brain drain because they have high stay rates as 88% and 79% respectively, but for countries such as Japan and South Korea the notion of brain circulation is supported because their stay rates are as low as 13% and 11%. The advantages of their study are that they could differentiate patterns by countries based on quantitative analysis, although it is only a simple description of statistics at aggregate levels due to the limitations of data. A major deficiency of the discussion is that their definition of brain circulation only includes returning scientists and does not consider the role of diaspora knowledge network. Also, it is insufficient to identify origin country’s loss by measuring the expatriate population instead of measuring the population’s quality and productivity.
By comparison, Gaillard and Gaillard (1998) have a more in-depth look into the international scientific migration. They point out that it used to be difficult for countries which suffered from migrations of talent to offset losses by the return of the scientists or by access to scientific work produced abroad, because brain drain has been a steady and severe problem from the 1960s to the 1990s which cannot be compensated with a small number of return scientists. However, they contend that the tendency to assign countries the label of “winner” or “loser” in migration patterns is problematic since the world is entering an era of changing economic paradigms and an increasingly interconnected network of scientists via electronic communication methods. The growing scientific development in some countries and the shrinking economic gap between home and host countries encourage the return flows of scientists and technologists. Based on analysis of different types of countries, they suggest that low-income countries, especially those in Africa, will find it hard to subvert their disadvantages in the global flow of scientific talent because of their lack of improving economies and network connections. Middle-income developing countries that have been upgrading their education and innovation system are more likely to benefit from cooperation with developed countries.

**Summary**

Previous studies provide a theoretical basis for the study of "brain circulation." First, the flow of international students is influenced by a variety of factors that characterize both home and host countries. Second, international students choose to stay in the host country or return to the home country after graduation, and their choice has a certain impact on both countries through the physical distribution of human capital they
represent. Third, international students who stay in the host country after graduation can still keep a connection to their home country and contribute to the research and development in their home country.

Moreover, previous studies suggest that brain circulation is a very dynamic process. It has evolved over time as the global economy, policy and communication methods have changed. Its embodiment also varies across countries. Developed and some fast-developing countries benefit from international mobility and connections among countries, while in lower-income countries, brain circulation has not shown an evident role in the national development due to weak infrastructure and incomplete domestic education system, and thus the consequence of outbound student mobility appears as “brain drain” to these countries. Therefore, the complicatedness of “brain circulation” requires researchers to take comprehensive factors into consideration and apply the concept to countries with differentiation.

Previous studies also show that there is a gap in the study of brain circulation, especially when it comes to the concept and mechanism of expatriate talent or diaspora knowledge network. In particular, there are two questions to be addressed. First, the concept of brain circulation is to be enriched. Apart from returning scientists, it also needs to incorporate expatriate researchers and have an adequate investigation on the mechanism of how expatriate researchers contribute to their home country. Second, the method of studying expatriate researchers and diaspora knowledge network is limited, largely due to lack of data. Previous studies mainly prove that there is an increasing number of expatriate researchers, but cannot perform in-depth analysis. Therefore, it is not clear to what extent expatriate talent contribute to the research and development in
their home country in the form of research collaboration. This study aims to fill this gap through performing quantitative analyses of the research collaboration between origin and host countries that involves expatriate researchers.
This dissertation will seek evidence from large data sets from a variety of sources and adopt a quantitative approach by performing both descriptive and regression analyses. Since the research questions to be answered in this study involve different data sets and methods, this chapter will introduce the data that will be used in order and explain how the utilization of specific data sets will help answer each of the research questions.

Data

Three major data sets will be used in this study. The first one is on international student mobility, drawn from the Open Doors Report published by Institute of International Education (IIE). The second data set is The National Survey of College Graduates (NSCG) from National Science Foundation (NSF). The third data set is on academic publications by country, extracted from Web of Science (WOS). In addition, other data sets, such as World Bank and Academic Ranking of World Universities, will be included and integrated with these three major data sets in the statistical analysis.

Data on International Student Mobility

Open Doors Report on International Educational Exchange is an annual publication presented by IIE, reporting the number of students in and out of the United States every year. IIE has kept recording statistics of international students since its foundation in 1919 and began publishing Open Doors Report in 1954. Initially, IIE only reported the number of foreign students from each country in the United States, but later
it also covered U.S. students studying abroad (IIE, 2014). These statistics on international student mobility have been widely cited by educational researchers and reporters.

This study has obtained Open Doors Report of the time period from 1948 to 2013, but the data contain too many missing values for the years prior to 1993. Therefore, only the data after 1993 are considered in this study. The number of international students in the United States from each country is extracted for each year. Also, for each country the number of undergraduate students and graduate students is also provided; thus, the composition of international students from each country can be identified and analyzed.

IIE data include 222 countries in all. Countries with a population less than 1.5 million are dropped from the data because such countries tend to have zero values or missing values in international student mobility. These countries are also called “small states,” as defined by World Bank (World Bank, 2012). Among countries with a population above 1.5 million, a few of them used to exist in the early 1980s but vanished later, and some others were reconstructed and established as new nations due to political movements during the past three decades. Thus, the number of countries for each year is not constant. Every year the data may include a different set of countries. For some countries, data were not collected for all years. Observations with missing values of students in the United States are dropped from the data because the number of international students will be examined as a dependent variable in the regression models in this study.

**Data on U.S. College Graduates**

NSCG is a longitudinal biennial survey among the nation’s college graduates. The survey samples individuals who are living in the United States, have at least a bachelor’s
degree and are under the age of 76. The survey was designed to provide data on various characteristics of the college-educated individuals in the workforce, including their education, occupation, work activities, income, and demographic information. NSCG data have been used to understand the relationship between college education and career opportunities (NSF, 2013).

NSCG data are particularly useful for this study because the survey collects information on individual’s place of birth, fields of study, educational attainment, and occupational history. Given these, it is possible to identify the group of people who are foreign-born, U.S.-educated, and work in the United States after graduation. In addition, the survey covers the population who graduated from college prior to a given date and year. Therefore, the data can display the nation’s stock of labor force who are college-educated at a certain time point.

A problem with using NSCG data is that the regression analysis in this study will rely on the population of college graduates rather than the sample. In the NSCG, every sample case has a sample weight that reflects the portion of the population the case represents. The sample weight shows weighting adjustments that were made to account for the sample selection, nonresponse, trimming procedures to eliminate extreme weights and to ensure the sampling weights agree with the sampling frame estimates for certain key sampling variables (NSF, 2013). Thus, the parameter of the population can be derived from the sample investigated by the survey. From NSCG data, the number of foreign-born, U.S.-educated college graduates who work in research fields in the United States is calculated. By considering the sampling weight, the size of this group of people in the population can be obtained.
NSCG was initiated in 1972. The current data files for public use include the survey of 1993, 2003, 2010, and 2013, which provides a coverage of the national population of college graduates as of the survey reference date. As the information on place of birth is unrestricted only in data files of 2003, 2010 and 2013, the regression analysis involving NSCG can only utilize data of these three years since respondent’s nationality is a necessity for calculating the population of expatriate researchers from each country.

**Data on Research Publications**

Web of Science (WOS) is an online subscription-based scientific citation indexing service maintained by Thomson Reuters that provides a comprehensive citation search (Drake, 2003). It is considered to have dominated the field of academic reference mainly through annually releasing journal impact factor which evaluates the importance and influence of specific publications. As a standard platform of scientific, technical and scholarly literature with science citation index, it is widely used by researchers, librarians, universities, and governmental agencies (Falagas, Pitsouni, Malietzis & Pappas, 2008; Web of Science, 2015; Ganguli, 2015). Although WOS has archived academic articles published since 1900, only the data from 1993 to 2012 will be used in this study so as to be consistent with the time range of IIE data.

The WOS data will be mainly used to retrieve the number of collaborative publications between the United States and other countries, which is treated as a dependent variable in the regression analyses. The purpose is to reveal whether there is a relationship between the expatriate researchers and the research collaboration between their home country and the United States. The rationale for establishing this relationship
is that international student mobility leads to the academic collaboration between two
countries through providing foreign-born, U.S.-educated researchers who stay in the host
country but have a connection with their home country.

Other Data Sets

As a variety of characteristics of countries are considered in the statistical models,
it is necessary to aggregate the IIE data with data from other sources that include
economic, demographic, and educational indicators. Data on economy and population of
249 countries are extracted from the World Bank Databank (World Bank, 2016a).
Economy is measured by country’s GDP per capita, and the population for tertiary
education of each country is adopted. Observations with missing economy or population
information in the World Bank data are dropped from the sample.

Education indicator is drawn from Academic Ranking of World Universities
(ARWU). The level of educational development in one country is indicated by its number
of top 500 universities. It is considered to be a trustworthy indicator of the academic
status of higher education institution worldwide and frequently cited by researchers in
higher education studies (Perkins & Neumayer, 2014). A country with more universities
that are ranked among ARWU’s top 500 list is usually considered possessing more
academic and research strengths compared to countries with fewer or without any top
universities.

With regard to political status, this study makes reference to the Polity IV project,
as Perkins and Neumayer (2011) do in their analysis. The Polity IV is a quantitative
research project on political regime characteristics and transitions from 1800 to 2012. It
reports polity scores of 167 countries between 1946 and 2013 and measures the political
status of a country by using a scale from -10 (the most autocratic) to 10 (the most democratic) (Polity IV, 2014).

In previous studies, there is not a consistent and standard way of selecting factors on international student mobility, mainly because the availability of data changes given different research questions. Therefore, this study utilizes data and adjusts the set of independent variables to fit the research questions, based on both previous studies and the data that can be obtained.

The Pattern of International Student Mobility

Variables

Table 1 lists the main variables that will be examined in the regression analysis of international student mobility. The dependent variable is the number of students from each country in the United States of a given year, including total number, undergraduate students and graduate students for different models. The independent variables are explained as below:

**Gross Domestic Product per capita.** National economy is indicated by GDP per capita of each country in constant 2005 U.S. dollars. Taking the data of 2013 for example, Norway has the highest GDP per capita, which is 66511.86 dollars. Burundi has the lowest GDP per capita, which is 150.75 dollars. A wide variation in GDP per capita by country can be expected. Since data are not of good quality on expenditure in higher education or education in general, GDP per capita works as a comprehensive indicator for measuring a country’s ability to finance its education and people’s affordability of studying abroad.
Table 3.1.
Variables of international student mobility and country characteristics

<table>
<thead>
<tr>
<th>Variable</th>
<th>Description</th>
<th>Source</th>
</tr>
</thead>
<tbody>
<tr>
<td>Number of international students</td>
<td>The total number of international student in USA at a given time.</td>
<td>IIE</td>
</tr>
<tr>
<td>GDP per capita</td>
<td>Gross domestic product per capita (in constant 2005 U.S. dollars).</td>
<td>World Bank</td>
</tr>
<tr>
<td>Population for tertiary education</td>
<td>Population for tertiary education.</td>
<td>World Bank</td>
</tr>
<tr>
<td>Publication per million population</td>
<td>Number of publication per million population.</td>
<td>WOS</td>
</tr>
<tr>
<td>Rank</td>
<td>Number of ARWU Top 500 universities.</td>
<td>ARWU</td>
</tr>
<tr>
<td></td>
<td>Categorical: 0 “None”; 1 “One to nine universities”; 2 “Eleven to nineteen”; 3 “Twenty to twenty-nine”; 4 “Thirty to thirty-nine”; 5 “Forty or more”.</td>
<td></td>
</tr>
<tr>
<td>Polity</td>
<td>Polity regime type.</td>
<td>Polity IV</td>
</tr>
<tr>
<td></td>
<td>Categorical: 1 “Full democracy”; 2 “Democracy”; 3 “Open Anocracy”; 4 “Closed Anocracy”; 5 “Autocracy”.</td>
<td></td>
</tr>
<tr>
<td>Language</td>
<td>Whether English is an official language of a country.</td>
<td>Nations Online</td>
</tr>
<tr>
<td>Distance</td>
<td>The flight distance between the capitals of two countries (in mileages).</td>
<td>Distance between Cities</td>
</tr>
</tbody>
</table>
**Population for tertiary education.** Instead of the total population of each country, the population for tertiary education is used in the analysis because it is more relevant to the student population who may enroll in the higher education system at home and later study abroad or who may directly attend U.S. universities. The value of this variable ranges from 1,947 to 118 million in the 2013 sample. India has the largest population for tertiary education, while the British Virgin Islands has the smallest.

**Rank.** This variable refers to the number of ARWU’s Top 500 universities a country owns. Its values change every year. The distribution of top universities is quite uneven around the globe. The United States has had the most top 500 universities over time, while dozens of countries have less than fifty top universities and hundreds of countries have none.

**Publication per million population.** This variable measures the research productivity of a country. It is considered more relevant to research activities than the number of universities which may indicate both education and research. Countries have quite unequal research output. For example, Switzerland has about 2379.93 publications per million people in 2012, while the Central African Republic, Eritrea, and Zaire has zero.

**Language.** Language is coded as a binary variable indicating if English is an official language in the country. Countries with English as an official language are given a value of 1; otherwise, they are given a value of 0.

**Distance.** It is measured by the flight distance between the capital of the United States and that of any other country of origin in the data. Distance ranges from 455 to
10,163 miles. The closest country to the United States is Canada, and the furthest one is Indonesia.

**Polity.** The scores representing the polity regime type for countries range from -10 to 10. A Higher score means higher democracy. A lower score means anocracy or autocracy. Defined by Polity IV Project, polity scores can also be converted into categories, including full democracy (score 10), democracy (6 to 9), open anocracy (1 to 5), closed anocracy (-5 to 0), and autocracy (-6 to -10). This study uses a set of dummies representing these categories so that the interpretation of result can be associated with specific types of countries and thus be more meaningful.

**Cleaning Data**

As data sets from different sources are not consistent in the number of countries included, the first step of cleaning data is to determine how many countries should be kept in the sample for the analysis. For example, the IIE data of 2011 includes 213 countries. World Bank data contains 214 countries with non-missing GDP per capita and 221 countries with non-missing population for tertiary education. By keeping only countries included in both data sets, there are 196 countries left in the sample.

The second step is to screen the values of GDP per capita and population for tertiary education and drop missing values for these indicators from the sample. It is not proper to apply cross-sectional imputation because countries are distinct in numerous aspects and imputation depending on just a small set of variables would introduce too much bias. Therefore, list-wise deletion is preferred for countries with missing values for independent variables. However, time-wise imputation is utilized if countries have
missing values for only one year but not the year before or after. The missing value then can be replaced with the mean of the year before and after combined.

The third step is to check the variable of publications per million people. The data from Web of Science are only available through 2012. Countries with missing values are given zero value because such countries usually have poor education and research systems. The only exception is that Hong Kong has abnormal counts of publications and missing values since 2000, probably because China resumed the exercise of sovereignty over Hong Kong in 1997 and Hong Kong’s publications were later counted into China’s total. Therefore, Hong Kong from 2000 to 2012 are assigned missing values regarding their number of publications.

Dozens of countries do not have a polity index because they are not included in the Polity IV project. Such countries are not dropped directly but will become missing when polity index is taken into account in the regression models. The same steps of cleaning data mentioned above are applied to all years. Finally, a sample of 3,292 observations, including data of 158 countries from 1993 to 2013, is obtained for further analyses.

**Gravity Models**

This study will apply gravity model to the analysis of international student mobility. Gravity model begins with Newton’s law of the gravitational force (GF$_{ij}$) between two objects $i$ and $j$ and utilizes this gravitational force concept as an analogy to explain the trade, capital flows and migration between countries and has specified alternative forms which take economic and population factors into consideration (Reinert, 2009). The basic model is expressed as:
\[ GF_{ij} = \frac{M_i M_j}{D_{ij}}, \ i \neq j \]  

(1)

where \( GF_{ij} \) is proportional to the masses of the objects \((M_i \text{ and } M_j)\) and indirectly proportional to the distance between them \((D_{ij})\).

By taking the logarithms of each side of the gravitational force formula, the volume of the trade or flow between two countries and its determinants are found to be in a linear relationship.

\[ \ln GF_{ij} = \ln M_i + \ln M_j - \ln D_{ij}, \ i \neq j \]  

(2)

Many researchers have applied gravity models to the study of international migration, student flow, and trade, by including factors such as university quality, political regime type, and language in their models (Bouwel & Veugelers, 2009; Gonzalez, Mesanza, & Mariel, 2011; Felbermayr & Reczkowski, 2012). Based on the variables that will be examined in this study, a gravity model is developed as below:

\[
\begin{align*}
\ln S_{it} &= \alpha + \beta_1 \ln(GDPC_{it}) + \beta_2 \ln(POINTER_{it}) + \beta_3 RANK_{it} + \beta_4 \ln(PUBPM_{it}) + \\
&\quad \beta_5 POL_{it} + \beta_6 L_i + \beta_7 D_i + \beta_8 Year_i + \epsilon_{it}
\end{align*}
\]  

(3)

where \( S_{it} \) is the number of students from country \( i \) to the United States in year \( t \). Since one of the two countries is certain, variables indicating the characteristics of the United States go into the constant term \( \alpha \), and only characteristics of country \( i \) are included in model (3). \( GDPC_{it} \) is the GDP per capita of country \( i \); \( POINTER_{it} \) is the population for tertiary education of the country; \( RANK_{it} \) is a set of dummies representing the number of top 500 universities in the country; \( PUBPM_{it} \) is the number of publications per million
population of the country; \( POL_{it} \) is a set of dummies representing the polity regime type of the country; \( L_i \) is the dummy variable indicating if English is official language in country \( i \); \( D_i \) is geographic distance between the capital of country \( i \) and Washington, D.C. in the United States. \( L_i \) and \( D_i \) are not subjective to the time change. \( Year_t \) is a group of dummy variables indicating the year of the data.

Model (3) controls for year effects by including year dummies, as time-series variables can be related simply because variables such as population growth, economic growth and inflation have a naturally rising magnitude. Without controlling for year effects, the natural growth in the independent variable may be mistaken as part of a causal relationship.

In addition to year effects, it may also be necessary to control for country effects. Since countries repeat in panel data and some unobservable country’s characteristics may have an influence on the dependent variable, controlling for country dummies helps account for country endogeneity. Thus, a country fixed-effects model is also developed based on model (3), which is

\[
\ln S_{it} = \alpha + \beta_1 \ln (GDPC_{it}) + \beta_2 \ln (POPTER_{it}) + \beta_3 \text{RANK}_{it} + \beta_4 \ln (PUBPM_{it}) + \beta_5 \text{POL}_{it} + \beta_6 L_i + \beta_7 D_i + \beta_8 Year_t + \beta_9 \text{CNTID}_i + \varepsilon_{it}
\]

(4)

Where \( \text{CNTID}_t \) is a group of dummy variables representing each country in the data. A Hausman test will be run to determine whether a random-effects or fixed-effects model is more appropriate. If the test statistic is large, the initial hypothesis that random-effects model can adequately simulate the country-level model should be rejected, and fixed-effects model is preferred.
Expatriate Researchers and International Research Collaboration

The other goal of this dissertation is to explore how international student mobility is related to the academic collaboration between two countries through researchers who stay in the host country after graduation, which in fact answers the second and the third research questions proposed in the introduction chapter. Both NSCG (National Survey of College Graduates) data and WOS (Web of Science) data will be examined in this part of analysis. NSCG data will be utilized to describe the size and composition of international students from each country who do not return after graduation. WOS data provide the number of publications co-authored by researchers from the United States and other countries. For example, in 2012, the value of co-authored publications between the United States and other countries ranges from 0 to 16,654, and China has the largest number of co-authored academic papers with the United States.

Exploring NSCG Data

A descriptive analysis is conducted to understand the group of foreign-born, U.S.-educated college graduates in the United States. More specifically, it examines the size of this group among the total college-graduated population in the country, the levels of degrees they have obtained, their fields of study, sectors of employer they work in, and their participation in research activities. In addition, by comparing the number of researchers from each country over time, it will be clear from which countries students are more likely to stay in the United States after graduation and how the pattern has changed over time.

The association between international students and college graduates in the United States will also be discussed. As IIE data report the number of undergraduate and
graduate students from each country, it is possible to examine the correlation between the students of different academic levels and the foreign-born college graduates who work as researchers in the United States, and thus know which group of international students is more relevant to the foreign-born research labor force in the United States.

**Variables**

Apart from the description of research labor force in the United States, this study also examines the relationship between research collaboration and its determinants, including GDP per capita, researchers in both origin country and the United States, academic capacity indicated by the number of ARWU’s Top 500 universities, polity, language, and distance. Most of the variables regarding country’s characteristics in Table 3.2 have been introduced in Table 3.1. The only difference is that dependent variable has changed and there are two new independent variables indicating the number of domestic and expatriate researchers.

Research production is mainly affected by two types of resources: financial and human resources (Zhang & Ehrenberg, 2010; Varghese et al., 2014; Zhang, Bao & Sun, 2016). Regarding human resources, research collaboration between a given country of origin and the United States is contributed by researchers in both countries, including researchers in the country of origin, researchers from the country of origin who work in the United States, and other researchers in the United States. The number of foreign-born, U.S.-educated researchers who stay in the United States can be calculated for each country given NSCG data. These foreign-born researchers specifically refer to those who have basic research or applied research as their main work activity in their principal job and have four-year colleges or universities, medical schools or research institute as their
Table 3.2

Variables of research collaboration and country’s characteristics

<table>
<thead>
<tr>
<th>Variable</th>
<th>Description</th>
<th>Source</th>
</tr>
</thead>
<tbody>
<tr>
<td>Research collaboration</td>
<td>Number of publications co-authored by researchers from USA and another country.</td>
<td>WOS</td>
</tr>
<tr>
<td>GDP per capita</td>
<td>Gross domestic product per capita in $1000 (in constant 2005 U.S. dollars).</td>
<td>World Bank</td>
</tr>
<tr>
<td>Domestic researchers per thousand</td>
<td>Number of researchers in the sector of higher education of a given country per thousand population.</td>
<td>UIS</td>
</tr>
<tr>
<td>Expatriate researchers per thousand</td>
<td>Number of expatriate researchers in the United States per thousand population of country of origin.</td>
<td>NSCG</td>
</tr>
<tr>
<td>Rank</td>
<td>Number of ARWU Top 500 universities. Categorical: 0 is “none”, 1 is “1-9”, 2 is “11-19”, 3 is “20-29”, 4 is “30-39”, and 5 is “&gt;40”.</td>
<td>ARWU</td>
</tr>
<tr>
<td>Polity</td>
<td>Polity regime type. Categorical: 1 “Full democracy”; 2 “Democracy”; 3 “Open Anocracy”; 4 “Closed Anocracy”; 5 “Autocracy”.</td>
<td>Polity IV</td>
</tr>
<tr>
<td>Language</td>
<td>Whether English is an official language of a country. Dummy variable: 0 is no; 1 is yes.</td>
<td>Nations Online</td>
</tr>
<tr>
<td>Distance</td>
<td>The flight distance between the capitals of two countries (in mileages).</td>
<td>Distance between Cities</td>
</tr>
</tbody>
</table>
employer sector in the NSCG survey. In addition, the number of researchers in higher education sector in each country is reported in the UIS (UNESCO Institute for Statistics) data, which forms the variable of domestic researchers per million population in this study. Thus, the number of researchers from a given country who work in either origin country or the United States can be both examined in the models.

Modeling Research Collaboration

The most crucial part of examining collaborative publications is selecting an appropriate model. Unlike the number of international students which simulates a normal distribution after logarithm transformation, the number of collaborative publications between a particular country and the United States shows a zero-inflated distribution even after transformation (see Figure 3.1), which means there are too many zero values for the dependent variable. In this case, regular linear regression does not fit the data, because the data violate the assumption that the dependent variable should be normally distributed or approximately normally distributed.

![Figure 3.1 Distribution of collaborative publications before and after transformation](image)
Researchers have adopted alternative methods to deal with count data with a boundary at zero, especially with excess zero values, including two-part model, Poisson regression, zero-inflated Poisson regression, negative binomial regression, and zero-inflated binomial regression. In this study, negative binomial regression will be used for the analysis of collaborative publications. Negative binomial regression is a type of generalized linear model in which the dependent variable $Y$ is a count of the number of times an event occurs, with $k$ successes and $r$ failures. $Y$ has a negative binomial distribution if it has a probability mass function:

$$\Pr(Y = k) = \frac{r^{(r+k)}}{k!r^r} p^k (1 - p)^r, \quad k = 0,1,2,\ldots$$ \hspace{1cm} (5)

where $p$ refers to the probability of “success.” Thus, $\mu = \frac{pr}{1-p}$ is the mean or the expected value of $Y$, which is then related to explanatory variables:

$$\ln \mu = \beta_0 + \beta_1 x_1 + \beta_2 x_2 + \cdots + \beta_p x_p$$ \hspace{1cm} (6)

where the predictor variables $x_1, x_2, \ldots, x_p$ are given, and the population regression coefficients $\beta_0, \beta_1, \beta_2, \ldots, \beta_p$ are to be estimated.

This study chooses negative binomial regression over other methods due to the following reasons. First, two-part model and zero-inflated Poisson model simulate a binary choice logistic regression for the probability of observing a positive-versus-zero outcome, which is problematic for dealing with panel data because countries with zero outcome may change over time. To control for year or country effects, estimating fixed effects on non-linear regression causes incidental parameter problem. By contrast, negative binomial regression does not treat observations with zero or positive outcomes separately and works as a linear model. Therefore, two-part model and zero-inflated model are not fit for this analysis. Second, compared with Poisson regression, negative
binomial regression is for modeling over-dispersed count outcome variables which have a larger variance than mean. Although Poisson model is often presented as the natural approach for count data, it requires that the mean and the variance of the outcome variable should be nearly equal, while negative binomial model is found to be much more flexible and more likely to fit count data better (Kleinman, 2012). In a study of the productivity of mobile research scientists, negative binomial model is also chosen over Poisson regression to examine the relationship between the number of publications and researcher’s characteristics (Fernandez-Zubieta, Guena & Lawson, 2015).

Zero-inflated negative binomial regression is also excluded because of incidental parameter problem. Moreover, Paul Allison (2012) suggests that zero-inflated negative binomial regression is not always necessary. He found from his experience that a standard negative binomial model fits better than a zero-inflated model, and the difference in fit statistics between these two models is usually trivial. In our case, the BIC statistics for regular and zero-inflated negative binomial model (without country fixed effects being controlled for) are 2500.635 and 2516.376 respectively. The difference between the two models is minor.

Therefore, negative binomial regression model is selected to examine the relationship between expatriate researchers and international academic collaboration. Considering a variety of factors that may influence collaboration between two countries, the negative binomial model is defined as below,

\[
\ln CO_{it} = \alpha + \beta_1 \ln GDP_{it} + \beta_2 \ln OVR_{it} + \beta_3 \ln HMRS_{it} + \beta_4 RANK_{it} + \\
\beta_5 POL_{it} + \beta_6 L_i + \beta_7 \ln D_i + \beta_8 YEAR_i
\]  

(7)
where $CO_{it}$ is the number of co-authored papers between country $i$ and the United States in year $t$; $OVRS_{it}$ is the number of researchers who stay in the United States as researchers per thousand population of country $i$ in year $t$; $HMRS_{it}$ is the number of researchers per thousand population in country $i$ in year $t$.

In addition, country fixed-effects models may also be tested depending on the result of Hausman test. In the fixed-effects model, time-invariant variables, such as language and distance are omitted due to no variation. The fixed-effects model is expressed as below,

$$lnCO_{it} = \alpha + \beta_1 lnGDPC_{it} + \beta_2 lnOVRS_{it} + \beta_3 HMRS_{it} + \beta_4 RANK_{it} + \beta_5 POL_{it}$$

$$+ \beta_6 YEAR_i + \beta_7 CNTID_i$$

With variables and models being defined, the following chapters will be centered on presenting the results of descriptive and regression analysis to respond to the research questions proposed at the beginning of this dissertation. Chapter 4 will discuss how characteristics of countries determine the international student mobility to the United States. Chapter 5 will describe the population of international students and expatriate researchers in the United States. Chapter 6 will further investigate whether and how expatriate researchers play a role in the research collaboration between the United States and their countries of origin.
CHAPTER 4
DETERMINANTS OF INTERNATIONAL STUDENT MOBILITY

This chapter focuses on describing the international students in the United States and how the characteristics of their home countries determine the size and academic level of students who study in the United States. As an inseparable part of brain circulation, the flow of students from one country to another sows the seed for future labor force who may return to home country or stay in host country after graduation and who participate in the academic collaboration between their home and host countries. Therefore, it is important to investigate the pattern of the mobility before understanding how academic collaboration is advanced by student mobility and how countries play different roles in this global movement.

An Overview of International Students in the United States

Population of International Students

From 1993 to 2013, the United States has seen a soaring population of foreign students entering the country for college-level education. Figure 4.1 describes the total number of international students in the United States over time. In spite of a slight decline following the year of 2002, the size has almost doubled after two decades since 1993. With regard to academic levels, international students consist of undergraduate, graduate, non-degree students, and students on OPT, among which the first two categories make up the majority (see Figure 4.2). In general, these four categories have all increased during the past two decades, but there seem to be more fluctuations with the number of
undergraduate and graduate students over time.

There are more graduate students than undergraduates between 2001 and 2010, but undergraduate students have outrun graduate students since 2011, and have shown a faster-growing trend in most recent years. These two largest groups will be discussed separately in the analysis. Non-degree international students and students on OPT have
also increased since 2003, although their numbers remain relatively low. Particularly, the percentage of students on OPT among the total grew from 2.54% to 11.96% between 1993 and 2013 (see Appendix A), which implies a growth of international students who work in the United States after graduation. Both non-degree international students and students on OPT are counted into the total number of international students in the following analysis.

The growing population of international students has emerged in company with the growing accommodation capacity of U.S. colleges and universities. The United States has experienced an accelerating expansion of higher education since the 1990s. National Center for Education Statistics (2016) reports that the enrollment in U.S. degree-granting postsecondary institutions has increased by 18% between 1993 and 2003, and by 20% from 16.9 million to 20.4 million students between 2003 and 2013.

The growth of international students has been driven by a variety of forces. First of all, the United States has shown a strong need for talent, particularly in STEM fields. The thriving knowledge-based economy and computer industry attract students to study in the United States. Consequently, the number of students in engineering and computer science fields has increased by 10% annually between 2006 and 2016 (IIE, 2016). To retain talent, the U.S. government also stipulates and implements favorable visa policy for international students who pursue degrees in STEM fields and for researchers who work in critical areas (USCIS, 2016).

Moreover, U.S. colleges and universities have found great potential in the international market. With the rise of middle class in well-off developing countries, more families can afford the cost of studying abroad, which means a great source of tuition
revenue for the U.S. colleges and universities. During financial crisis periods, U.S. colleges and universities with reduced budgets could sustain by recruiting more international students who came to study at their own expenses. For example, Figure 4.2 displays a pattern that the number of international students grew faster after 2008 when the financial crisis happened, which seems to suggest a relationship between the economic status of U.S. higher education and its acceptance of international students.

Finally, U.S. colleges and universities are aware of their status in the world. To remain on the top of the domestic and global rankings of universities, there has been a tacit competition in getting international students. Representatives of U.S. colleges and universities go around the globe to recruit students and foster overseas partnerships so that they can have a growing impact in the interconnected world (Wildavsky, 2010).

**International Students by Place of Origin**

Countries play unequal parts in sending international students to the United States. The vast majority of international students have come from the top places of origin. In 2013, the top twenty places of origin contributed about 79% of the total foreign students who were studying in the United States. There has been a general growth of students from top origin countries between 1993 and 2013, in spite of some change of countries’ positions in the ranking over time (see Appendix B). Among the top twenty countries, the gap between the first and the twentieth has been enlarged over time. For example, in 1993, the topmost country, which was China then, had about 40,000 more students in the United States than Russia which was ranked the twentieth; this difference later exceeded 260,000 between China and Thailand who were ranked the first and the twentieth in 2013.
Figure 4.3 shows places of origin that were ranked among the top ten in any of the three years -- 1993, 2003, and 2013, and displays the change of the number of international students from these places over time. Developing countries or areas have been the major origins of international students. Particularly, China, India, Saudi Arabia, and Vietnam show a much higher change rate from 1993 to 2013 compared with other countries. Among developed countries, only Canada remains to be among the top ten, while Germany, France, and the United Kingdom were ranked behind the tenth (see Appendix B) and they have merely increased compared with developing countries.

Although developing countries generally have a much higher growth rate of students than developed countries over time, it is not adequate to conclude that developing countries have a stronger connection with the United States in education than developed countries, given that countries have diverse characteristics and history of studying abroad. For example, China and India currently have a much larger population than any other country, and they are more likely to have a large size of students studying
in the United States. However, China did not have massive waves of students entering the United States until the 1980s, while students from Europe started swarming into America as early as at the end of World War I. Similarity in culture and languages have also made it relatively easy for European students to settle down in the United States, and Europe is still the top destination of studying abroad for American students (IIE, 2014). Therefore, it is hard to say that European countries, particularly those industrialized countries in West Europe, are losing their significance in their educational and research connections with the United States.

The ranking of top places of origin also varies by academic levels (see Figure 4.4 and 4.5). Some countries have a higher position on graduate student level than on undergraduate level. India, for example, had the second largest number of graduate students in the United States among all countries, but the fourth largest number of undergraduate students in 2013. On the opposite, some countries are ranked higher on the undergraduate level. For example, Saudi Arabia shows a pronounced contrast that it was the third largest source country of undergraduates in the United States in 2013, but was only ranked the fifth on the graduate level and the seventh in general. The difference in the ranks of the same country suggests that country’s characteristics have unequal effects on students of different academic levels who study abroad.

The descriptive results also suggest how various factors may have affected the student mobility. For example, among developed countries, Canada, Germany, France, and United Kingdom have been among the top twenty countries of origin, but only Canada remained to be among the top ten over time. Given that Canada has a neck-and-neck economy with the other three countries but a smaller population, an educated guess
is that Canada’s geographic closeness to the United States makes it one of the top ten countries of origin. Among developing countries, even with a comparable population to China, India did not increase as rapidly as China in terms of its students in the United States between 2003 and 2013. This decade was the ten years during which China overtook many other countries and became the second largest economy in the world. Although both being developing countries, China’s GDP per capita reached 7,077.77
dollars in 2013, almost five times as much as that of India, which was 1456.20 dollars (World Bank, 2016a). The variation in economic conditions may mainly or partly explain the difference between these two countries in student mobility.

The intuitive analysis of examples above suggests that the difference in student mobility by country is not determined by only one characteristic of the countries. The pattern can be explained more comprehensively. A more proper way to examine how student mobility varies by country of origin is to perform a regression analysis and compare countries when conditions are hypothetically equal, in terms of population, economy, quality of education and other aspects.

Description of Variables

Summary Statistics

Table 4.1 describes the summary statistics of variables used in this research, including their mean, standard deviation, minimum, median and maximum values. Since the variables come from different data sources and not all countries always have complete information, it is unavoidable that some variables have more missing values than others (see the last column in Table 4.1). As the original values of the variables on the top of the list are on different scales and have larger variances, they were transformed into their natural logarithm form so that their values could fall into an equally reasonable range.

Transformation is particularly necessary for the dependent variable. By taking a close look at the total number of international students from each country in the United States, a highly-skewed distribution is noticed. After logarithm transformation, the
<table>
<thead>
<tr>
<th>Variables</th>
<th>Mean</th>
<th>SD</th>
<th>Min</th>
<th>Median</th>
<th>Max</th>
<th>N</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total international students</td>
<td>3697.63</td>
<td>12449.35</td>
<td>1</td>
<td>754</td>
<td>274439</td>
<td>3292</td>
</tr>
<tr>
<td>International graduate students</td>
<td>1627.15</td>
<td>6650.59</td>
<td>0</td>
<td>206.50</td>
<td>115727</td>
<td>3288</td>
</tr>
<tr>
<td>International undergraduates</td>
<td>1609.74</td>
<td>4730.44</td>
<td>0</td>
<td>405</td>
<td>110550</td>
<td>3289</td>
</tr>
<tr>
<td>GDP per capita</td>
<td>8847.31</td>
<td>13666.42</td>
<td>69.58</td>
<td>2404.27</td>
<td>69094.75</td>
<td>2935</td>
</tr>
<tr>
<td>Population for tertiary education</td>
<td>3610011</td>
<td>1300000</td>
<td>135</td>
<td>872758.5</td>
<td>130111422</td>
<td>2976</td>
</tr>
<tr>
<td>Distance</td>
<td>5476.29</td>
<td>2124.87</td>
<td>455</td>
<td>5326</td>
<td>10163</td>
<td>3292</td>
</tr>
<tr>
<td>Number of academic publications per million</td>
<td>186.90</td>
<td>358.43</td>
<td>0</td>
<td>20.58</td>
<td>2576.97</td>
<td>2903</td>
</tr>
<tr>
<td>Total international students (ln)</td>
<td>6.46</td>
<td>2.02</td>
<td>0</td>
<td>6.63</td>
<td>12.52</td>
<td>3292</td>
</tr>
<tr>
<td>International graduate students (ln)</td>
<td>5.33</td>
<td>2.09</td>
<td>0</td>
<td>5.34</td>
<td>11.66</td>
<td>3288</td>
</tr>
<tr>
<td>International undergraduates (ln)</td>
<td>5.87</td>
<td>1.88</td>
<td>0</td>
<td>6.01</td>
<td>11.61</td>
<td>3289</td>
</tr>
<tr>
<td>GDP per capita (ln)</td>
<td>7.87</td>
<td>1.65</td>
<td>4.21</td>
<td>7.79</td>
<td>11.14</td>
<td>2935</td>
</tr>
<tr>
<td>Population for tertiary education (ln)</td>
<td>13.77</td>
<td>1.66</td>
<td>4.91</td>
<td>13.68</td>
<td>18.68</td>
<td>2976</td>
</tr>
<tr>
<td>Distance (ln)</td>
<td>8.51</td>
<td>0.51</td>
<td>6.12</td>
<td>8.58</td>
<td>9.23</td>
<td>3292</td>
</tr>
<tr>
<td>Number of academic publications per million (ln)</td>
<td>3.41</td>
<td>2.06</td>
<td>0</td>
<td>3.07</td>
<td>7.86</td>
<td>2903</td>
</tr>
<tr>
<td>Number of top 500 universities</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>0</td>
<td>.392</td>
<td>.488</td>
<td>0</td>
<td>0</td>
<td>1</td>
<td>3292</td>
</tr>
<tr>
<td>1-9</td>
<td>.096</td>
<td>.295</td>
<td>0</td>
<td>0</td>
<td>1</td>
<td>3292</td>
</tr>
<tr>
<td>10-19</td>
<td>.013</td>
<td>.114</td>
<td>0</td>
<td>0</td>
<td>1</td>
<td>3292</td>
</tr>
<tr>
<td>20-29</td>
<td>.012</td>
<td>.110</td>
<td>0</td>
<td>0</td>
<td>1</td>
<td>3292</td>
</tr>
<tr>
<td>30-39</td>
<td>.004</td>
<td>.063</td>
<td>0</td>
<td>0</td>
<td>1</td>
<td>3292</td>
</tr>
<tr>
<td>40 and more</td>
<td>.004</td>
<td>.065</td>
<td>0</td>
<td>0</td>
<td>1</td>
<td>3292</td>
</tr>
<tr>
<td>Polity index</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Full democracy</td>
<td>.175</td>
<td>.380</td>
<td>0</td>
<td>0</td>
<td>1</td>
<td>3292</td>
</tr>
<tr>
<td>Democracy</td>
<td>.303</td>
<td>.459</td>
<td>0</td>
<td>0</td>
<td>1</td>
<td>3292</td>
</tr>
<tr>
<td>Open Anocracy</td>
<td>.113</td>
<td>.317</td>
<td>0</td>
<td>0</td>
<td>1</td>
<td>3292</td>
</tr>
<tr>
<td>Closed Anocracy</td>
<td>.146</td>
<td>.354</td>
<td>0</td>
<td>0</td>
<td>1</td>
<td>3292</td>
</tr>
<tr>
<td>Autocracy</td>
<td>.180</td>
<td>.384</td>
<td>0</td>
<td>0</td>
<td>1</td>
<td>3292</td>
</tr>
<tr>
<td>English as an official language</td>
<td>.268</td>
<td>.443</td>
<td>0</td>
<td>0</td>
<td>1</td>
<td>3292</td>
</tr>
</tbody>
</table>
dependent variable looks more normally distributed. Similarly, GDP per capita, the population for tertiary education, and publication per million population also have highly-skewed distribution, and they are transformed into their logarithm form as well. Among all the variables, two determinants of international student mobility deserve extra attention because they are more relevant to higher education and research capacity of countries of origin.

**Competitiveness of Higher Education**

The competitiveness of higher education by country is indicated by the number of ARWU’s Top 500 universities in each country. The number of top universities is considered to represent the quality and strengths of higher education and research capacity of a country. The United States has made up the biggest share of top 500 universities in ARWU ranking over time compared with any other country (see Figure 4.6), which embodies the leading position of U.S. higher education in the world and explains why the country could attract and accommodate a large population of international students.

The global distribution of Top 500 universities has been quite stable for most countries. Between 2003 and 2013, only Japan has experienced an obvious decline from 36 to 20 top universities, while China has had a fast growth from 9 to 28. Meanwhile, the data suggest that more countries have entered the Top 500 family over time.
Countries are divided into 6 groups based on their number of Top 500 universities, excluding the United States (see Table 4.2). In 2003, 38 countries had one or more Top 500 universities. In 2013, 44 countries were on the list. Countries that were ranked on the top in 2003, particularly Germany, UK, and Japan, had fewer top universities and fell into lower categories in 2013. Countries that were ranked in the lowest group, such as China and South Korea had more top universities in 2013 than in 2003. The redistribution of top universities among countries implies that the disparity in higher education between the top and the bottom of this list has generally decreased over time, although in a mild and slow way.

Table 4.3 shows how student mobility varies across countries by their number of top universities. In 2003, countries with 20 to 29 and 30 to 39 top universities had more students in the United States than other groups, except countries with 1 to 9 universities. Considering that China and India were both in this group in 2003, the mean of this group...
Table 4.2
Countries with Top 500 Universities in 2003 and 2013 (USA excluded)

<table>
<thead>
<tr>
<th>No. of Top</th>
<th>2003</th>
<th>2013</th>
</tr>
</thead>
<tbody>
<tr>
<td>40 and above</td>
<td>Germany, UK</td>
<td></td>
</tr>
<tr>
<td>30-39</td>
<td>Japan</td>
<td>Germany, UK</td>
</tr>
<tr>
<td>20-29</td>
<td>France, Canada, Italy</td>
<td>China, France, Canada, Japan</td>
</tr>
<tr>
<td>10-19</td>
<td>Australia, Netherlands, Spain, Sweden</td>
<td>Australia, Italy, Netherlands, Spain, Sweden, South Korea</td>
</tr>
<tr>
<td>1-9</td>
<td>China, South Korea, Belgium, Switzerland, Taiwan, Austria, Brazil, Finland, Israel, Denmark, Hong Kong, South Africa, Ireland, Norway, Portugal, Chile, Greece, Hungary, New Zealand, Poland, Russia, Singapore, Argentina, Czech,</td>
<td>Belgium, Switzerland, Taiwan, Austria, Brazil, Finland, Israel, Denmark, Hong Kong, Saudi Arabia, South Africa, Ireland, Norway, Portugal, Chile, Greece, Hungary, Iran, Malaysia, New Zealand, Poland, Russia, Singapore, Argentina, Czech, Egypt, India, Mexico, Serbia, Slovenia, Turkey</td>
</tr>
<tr>
<td>Total</td>
<td>38</td>
<td>44</td>
</tr>
</tbody>
</table>

would be 5968.08 if these two countries are excluded. Similarly, China and India’s large population of students studying abroad inflates their group means respectively in 2013. If they are excluded from the calculation, the mean of international students sent by countries which had 20 to 29 top universities in 2013 will be 18646.67, and countries which had 1 to 9 top universities will be 5910.7.
Table 4.3
Mean of number of international students by rank category in 2003 and 2013 (USA excluded)

<table>
<thead>
<tr>
<th>No. of Top 500 Universities</th>
<th>2003 All</th>
<th>2003 Excluding China and India</th>
<th>2013 All</th>
<th>2013 Excluding China and India</th>
</tr>
</thead>
<tbody>
<tr>
<td>40 and above</td>
<td>8592</td>
<td>8592</td>
<td>--</td>
<td>--</td>
</tr>
<tr>
<td>30-39</td>
<td>40835</td>
<td>40835</td>
<td>10175.50</td>
<td>10175.50</td>
</tr>
<tr>
<td>20-29</td>
<td>12381</td>
<td>12381</td>
<td>82594.75</td>
<td>18646.67</td>
</tr>
<tr>
<td>10-19</td>
<td>2739.50</td>
<td>2739.50</td>
<td>19960</td>
<td>19960</td>
</tr>
<tr>
<td>1-9</td>
<td>10595.39</td>
<td>5968.08</td>
<td>9032.07</td>
<td>5910.70</td>
</tr>
<tr>
<td>0</td>
<td>1289.57</td>
<td>1289.57</td>
<td>1364.36</td>
<td>1364.36</td>
</tr>
</tbody>
</table>

By comparing the groups, a trend can be detected over time. Old industrialized countries with twenty or more top universities used to be the main sender of international students to the United States, while countries with the largest population at that time had fewer top universities at home and fewer students in the United States. In 2013, both developed and developing countries with at least 10 top universities had more international students in the United States than other groups. This suggests that the gap in academic capacity between the country of origin and the United States may determine whether the country is capable of providing qualified students for U.S. colleges and universities. As more developing countries are trying to catch up with U.S. academic capacity and become more competitive in higher education, they will have more students academically prepared for studying in the United States.

**Research Productivity by Country**

In addition to measuring the quality of higher education, another variable, academic publications per million population, is also incorporated to indicate the research capacity of the country of origin. Academic publication is considered a reasonable
measurement of research productivity by researchers (Graves, Marchand, & Thompson 1982; Toutkoushian, Porter, Danielson, & Hollis, 2003; Fernandez-Zubieta, Guena & Lawson, 2015). With no doubt, the United States has contributed the largest number of academic publications among all countries from 1993 to 2012 (see Figure 4.7). Other countries have also grown. Particularly, developing countries have increased rapidly.

Countries with a greater number of publications are supposed to be competitive in research, but the effect of research capacity on student mobility is unclear yet. Its role may vary across countries. Developed countries with strong research capacity may be able to prepare high-quality students for studying abroad on the one hand but also likely to attract and retain domestic students on the other hand, while developing countries with comparable research capacity may be still in a developing phase where more researchers are needed and students are encouraged to study abroad and return. Therefore, the effect of academic capacity on student mobility may be a mixed one. However, a simple correlation test shows that a positive correlation exists between academic publications
and student mobility and suggests a general pattern that top countries of origin for international students are also main producers of academic publications.

Regression Models

Pooled OLS Regression Models

With a better knowledge of the variables that will be examined in the regression model, the relationship between student mobility to the United States and its determinants can be further explored and quantified. Although pooled OLS regression models are first tested without country fixed effects being considered, year fixed effects are always controlled for by including year dummies because the population and economic variables simply have a natural, rising trend over time.

Table 4.4 reports the coefficients of variables for the country pooled OLS regression models. Model (1) focuses on the three basic, main variables that are usually examined in gravity models, which are GDP per capita, population, and geographic distance. With no surprise, GDP per capita and population for tertiary education both have a significant and positive effect on the dependent variable, while distance has a significant and negative one. Every one percent increase in the GDP per capita of a particular country indicates 0.53 percent increase in the number of their students in the United States. For every 1 percent increase in the population for tertiary education, there would be 0.89 percent increase in the number of international students. In addition, every 1 percent increase in the geographic distance between the United States and country origin is associated with 0.25 percent decrease in the dependent variable.
Model (2) incorporates two academic-related variables based on model (1). The effect of GDP per capita, population for tertiary education, and distance remain significant, with only slight change in their coefficients. When all other variables are controlled for, countries with 1 to 9, 10 to 19, 20 to 29, and 40 or more top universities show a significant, negative impact on the dependent variable, which are respectively 0.60, 0.62, 0.62, 0.44 times as many as students in the United States from countries with no top universities. In addition, the number of academic publications per million population has a significant, positive association with the dependent variable. When the number of publications per million population of a country goes up by 1 percent, the number of students from this country in the United States goes up by 0.27 percent.

Based on model (2), political index and language dummy are added to model (3). The coefficients of GDP per capita, population and distance remain significant. The number of top universities dummies and the number of publications per million population have similar effects on the dependent variable. Compared with countries which have full democracy, countries with democracy on average have 1.50 times as many as students in the United States. Countries with English being an official language on average have 1.52 times as many as students in the United States from countries where English is not an official language.

Model (2) and (3) have almost only half of the sample size in model (1), but model (3) has a larger value of adjusted R-squared, which suggests that variables included in model (3) explain more, which is 70% of the variation in the dependent variable. Regression models are also tested for each year separately, and they show similar results as reported in the pooled regression.
Table 4.4
Country pooled OLS regression of international students on country’s characteristics

<table>
<thead>
<tr>
<th>Total international students (ln)</th>
<th>(1)</th>
<th>(2)</th>
<th>(3)</th>
</tr>
</thead>
<tbody>
<tr>
<td>GDP per capita (ln)</td>
<td>0.531***</td>
<td>0.285***</td>
<td>0.334***</td>
</tr>
<tr>
<td></td>
<td>(0.011)</td>
<td>(0.037)</td>
<td>(0.041)</td>
</tr>
<tr>
<td>Population for tertiary education (ln)</td>
<td>0.891***</td>
<td>0.944***</td>
<td>0.922***</td>
</tr>
<tr>
<td></td>
<td>(0.014)</td>
<td>(0.025)</td>
<td>(0.025)</td>
</tr>
<tr>
<td>Distance (ln)</td>
<td>-0.253***</td>
<td>-0.419***</td>
<td>-0.396***</td>
</tr>
<tr>
<td></td>
<td>(0.046)</td>
<td>(0.073)</td>
<td>(0.078)</td>
</tr>
</tbody>
</table>

No. of Top 500 universities ("0" omitted)

| 1-9 | -0.504*** | -0.512*** |
|     | (0.096)   | (0.103)   |
| 10-19 | -0.483**  | -0.399*   |
|      | (0.169)   | (0.180)   |
| 20-29 | -0.474**  | -0.476**  |
|      | (0.171)   | (0.173)   |
| 30-39 | 0.016     | 0.102     |
|      | (0.219)   | (0.270)   |
| >=40 | -0.828*** | -0.831*** |
|      | (0.127)   | (0.150)   |

Publication per million population (ln)

| 0.272*** | 0.252*** |
|          | (0.031)  | (0.030)  |

Polity ("full democracy" omitted)

| Democracy | 0.405*** | (0.107)   |
| Open Anocracy | 0.019 | (0.145)   |
| Closed Anocracy | -0.029 | (0.138)   |
| Autocracy | -0.027 | (0.144)   |
| English | 0.421*** | (0.063)   |

\[
Constant \begin{align*}
-7.867*** \\
(0.494)
\end{align*}, \begin{align*}
-5.797*** \\
(0.778)
\end{align*}, \begin{align*}
-6.229*** \\
(0.820)
\end{align*}

<table>
<thead>
<tr>
<th>Year FE</th>
<th>Yes</th>
<th>Yes</th>
<th>Yes</th>
</tr>
</thead>
<tbody>
<tr>
<td>N</td>
<td>2780</td>
<td>1321</td>
<td>1309</td>
</tr>
<tr>
<td>(R^2)</td>
<td>0.659</td>
<td>0.673</td>
<td>0.700</td>
</tr>
</tbody>
</table>

Standard errors in parentheses
* \( p < 0.05 \), ** \( p < 0.01 \), *** \( p < 0.001 \)
Country Fixed-effects Model

Since the data used in this study are essentially panel data which observe about 200 countries across years, country-level effects should be considered. A Hausman test is conducted to compare the fitness of pooled model and country fixed-effects model. It is concluded that coefficients are not consistent under the two methods (random-effects and fixed-effects) and random-effects model cannot adequately model country-level effects (chi-squared = 29.31; Prob>Chi2 = 0.0318). Therefore, it is necessary to examine country fixed-effect models. When both year and country fixed effects are controlled for, time-invariant variables such as geographic distance and language are omitted from the models because these two variables remain the same for any given country over time.

Table 4.5 reports the results of fixed-effects models. In Model (1), GDP per capita and population for tertiary education both have significant, positive effect on the dependent variable, when other variables are held constant. For every 1 percent increase in GDP per capita of the sender country, the total number of international students from the country will increase by 0.55 percent. For every 1 percent increase in population for tertiary education, the number of international students will increase by 0.65 percent.

In Model (2), the coefficient of GDP per capita becomes insignificant, while population for tertiary education remains to have a significant and positive effect on the dependent variable. Higher-education-related variables show a significant, positive association with the dependent variable. Countries which have 10 to 19, 20 to 29, 30 to 39, and 40 or more top universities, on average, have 1.67, 3.05, 4.27, and 3.86 times respectively as many as international students in the United States from countries with no top universities. The number of publications per million population does not seem to have
Table 4.5
Country fixed-effects OLS regression of international students on country’s characteristics

<table>
<thead>
<tr>
<th>Total international students (ln)</th>
<th>(1)</th>
<th>(2)</th>
<th>(3)</th>
</tr>
</thead>
<tbody>
<tr>
<td>GDP per capita (ln)</td>
<td>0.545***</td>
<td>0.140</td>
<td>0.110</td>
</tr>
<tr>
<td></td>
<td>(0.144)</td>
<td>(0.180)</td>
<td>(0.178)</td>
</tr>
<tr>
<td>Population for tertiary education (ln)</td>
<td>0.649***</td>
<td>0.994***</td>
<td>0.998***</td>
</tr>
<tr>
<td></td>
<td>(0.172)</td>
<td>(0.183)</td>
<td>(0.184)</td>
</tr>
</tbody>
</table>

No. of Top 500 universities (0 omitted)

| 1-9 | 0.311 | 0.322 |
|     | (0.199) | (0.206) |
| 10-19 | 0.515* | 0.530* |
|       | (0.208) | (0.214) |
| 20-29 | 1.114*** | 1.140*** |
|       | (0.217) | (0.221) |
| 30-39 | 1.451*** | 1.469*** |
|       | (0.218) | (0.221) |
| >=40 | 1.350*** | 1.361*** |
|       | (0.222) | (0.227) |

Publication per million population (ln)

| 0.212 | 0.225* |
|       | (0.108) | (0.112) |

Polity (“full democracy” omitted)

| Democracy | 0.017 |
|           | (0.088) |
| Open Anocracy | 0.136 |
|               | (0.113) |
| Closed Anocracy | 0.120 |
|                | (0.129) |
| Autocracy | -0.051 |
|           | (0.185) |

Constant

| -6.802* | -8.963** | -8.861*** |
|         | (2.863) | (3.282) | (3.273) |

Year FE: Yes  | Country FE: Yes

| N | 2780 | 1321 | 1309 |
| R² | 0.635 | 0.622 | 0.616 |

Standard errors in parentheses
* p < 0.05, ** p < 0.01, *** p < 0.001
In model (3), the coefficients of GDP per capita, population for tertiary education, and number of top universities do not change much compared to those in model (2). The newly added polity dummies do not suggest any significant effect on the dependent variable when other variables are taken into account, but it makes the coefficient of number of publications per million population become significant. The number of international students will have 0.22 percent increase for every 1 percent increase in the number of publications per million population. The decreasing R-squared values across these three models suggest that including university data and polity data do not improve the power of explanation of models.

By comparing pooled model and country fixed-effects model, there are several noteworthy differences. First, GDP per capita is significant in all pooled models but not significant in the country fixed-effects full model. Second, the coefficients of the number of top universities flip into positive in the fixed-effects model as opposed to pooled model. Third, the variable of academic publication becomes insignificant in the fixed-effects model. Finally, the polity dummies also turn into insignificant in the fixed-effects model. These changes may be because fixed-effects model manages to control for some unobserved country characteristics that are omitted but related to both the dependent variable and the independent variables in the pooled model.

Fixed-effects Models by Academic Level

As previously discussed, the relationship between student mobility and its determinants may vary by academic level. Variables may have different impacts on the mobility of graduate students and undergraduate students. Some variables may play an
important role to graduate students but not significantly affect undergraduate student mobility. Therefore, models are tested with the dependent variable being specified as the number of international graduate students and the number of international undergraduate students. Table 4.6 reports the coefficients of fixed-effects models of international undergraduate students on determinants.

In model (1), both GDP per capita and population for tertiary education suggest a significant, positive impact on the dependent variable. When other variables are held constant, the number of undergraduate students will increase by 0.55 percent for every 1 percent increase in GDP per capita. For every 1 percent increase in population for tertiary education, the number of undergraduate students will increase by 0.84 percent.

In model (2), the coefficients of GDP per capita and population for tertiary education remain significant and positive. When other variables are controlled for, countries with ten to nineteen, twenty to twenty-nine, thirty to thirty-nine, and forty or more top universities on average respectively have 2.01, 7.34, 12.68, and 12.37 times as many as undergraduate students from countries with no top universities. The coefficient of the number of publications per million population is not significant.

In model (3), the coefficients of polity dummies are not significant. The other variables which are significant in model (2) remain significant and their coefficients only change slightly. Similar to Table 4.6, the adjusted R-squared here also decreases in model (2) as the dummies indicating the number of top universities are added and sample size drops. Model (3) has higher adjusted R-squared value than model (2), which suggests that 50.1% of the variation in the number of undergraduate students can be explained by the independent variables in model (3).
Table 4.6

Country fixed-effects OLS regression of international undergraduate students on country’s characteristics

<table>
<thead>
<tr>
<th>Undergraduate</th>
<th>(1)</th>
<th>(2)</th>
<th>(3)</th>
</tr>
</thead>
<tbody>
<tr>
<td>GDP per capita (ln)</td>
<td>0.556***</td>
<td>0.150</td>
<td>0.111</td>
</tr>
<tr>
<td></td>
<td>(0.185)</td>
<td>(0.210)</td>
<td>(0.212)</td>
</tr>
<tr>
<td>Population for tertiary education (ln)</td>
<td>0.842***</td>
<td>1.049***</td>
<td>1.021***</td>
</tr>
<tr>
<td></td>
<td>(0.209)</td>
<td>(0.202)</td>
<td>(0.203)</td>
</tr>
<tr>
<td>No. of Top 500 universities (0 omitted)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1-9</td>
<td>0.225</td>
<td>0.234</td>
<td></td>
</tr>
<tr>
<td></td>
<td>(0.191)</td>
<td>(0.190)</td>
<td></td>
</tr>
<tr>
<td>10-19</td>
<td>0.696**</td>
<td>0.711**</td>
<td></td>
</tr>
<tr>
<td></td>
<td>(0.245)</td>
<td>(0.247)</td>
<td></td>
</tr>
<tr>
<td>20-29</td>
<td>1.993***</td>
<td>2.021***</td>
<td></td>
</tr>
<tr>
<td></td>
<td>(0.213)</td>
<td>(0.214)</td>
<td></td>
</tr>
<tr>
<td>30-39</td>
<td>2.540***</td>
<td>2.554***</td>
<td></td>
</tr>
<tr>
<td></td>
<td>(0.207)</td>
<td>(0.208)</td>
<td></td>
</tr>
<tr>
<td>&gt;=40</td>
<td>2.515***</td>
<td>2.514***</td>
<td></td>
</tr>
<tr>
<td></td>
<td>(0.212)</td>
<td>(0.213)</td>
<td></td>
</tr>
<tr>
<td>Publication per million population (ln)</td>
<td>0.093</td>
<td>0.128</td>
<td></td>
</tr>
<tr>
<td></td>
<td>(0.094)</td>
<td>(0.093)</td>
<td></td>
</tr>
<tr>
<td>Polity (“full democracy” omitted)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Democracy</td>
<td>0.097</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>(0.090)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Open Anocracy</td>
<td>0.218</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>(0.119)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Closed Anocracy</td>
<td>0.191</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>(0.140)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Autocracy</td>
<td>-0.056</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>(0.160)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Constant</td>
<td>-10.195**</td>
<td>-10.023**</td>
<td>-9.522*</td>
</tr>
<tr>
<td></td>
<td>(3.457)</td>
<td>(3.740)</td>
<td>(3.773)</td>
</tr>
<tr>
<td>Year FE</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>Country FE</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>N</td>
<td>2779</td>
<td>1321</td>
<td>1309</td>
</tr>
<tr>
<td>R²</td>
<td>0.563</td>
<td>0.498</td>
<td>0.501</td>
</tr>
</tbody>
</table>

Standard errors in parentheses

* p < 0.05, ** p < 0.01, *** p < 0.001
Table 4.7 shows the results of fixed-effects models of international graduate students. In model (1), when other variables are held constant, the number of undergraduate students will have 0.65 percent increase for every 1 percent increase in GDP per capita. For every 1 percent increase in population for tertiary education, the dependent variable will increase by 0.49 percent.

In model (2), GDP per capita and population for tertiary education remain significant and positive, with only change in the value of coefficients. When other variables are held constant, countries with twenty to twenty-nine top universities on average have 2.05 times as many as undergraduate students from countries with no top universities. Countries with 30 or more top universities on average have 2.61 times as many as graduate students from countries with no top universities. The number of publications per million population has no significant effect here.

In model (3), when other variables are controlled for, polity dummies do not show any significant effect on the dependent variable. The coefficients of GDP per capita, population for tertiary education, and the number of top universities remains significant and positive. The independent variables in model (3) can explain 67.9% of the variance in the number of graduate students.
Table 4.7
Country fixed-effects OLS regression of international graduate students on country’s characteristics

<table>
<thead>
<tr>
<th>Graduate</th>
<th>(1)</th>
<th>(2)</th>
<th>(3)</th>
</tr>
</thead>
<tbody>
<tr>
<td>GDP per capita (ln)</td>
<td>0.651***</td>
<td>0.290</td>
<td>0.255</td>
</tr>
<tr>
<td></td>
<td>(0.140)</td>
<td>(0.162)</td>
<td>(0.148)</td>
</tr>
<tr>
<td>Population for tertiary education (ln)</td>
<td>0.489**</td>
<td>0.789***</td>
<td>0.748***</td>
</tr>
<tr>
<td></td>
<td>(0.150)</td>
<td>(0.215)</td>
<td>(0.205)</td>
</tr>
<tr>
<td>No. of Top 500 universities (0 omitted)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1-9</td>
<td>0.324</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>(0.194)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>10-19</td>
<td>0.367</td>
<td>0.389</td>
<td></td>
</tr>
<tr>
<td></td>
<td>(0.211)</td>
<td>(0.220)</td>
<td></td>
</tr>
<tr>
<td>20-29</td>
<td>0.720***</td>
<td>0.756***</td>
<td></td>
</tr>
<tr>
<td></td>
<td>(0.212)</td>
<td>(0.214)</td>
<td></td>
</tr>
<tr>
<td>30-39</td>
<td>0.960***</td>
<td>0.986***</td>
<td></td>
</tr>
<tr>
<td></td>
<td>(0.212)</td>
<td>(0.213)</td>
<td></td>
</tr>
<tr>
<td>&gt;=40</td>
<td>0.959***</td>
<td>0.972***</td>
<td></td>
</tr>
<tr>
<td></td>
<td>(0.216)</td>
<td>(0.218)</td>
<td></td>
</tr>
<tr>
<td>Publication per million population (ln)</td>
<td>0.191</td>
<td>0.216*</td>
<td></td>
</tr>
<tr>
<td></td>
<td>(0.098)</td>
<td>(0.101)</td>
<td></td>
</tr>
<tr>
<td>Polity (“full democracy” omitted)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Democracy</td>
<td>-0.058</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>(0.103)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Open Anocracy</td>
<td>0.011</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>(0.120)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Closed Anocracy</td>
<td>-0.080</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>(0.129)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Autocracy</td>
<td>-0.304</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>(0.247)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Constant</td>
<td>-6.398*</td>
<td>-8.296*</td>
<td>-7.449*</td>
</tr>
<tr>
<td></td>
<td>(2.593)</td>
<td>(3.619)</td>
<td>(3.388)</td>
</tr>
</tbody>
</table>

| N          | 2779     | 1321     | 1309     |
| R²         | 0.560    | 0.682    | 0.679    |

Standard errors in parentheses
* p < 0.05, ** p < 0.01, *** p < 0.001
Summary and Discussions

Countries characteristics such as GDP and population are found to matter in student mobility. First, in fixed-effects models, GDP per capita becomes insignificant only when the dummies of the number of top universities are taken into account. It seems that education-related variables have a stronger power of explanation than GDP in the country fixed-effects model. However, the insignificance of GDP per capita does not mean that economy is not important in the student mobility, but that economy could have turned into education or academic capacity which determines student mobility in a more relevant way. This resonates with Perkins and Neumayer’s (2014) research in that GDP per capita or country of origin does not show a significant effect on student mobility when other variables are held constant. Second, the straightforward relationship between population for tertiary education and mobile students is confirmed by the results. The finding here is well aligned with previous studies that have discussed and verified that the growth of population, particularly in developing countries, leads to the increase of international students in developed countries (Agarwal & Winkler, 1985).

In addition, higher education and research development play an important role in student mobility. The number of top universities shows a clear pattern in which countries with more top universities have more students studying in the United States than countries with no top universities. Intuitively, one may expect that countries with no top universities have less capacity for educating highly skilled talent and are more likely to send students abroad. However, the coefficients in fixed-effects model suggest the opposite, that is, quality of education above a certain level in the country of origin is a prerequisite for students to study in more developed countries. It is probably because
studying abroad requires a well-educated population of students who at least have graduated from high school and meet the admission criteria of U.S. colleges and universities. Therefore, countries with similar education capacity to the United States are more likely to have such an education system that can foster students who are capable of pursuing their study in the United States. Nevertheless, the coefficients of the dummies representing the number of top universities imply that it is not simply a linear positive relationship. Countries with 30 to 39 top universities have a higher average number of international students in the United States than countries with 40 or more, and the difference between these two categories is found to be significant. This makes sense because students from countries which have comparable education and research capacity to the United States may not be motivated as much as students from other countries to study in the United States when they can have the opportunity to receive a quality education at home.

A robustness check has also been conducted on the categorization of the number of top universities. If the bands are too broad, for example, using 15 instead of 10, the non-linear positive pattern among the countries with 30 or more top universities will not be detected. If the bands are narrower than 10, for example, using 5 instead of 10, countries with 40 to 45 top universities on average are found to have fewer international students in the United States than countries with 35 to 39 top universities, which is consistent with what has been shown in the analysis above. However, using narrower bands means too few observations for each category. Therefore, using 10 as the band width is the most proper here.
Research capacity is also indicated by the number of publications per million population which, however, does not have a significant effect on the dependent variable, when the number of top universities is already controlled for in the model. The number of publications per million population is supposed to indicate the research capacity of a country, but it does not appear to suggest that students from countries with more publications per capita are more likely to study in the United States, even when the number of top universities is not held constant in the model. It is probably because the number of publications only measures the quantity of research production, which has a mixed relationship with the number of students studying abroad. Publications are produced by researchers from universities, research institutes, and industries, and do not necessarily reflect the research capacity of the education sector. If a country is productive in terms of quantity of research output while its education system is not competitive enough in quality, students in this country are still likely to seek better education in more developed countries.

Finally, there are some significant differences between graduate and undergraduate students. An important finding is that only countries with 20 or more top universities have significantly more graduate students than countries with no top universities do in the United States, while countries with 10 or more top universities have significantly more undergraduates than countries with no top universities. This suggests that having a large number of international students in the United States on graduate level is more relevant to the academic capacity of the country of origin. Countries with just slightly more top universities and slightly better academic capacity do not have evident strength in sending graduate students compared with countries with no top universities,
while the former has an advantage in sending undergraduates to the United States. In other words, studying abroad on the graduate level has a higher requirement for the quality of education in the country of origin than on undergraduate level, when other conditions are held constant.
CHAPTER 5
FOREIGN COLLEGE GRADUATES AND RESEARCHERS IN THE UNITED STATES

As many foreign students have chosen to stay and work in the United States after graduation, the country acquires valuable labor force (Suter & Jandl, 2008; Florida, 2008; Dreher & Poutvaara, 2011). This chapter provides an overview of foreign-born college graduates who have stayed in the United States. The description and discussion in this chapter aim to reveal the link between international students and the highly skilled labor force in the country, based on the data from the National Survey of College Graduates.

Description of Foreign-born College Graduates

Foreign-born college graduates refer to those who were born out of the United States, came to the United States on a student visa and stayed in the United States at the time of the survey. Although foreign-born college graduates make up a small proportion of the total population of college graduates in the United States, they have increased over time during the past two decades. Between 1993 and 2013, the percentage of foreign-born college graduates among all college graduates has grown from less than 3% to nearly 4%. This seemingly slow growth is due to a simultaneously faster-growing population of native students and graduates. As a matter of fact, the size of foreign-born college graduates in the United States has more than doubled from 773,266 to 1,807,260 during this time period.
The composition of types of degrees obtained by college graduates is quite different for foreign-born students and U.S.-born students (see Figure 5.1). In 2013, about 65% of U.S.-born college graduates received bachelor’s degree, 26.6% received master’s degree, 2.8% received a doctoral degree, and 5.7% received a professional degree, while 32.9%, 42.4%, 19.0% and 5.8% of foreign-born college graduates obtained these four types of degrees respectively. The composition of U.S.-born college graduates embodies a normal pyramid pattern of higher education. By contrast, foreign-born college graduates are more concentrated on academic levels above bachelor’s degree, with a much larger proportion of master’s and doctoral degrees. This structure has not changed much between 1993 and 2013. A few possible reasons may explain the special composition of foreign-born graduates of different academic levels. First, foreign students are more interested in pursuing advanced degrees in the United States to enhance their competitiveness, which is supported by the IIE data as shown in the previous
chapter. Second, international students are more likely to receive financial support for
graduate-level than undergraduate-level studies in U.S. universities, which enables those
who cannot afford the cost of studying abroad to pursue a graduate-level degree in the
United States. Third, foreign-born graduates who have obtained higher degrees are more
likely to stay in the United States due to visa policy preferences and job opportunities.

In addition, foreign-born graduates also show a preference for certain fields of
study (see Figure 5.2). Although the proportion of students in science and engineering\(^1\)
(S&E) fields has increased for both U.S.-born and foreign-born college graduates
between 1993 and 2003, the majority of foreign-born college graduates obtained their
highest degree in S&E fields, while the majority of U.S.-born college graduates studied in
non-S&E fields.

The difference may be due to the following reasons. First, the United States has
more advantages in S&E fields than in non-S&E fields relative to other countries, while
non-S&E fields are hard to compare. Thus, students majoring S&E fields from
developing countries are motivated to study advanced science and technology in U.S.
colleges and universities. Second, language and cultural barriers prevent more
international students from studying in non-S&E fields in the United States. Third,
developing countries hope to become more competitive in the global economy, and thus
put efforts in developing STEM education at home, which generates a large pool of
students in S&E fields who want to study abroad. Finally, U.S. government has
implemented policies that encourage STEM education and attract foreign students in

\(^1\) S&E include natural science and social sciences. Non-S&E include management and administration,
education (except science and math teacher education), social service and related fields, sales and
marketing, art and humanities, and others.
Figure 5.2 Fields of study of U.S.-born and foreign-born college graduates in 2013

STEM fields, which plays a screening role of selecting international students to the U.S. colleges and universities and retaining them in the United States. For example, students with a college degree in STEM fields can acquire OPT employment authorization with a longer extension than students in non-S.E. fields (USCIS, 2016).

Since millions of foreign-born graduates have chosen to stay in the United States, what kind of work do they do? Figure 5.3 shows the employer sectors in which college graduates work, including education, government, and business. In general, both U.S.-born and foreign-born students are more concentrated in the business sector, followed by the education sector. A very small percentage of students enter governments. The distribution of students across employer sectors is largely determined by the structure of job market and availability of job opportunities by sector. However, U.S.-born and foreign-born students differ in that foreign students are less likely to obtain governmental jobs, probably because national security policy requires background clearance and only allows U.S. citizens or permanent residents to work in the governmental sector. A higher
Figure 5.3 Employer sectors of U.S.-born and foreign-born college graduates in 2013

percentage of foreign-born graduates work in the education sector, which implies that foreign-born graduates are more likely to work as professors or researchers in colleges and universities compared with native college graduates.

Moreover, NSCG data suggest that foreign college graduates are more likely to be engaged in research and development (R&D) activities than U.S.-born graduates in their work. In 1993, 31.5% of foreign-born graduates had R&D as their main work activity, while only 15.0% of U.S.-born graduates took on similar work. In 2013, the number reached 37.5% for foreign students, while it had barely changed for U.S.-born graduates. This pattern can be explained by the fact that foreign-born students are more likely to pursue higher level degrees and study in STEM fields, which largely determines the type of work they can do after graduation. Given that researchers are defined here as college graduates whose main work activity is R&D, Figure 5.4 shows that the percentage of foreign-born researchers among all researchers in the United States has increased over time, from less than 6 percent in 1993 to about 8 percent in 2013. The size has almost
Figure 5.4 Number of U.S-born and foreign-born college graduates as researchers over time tripled from 236,219 to 644,148 between 1993 and 2013.

The descriptive figures above have summarized the characteristics of foreign-born graduates who have stayed in the United States. First, there is a growing population of foreign-born graduates who have chosen to stay in the United States after graduation over time. Second, foreign-born graduates are more likely to obtain advanced degrees and study in S&E fields than native students. Third, foreign-born graduates mainly work in business and education sectors after graduation and are more likely to do research-related work relative to native students. Finally, despite being the minority in the labor force, foreign-born graduates are a growing group among the labor force of researchers in the United States. The findings here are consistent with what previous studies suggest, that is, researchers who made exceptional contributions to S&E fields in the United States are disproportionately drawn from the foreign-born population (Levin & Stephan, 1999).
Foreign-born Graduates by Place of Origin

As countries play unequal roles of sending students to the United States, do they also make up different proportions of foreign-born graduates and researchers who work in the host country? Taking top places of origin for example, India and China have the largest number of college graduates in the United States, which were 316,113 and 228,179 respectively in 2013, with evident growth since 1993. South Korea, Mexico, and Nigeria also have had some growth, while other countries remained quite stable over time (see Figure 5.5).

Figure 5.6 shows the type of degree obtained by foreign-born college graduates from top places of origin in 2013. It seems that the composition of students’ degrees varies by origin. For example, India, China, and Taiwan have a very low percentage of college graduates whose highest degree is bachelor’s degree but a much larger proportion of college graduates with master’s and doctoral degree than other places of origin. The general pattern has been relatively stable between 1993 and 2003, except that India and Taiwan both saw a slight growth in the proportion of bachelor’s degree throughout the years and China had a shrinking proportion of master’s degree but a growing part of doctoral degree.

Countries vary not only by academic levels but also by fields of study. Figure 5.7 shows that in general most top places of origin have more students study in S&E fields than in non-S&E fields. Countries with more college graduates with graduate degrees than bachelor’s degrees are likely to have a larger proportion of students in the S&E fields, such as India, China, and Vietnam. Over time, the proportions of college graduates in S&E fields from India, China, Philippines, and South Korea have kept growing, while
Figure 5.5 Number of foreign-born college graduates by place of origin over time

Figure 5.6 Type of degree obtained by foreign-born college graduates by place of origin (2013)
other places of origin have shown a fluctuating pattern between 1993 and 2013. Regardless, the general trend is that most top places of origin have more college graduates in S&E fields than in non-S&E fields in 2013 compared with 1993, except for Canada and Mexico.

Researchers also reveal that foreign students in S&E fields from certain countries have higher stay rate than others. For example, 4,121 and 1,496 doctoral recipients in S&E fields in 2006 were from China and India respectively. Their one-year stay rates were 92% and 89%, and five-year stay rates were 85% and 82%. Some countries, such as Romania and Iran, also have high one-year stay rate above 90% and five-year stay rate above 80%, although their size of doctoral recipients is much smaller than China and India. Most countries have 40% to 70% one-year stay rate and 30% to 60% five-year stay rate (Finn, 2014).
Given that countries differ greatly in academic levels, fields of study and stay rates of college graduates in the United States, it is speculated that foreign-born researchers should also have a very uneven distribution by place of origin. Figure 5.8 supports this guess as it shows that countries which have a larger proportion of college
graduates in S&E fields with graduate-level degrees do tend to have more graduates who perform research activities than other countries.

Moreover, figure 5.9 further displays the number of foreign-born researchers by place of origin over time. It is obvious that countries have contributed to the research labor force in the United States to different degrees. Particularly, India and China are the two largest suppliers of researchers, and their leading position has been strengthened over time. Other countries have remained at a relatively low level and have grown slowly when India and China have risen rapidly between 1993 and 2013. Countries other than India and China also show different sizes and growth rates of researchers in the United States.

By comparing the top places of origin for international students in the United States and the top places of origin for foreign-born researchers in the United States, it seems that the former determines the latter to a great extent and these two groups are interconnected. A correlation test between the number of international students and the number of researchers from each country suggests that this connection exists and they have a strong correlation because the Pearson correlation coefficient between these two variables is as high as 0.86. Additionally, the correlation between the number of foreign-born researchers and the number of international graduate students is 0.93, much higher than that between the number of foreign researchers and the number of international undergraduate students which is 0.67. This resonates with what has been noticed in the descriptive analysis, that is, countries with more graduate students in the United States tend to have more expatriate researchers who stay at work in the host country.
To sum up, the discussion above has revealed that a considerable number of foreign-born college graduates work as researchers in the United States. College graduates who stay in the United States are more likely to come from developing countries, gather in doctoral level and S&E fields, and take highly skilled jobs, as proved in previous studies (Suter & Jandl, 2008). Their role has transformed from international students into a highly skilled labor force in the United States. From the tradition view of student mobility, they may cause or aggravate “brain drain” for their home country if there are much fewer return talent than those who stay. Nevertheless, from the perspective of brain circulation, expatriate researchers may be able to establish a connection and exert a positive influence on their home country. Therefore, a more relevant question to be raised for this study is, when expatriate researchers are working in the host country, do they have collaboration with researchers in their home country? If yes, how big is their contribution to the research collaboration between their home country and the United States? How does this connection differ by country?
CHAPTER 6
EXPATRIATE RESEARCHERS AND INTERNATIONAL RESEARCH COLLABORATION

Description of International Research Collaboration

Due to uneven distribution of research resources and researchers, countries vary in their research productivity indicated by the number of papers published in scholarly journals, and countries should also have some levels of cooperation with each other in research as the world becomes more interconnected than before.

Figure 6.1 reports the number of publications by top country in 1993, 2003 and 2012 (Web of Science data are only available through 2012). The United States has been the leading country in producing academic publications, much more than any other country in the world between 1993 and 2012. In 1993 and 2003, Japan was the second largest country in academic publications, followed by other industrialized countries including the United Kingdom, Germany, France, and Canada. China has grown rapidly and replaced Japan in 2012 and published more than other countries except for the United States. All countries have seen growth in publications over time, although with different speeds. However, top countries which publish most papers are also the most industrialized countries in the world, while developing countries as a whole still fall behind. This fact further suggests that there is a need for countries to collaborate since they have unequal strengths in research, and such a need is especially strong and urgent for developing countries. Particularly, the United States as the most prolific and competitive country in research is set as a role model and an ideal partner by many other countries.
Figure 6.1. Number of publications of top countries in 1993, 2003 and 2012

Note: the most recent data available for publication is of the year 2012.

Figure 6.2. Collaborative publications between top countries and USA in 1993, 2003 and 2012
Figure 6.2 reports the change of the number of collaborative publications between the United States and other countries. In 1993, Canada has the most collaboration with the United States in academic publications, followed by Germany, the United Kingdom, Japan, France, and Italy. These industrialized countries have kept a strong tie with the United States between 2003 and 2012, while China rapidly exceeded all of them and other countries have also seen growth in academic collaboration with the United States.

The fast-growing collaboration between the United States and all other top countries suggests that the connection between countries has been strengthened over time, probably mainly because computer and internet technology have become increasingly popular and widely used around the world during recent decades. It has become much more convenient for researchers in different countries to communicate and cooperate than before. Certainly, government-sponsored exchange programs and the growing population of mobile talent have also advanced the opportunities for researchers from different countries to form connections (Meyer et al., 1997; Mahroum, Eldridge & Darr, 2006; Meyer & Wattiaux, 2006).

However, it is noteworthy that the ranking of top countries in collaborative publications is quite different from that in international students or foreign-born college graduates who stay in the United States. The analysis of student mobility and college graduates shows that developing countries make up the majority of the source of international students and foreign-born researchers in the United States, but countries that have the most research collaboration with the United States are mostly developed countries, except for China. It seems that countries with similar developmental status to the United States are more likely to establish an intensive collaborative relationship with
the United States, although they are not necessarily the major senders of international students. This contrast reveals that student mobility and research collaboration are two distinct patterns. Therefore, the second half of this chapter will focus on investigating the pattern of research collaboration between the United States and other countries.

**Regression Analysis of Research Collaboration**

Table 6.1 reports the summary statistics of variables that will be examined in the negative binomial regression models of collaborative publications. The dependent variable measures the number of collaborative publications between the United States and other countries. Similar to student mobility models, continuous variables are transformed into their logarithm form so that they have an approximately normal distribution and a similar range of values. Due to the limitations of data, some variables have much fewer observations than others, particularly the number of expatriate researchers and domestic researchers. Therefore, the number of non-missing observations in the regression models are largely restricted to these two variables.

To begin with, a Hausman test is conducted to check if country fixed-effects models are preferred to pooled models. A negative statistic (chi-square = -19.39) suggests that the null hypothesis that the data can be adequately simulated by random-effects models cannot be rejected. However, a negative chi-squared statistic is not an unusual outcome when the sample is relatively small (StataCorp, 2015). Since there are only three-year data and less than 200 observations in the model for this analysis, random-effects models are chosen over fixed-effects models.
Table 6.1
Summary statistics of variables for research collaboration models

<table>
<thead>
<tr>
<th>Variables</th>
<th>Mean</th>
<th>SD</th>
<th>Min</th>
<th>Median</th>
<th>Max</th>
<th>N</th>
</tr>
</thead>
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<tr>
<td>Collaborative publications</td>
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<td>1956.28</td>
<td>0</td>
<td>54.5</td>
<td>17198</td>
<td>464</td>
</tr>
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<td>GDP per capita</td>
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<td>14389.19</td>
<td>134.82</td>
<td>2967.08</td>
<td>66511.86</td>
<td>420</td>
</tr>
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<td>0.00</td>
<td>0.06</td>
<td>1.34</td>
<td>360</td>
</tr>
<tr>
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<td>0.00</td>
<td>0.82</td>
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<td>216</td>
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<tr>
<td>Distance</td>
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<td>2116.52</td>
<td>455</td>
<td>5274</td>
<td>10163</td>
<td>466</td>
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<tr>
<td>Number of collaborative publications (ln)</td>
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<td>2.50</td>
<td>0</td>
<td>4.02</td>
<td>9.75</td>
<td>464</td>
</tr>
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<td>GDP per capita (ln)</td>
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<td>4.90</td>
<td>8.00</td>
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<td>11.86</td>
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</tr>
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<td>1</td>
</tr>
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<td>1</td>
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<td>0</td>
<td>0</td>
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<td>1</td>
</tr>
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<td>40 and more</td>
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<td>0.07</td>
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<td>0</td>
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<td>1</td>
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<td>1</td>
<td>466</td>
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<td>1</td>
<td>466</td>
</tr>
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<td>1</td>
<td>466</td>
</tr>
<tr>
<td>Closed Anocracy</td>
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<td>0</td>
<td>0</td>
<td>1</td>
<td>466</td>
</tr>
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<td>0.44</td>
<td>0</td>
<td>0</td>
<td>1</td>
<td>466</td>
</tr>
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<td>466</td>
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Table 6.2

Negative binomial regression of collaborative publications (pooled)

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<th>(2)</th>
<th>(3)</th>
</tr>
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<td>GDP per capita (ln)</td>
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<td>0.123**</td>
<td>0.127**</td>
</tr>
<tr>
<td></td>
<td>(0.047)</td>
<td>(0.044)</td>
<td>(0.046)</td>
</tr>
<tr>
<td>Expatriate researchers (ln)</td>
<td>0.134**</td>
<td>0.111**</td>
<td>0.115**</td>
</tr>
<tr>
<td></td>
<td>(0.045)</td>
<td>(0.039)</td>
<td>(0.042)</td>
</tr>
<tr>
<td>Domestic researchers (ln)</td>
<td>0.467****</td>
<td>0.299***</td>
<td>0.328***</td>
</tr>
<tr>
<td></td>
<td>(0.044)</td>
<td>(0.037)</td>
<td>(0.036)</td>
</tr>
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<td></td>
</tr>
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<td>1.229***</td>
<td>1.130***</td>
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<tr>
<td></td>
<td></td>
<td>(0.149)</td>
<td>(0.148)</td>
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<td>10-19</td>
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<td>(0.191)</td>
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<td>(0.234)</td>
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<td>30-39</td>
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<td></td>
<td>(0.129)</td>
</tr>
<tr>
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<td></td>
<td></td>
</tr>
<tr>
<td>2010</td>
<td></td>
<td>0.528***</td>
<td>0.568***</td>
</tr>
<tr>
<td></td>
<td></td>
<td>(0.106)</td>
<td>(0.086)</td>
</tr>
<tr>
<td>2013</td>
<td></td>
<td>0.599***</td>
<td>0.619***</td>
</tr>
<tr>
<td></td>
<td></td>
<td>(0.126)</td>
<td>(0.104)</td>
</tr>
<tr>
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</tr>
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<td>Yes</td>
</tr>
<tr>
<td>BIC</td>
<td>2760.006</td>
<td>2652.242</td>
<td>2668.514</td>
</tr>
<tr>
<td>N</td>
<td>192</td>
<td>190</td>
<td>190</td>
</tr>
</tbody>
</table>

Standard errors in parentheses; * p < 0.05, ** p < 0.01, *** p < 0.001
Table 6.2 reports the results of pooled negative binomial regression models of collaborative publications on country characteristics. The key variables of interest are the number of expatriate researchers in the United States and the number of domestic researchers in countries of origin. Model (1) includes only GDP per capita and researcher variables with year dummies being controlled for. For every 1 percent increase in GDP per capita, the count of collaborative publications will increase by 0.37 percent, given the other independent variables are held constant. For every 1 percent increase in the number of expatriate researchers, the dependent variable will increase by 0.12 percent. For every 1 percent increase in the number of domestic researchers, the dependent variable will go up by 0.48 percent.

In model (2), as dummies for the number of top universities are included, coefficients of GDP per capita, expatriate and domestic researchers all become smaller, although remaining significant. When other variables are held constant, countries with different numbers of top universities, from low to high levels respectively, on average have 3.32, 6.37, 9.88, 11.08, and 13.54 times as many as collaborative publications by countries with no top universities. In model (3), the newly added polity dummies, distance, and language indicator do not show any significant effects when other variables are held constant. All other variables’ coefficients remain significant, with only slight change in the magnitude of coefficients.

Year dummies are controlled for in all three models, and it seems that time is a significant indicator. The dependent variable increases evidently in 2010 and 2013 compared with 2003, and the dummy of the year 2013 has a larger coefficient. Additionally, the model fit statistics are indicated by Bayesian Information Criterion.
Table 6.3

Negative binomial regression of collaborative publications by year

<table>
<thead>
<tr>
<th>Collaborative publications (ln)</th>
<th>2003</th>
<th>2010</th>
<th>2013</th>
</tr>
</thead>
<tbody>
<tr>
<td>GDP per capita (ln)</td>
<td>0.199***</td>
<td>0.146*</td>
<td>0.139</td>
</tr>
<tr>
<td></td>
<td>(0.050)</td>
<td>(0.059)</td>
<td>(0.089)</td>
</tr>
<tr>
<td>Expatriate researchers (ln)</td>
<td>0.178***</td>
<td>0.190***</td>
<td>0.019</td>
</tr>
<tr>
<td></td>
<td>(0.034)</td>
<td>(0.036)</td>
<td>(0.057)</td>
</tr>
<tr>
<td>Domestic researchers (ln)</td>
<td>0.384***</td>
<td>0.264***</td>
<td>0.325***</td>
</tr>
<tr>
<td></td>
<td>(0.063)</td>
<td>(0.043)</td>
<td>(0.064)</td>
</tr>
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<td>No. of ARWU Top 500 universities (0 omitted)</td>
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<td></td>
<td></td>
</tr>
<tr>
<td>1-9</td>
<td>0.920***</td>
<td>1.142***</td>
<td>1.194***</td>
</tr>
<tr>
<td></td>
<td>(0.217)</td>
<td>(0.206)</td>
<td>(0.290)</td>
</tr>
<tr>
<td>10-19</td>
<td>1.508***</td>
<td>1.905***</td>
<td>2.023***</td>
</tr>
<tr>
<td></td>
<td>(0.276)</td>
<td>(0.264)</td>
<td>(0.359)</td>
</tr>
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<td>20-29</td>
<td>1.812***</td>
<td>2.065***</td>
<td>2.368***</td>
</tr>
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<td></td>
<td>(0.297)</td>
<td>(0.303)</td>
<td>(0.393)</td>
</tr>
<tr>
<td>30-39</td>
<td>1.217**</td>
<td>2.388***</td>
<td>2.557***</td>
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<td>(0.376)</td>
<td>(0.306)</td>
<td>(0.390)</td>
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<td>(empty)</td>
<td>(empty)</td>
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<td>(0.327)</td>
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<td></td>
<td>(0.665)</td>
<td>(0.685)</td>
<td>(0.792)</td>
</tr>
<tr>
<td>Year FE</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>BIC</td>
<td>698.729</td>
<td>969.104</td>
<td>994.438</td>
</tr>
<tr>
<td>N</td>
<td>54</td>
<td>69</td>
<td>67</td>
</tr>
</tbody>
</table>

Standard errors in parentheses; * p < 0.05, ** p < 0.01, *** p < 0.001

(BIC) here. The BIC statistics suggest that variables added to model (2) and (3) improve the model fit based on model (1), but model (2) has more power of explanation than model (3).

Since there are only three years of data, negative binomial regression models are also examined for each year based on the same set of variables used in pooled model (2) (see Table 6.3). The yearly models show a changing pattern over time. First, GDP and expatriate researchers used to matter in 2003 and 2010, but not in 2013, while domestic
researchers have remained influential. Second, the coefficients of higher education dummies have been significant and have increased from 2003 to 2010, which suggests that the best universities in countries of origin have played an increasingly important role in establishing academic collaboration with the United States.

**Findings and Discussions**

First, GDP per capita matters for research collaboration. It can be assumed that higher GDP per capita means more investment in research and development by a country, which provides better conditions for researchers to conduct research and publish academic papers with collaborators both at home and abroad. Therefore, economic conditions are essential for a country to participate in international research collaboration. However, the relationship between GDP and research collaboration can also be reversed because researchers advocate that knowledge generates economic values (Amidon, Formica & Mercier-Laurent, 2005). It is possible that research collaboration contributes to the growth of GDP per capita. To avoid this reverse causality problem, lagged values of independent variables are often used as instruments; however, the selection of lag can be another controversial issue. A better solution is to conduct the Durbin-Wu-Hausman test for endogeneity before deciding whether it is necessary to use an instrumental variable (Cong, 2017). A large p-value is obtained from the test (p-value = 0.7136) and indicates that there is no significant endogeneity problem with the models. Therefore, GDP per capita is considered to have a significant and positive effect on research collaboration in this study.
Moreover, expatriate researchers and domestic researchers are both found to have a significant impact on research collaboration between their country of origin and the United States. However, they seem to be unequally influential, because the coefficient for domestic researchers is almost three times as much as that for expatriate researchers in the pooled models, and the coefficient of expatriate researchers becomes insignificant in the yearly model of 2013. This difference suggests that domestic researchers are more productive or effective in promoting research collaboration than expatriate researchers are. One reason is that the number of collaborative publications measured here counts in any co-authored papers by domestic researcher and American researchers who can be either expatriate researchers or other researchers in the United States. In other words, domestic researchers have more choice of research partners while expatriate researchers only have to cooperate with domestic researchers so as to contribute to the count of collaborative publications here. In addition, domestic researchers also include return scientists who have connections with researchers in the United States and can contribute to the growth of collaborative publications (Wagner, Leydesdorff & Bornmann, 2014). Another possible explanation is that domestic researchers are more motivated to cooperate with researchers in the United States because the United States has more advanced status in academic research, while expatriate researchers are more likely to cooperate with colleagues in the United States and only cooperate with researchers in their home country mostly when their research is relevant to their home country or their home country has certain strengths in the fields they work in.

Finally, the increasingly significant and positive coefficients for the dummies representing the number of top universities from low to high levels imply that countries
with more top universities are more likely to have a research collaboration with the United States. It makes sense because having more top universities generally means having more top researchers who can conduct international-level research. In other words, countries with greater research capacity are more likely to build up research collaborations with the United States.
CHAPTER 7
CONCLUSIONS, IMPLICATIONS, AND FUTURE CONSIDERATIONS

In previous chapters, this study aggregated data from IIE, NSCG, WOS, World Bank and others, and utilized OLS regression models for the analysis of international student mobility and negative binomial regression models for the analysis of collaborative publications between the United States and other countries. Based on the findings and discussions, two major conclusions can be drawn. Limitations and considerations for further research will also be discussed in this final chapter.

Major Conclusions

The Role of Expatriate Researchers

Researchers have observed that brain circulation takes place in different ways, mainly through returning scientists and diaspora knowledge network (Cao, 1996; Meyer et al., 1997; Mahroum, Eldridge & Darr, 2006; Meyer & Wattiaux, 2006). This dissertation resonates with them and further quantitatively demonstrates that brain circulation can take place when there is a diaspora knowledge network in the United States. More specifically, brain circulation has been embodied in the form of collaborative research between expatriate researchers and researchers in their home countries. Expatriate researchers can contribute to the research and development in their home countries even though they are not physically located in their home countries. This finding, to a great extent, disagree with the argument of “brain drain” that the mobility of students, researchers, and other highly skilled workers from sender countries to receiver
countries will certainly lead to a win-lose consequence and international students who do not return to home countries after graduation cause loss of talent and harm the interest of their home countries (Findlay, 2011).

Nevertheless, one should not exaggerate what expatriate researchers can do for their home country, in view of two main facts. First, what is drawn from the analysis in this study is a general pattern for most countries, but countries vary in their characteristics vastly in reality. Whether expatriate researchers have a significant impact on the research of a particular origin country depends on which country it is and how various aspects of the country co-determine its research activities. Some low-income countries have a few expatriate researchers in the United States, but it is extremely difficult for them to have any form of brain circulation due to poor education and research conditions. For example, Afghanistan, Central African Republic, Eritrea, Liberia, and Congo-Zaire have dozens to hundreds of expatriates who work as researchers in the United States, but there are no collaborative publications between these countries and the United States as suggested by the WOS data. In this case, the concept of “brain drain” has its own ground.

Second, domestic researchers are found to have a larger impact than expatriate researchers do on the collaborative publications between home country and the United States. As discussed in the previous chapter, domestic researchers in a given country can also work with American researchers who are not from the given country, or they are simply more motivated than expatriate researchers to initiate collaboration between countries. Thus, domestic researchers are the major driving force for the research collaboration between two countries. Moreover, returning scientists are not separated
from the group of domestic researchers in this analysis. Thus, the significant role of domestic researchers in a way supports researchers’ traditional opinion that returning scientists determine if a country is suffering from “brain drain” (Findlay, 2011) because returning scientists are an active part of the domestic research labor force and function more effectively in the international research collaboration than if they stay in the United States.

To sum up, expatriate researchers can contribute to brain circulation when there is a certain connection between them and their home countries. The concept of “brain circulation” has its practical foundation in the world, but should be applied to any particular country with careful consideration.

**Country Homophily in Student Mobility and Research Collaboration**

An interesting finding from the analysis is how the academic capacity of origin countries is positively associated with the number of students studying in the United States. The academic capacity of countries of origin, measured by their number of ARWU’s top 500 universities, is revealed to have a non-linear positive relationship with student mobility to the United States when other determinants are held constant. “Non-linear positive relationship” refers to the fact that within certain range countries with more top universities have more students in the United States, but countries with 40 or more top universities on average have fewer students in the United States than countries with 30 to 39 top universities (see Table 4.5).

Overall, the United States has the most top universities in the world, and it seems to receive more students from countries with similar academic capacity than from countries which fall behind in academic research; therefore, the general pattern is
considered to be a homophily relationship between the United States and origin countries in international student mobility. This conclusion is aligned with previous studies suggesting that the number of ARWU’s top 500 universities of origin country is positively related to student mobility (Van Bouwel & Veugelers, 2009; Perkins & Neumayer, 2014). The only difference is that previous studies treat the number of top universities as a continuous variable and simply suggests a general positive relationship while the variable is categorical in this study and reveals the curvilinear positive relationship. Similarly, there is also homophily between countries in research collaboration. The only difference is that the positive relationship between sender country’s academic capacity and the number of collaborative publications between sender country and the United States is linear, which means countries with more top universities are likely to have more collaborative publications with the United States (see Table 6.2).

The most intriguing finding is not the homophily between countries in student mobility or research collaboration themselves, but the connection and the difference between these two phenomena. First of all, student mobility homophily and research collaboration homophily are interconnected, because international students in the United States can convert into expatriate researchers who will contribute to research collaboration between their home and host countries. At the beginning of this dissertation, an identical or similar pattern between student mobility and research collaboration was expected to be found so as to confirm that there is a tight link between international students, expatriate researchers, and collaborative publications. However, although countries with 30 to 39 top universities have a closer relationship with the United States in student mobility than any other countries including those with 40 or
Figure 7.1 Top places of origin for international students, expatriate researchers and collaborative publications in 2013

Notes: The definition of developed and developing countries is based on World Bank classification of countries by income level (World Bank, 2016b).

more top universities, they are not the favorite partners in research collaboration by the United States.

Figure 7.1 presents how the composition of top places of origin in student mobility, college graduates and research collaboration has changed in the whole process. Nine out of fifteen top places of origin for international students are developing countries; however, as for college graduates who have stayed and become expatriate researchers in the United States, only five out of twelve top places of origin are developing countries. Moreover, when it comes to the top places for research collaboration with the United States, only one out of thirteen is a developing country.
Although these three parts are interconnected, the first two steps seem to have more association, while there is an evident gap between the second and the third because more developed countries are finally added and most developing countries disappear from the list of countries. Overall, it suggests that countries with more international students or expatriate researchers in the United States do not necessarily have more collaborative publications with the United States. Particularly, for developing countries that have a large student population and a considerable number of expatriate researchers in the United States, it can be questionable how they will benefit from brain circulation in the form of international research collaboration.

This finding further vividly reveals that research collaboration is not only determined by how many students and expatriate researchers a country has in the United States. In this process, there are many other mechanisms coming into play, such as bilateral student and researcher mobility, visiting scholars, or even language, culture and historical bonds (Appelt et al., 2015), which cannot be reflected by our data and models. Previous studies also suggest that the United States is able to directly attract and retain top researchers worldwide at postdoctoral and professor level (Lawson et al., 2015). Therefore, it can be concluded that international student mobility does not fully explain the mechanism of how research collaboration happens between countries.

The finding of country homophily in research collaboration well resonates with the posit that brain circulation is relatively easy to happen among countries at similar developmental stages (Cao, 1996). It can also be associated with previous studies on the mobility of researchers across countries which find that the top destination country for
mobile scientists from developed countries is also a developed country (Franzoni, Scellato & Stephan, 2015).

To sum up, brain circulation does exist, but not in all countries. There is a general pattern for all countries, but there are also important variations among countries. Brain circulation is more likely to happen when countries of origin have adequate research capacity that either can attract researchers back or can match U.S. research level so that its diaspora knowledge network is able to establish collaboration between the home country and the United States.

**Implications**

As different determinants are found to have a significant impact on international research collaboration, brain circulation can be improved or realized through making efforts from various aspects by countries which hope to avoid brain drain. Generally, several approaches can be adopted to bring brain circulation into full play.

First, the most fundamental and effective way is to enhance education and research in the origin country through developing economy and increasing financial support. As GDP always matters for education, it is important to increase and efficiently utilize the financial input in domestic research and all levels of education, including basic education and post-secondary education. More investment in basic education provides foundations for fostering a population that is better prepared for tertiary education. These students either attend universities in their home country or study abroad. Regardless of where they go, the country will have researchers with better quality both at home and abroad. Additionally, more financial input in universities and research institutions will
help improve the academic capacity of the country, which can not only cultivate and retain a large number of competitive researchers at home but also attract expatriate researchers to return. Given that domestic researchers play a more critical role in international research collaboration, advancing the country’s own capacity in education and research will pay off more than relying on expatriate researchers. With greater research capacity, it will be also easier for the country to participate in international collaboration with other developed countries. Moreover, the development of education and research will in turn contribute to the economic growth of the country and form a virtuous cycle in the long run.

Another method is to encourage and support various forms of educational exchange. Although developing domestic education is more fundamental than studying abroad, it takes time for developing countries to catch up with developed countries like the United States in cutting-edge science and technology. Thus, strengthening academic exchange and collaborative relationship with developed countries is necessary and helpful. The strong tie between the United States and other developed countries in research collaboration suggests that international collaboration can be promoted by many other activities in addition to student mobility. For example, U.S. Fulbright Program for academic exchange provides not only student grants, but also scholar grants, teacher grants, and grants for professionals. Although the program covers all geographic regions in the world, it has sponsored over 133,000 European scholars and students for coming to the United States and 217,000 U.S. scholars and students for visiting Europe, about 60% of its global total between 1949 and 2014 (IIE, 2015). Fulbright participants often engage in follow-on projects they started abroad after returning to their home countries, which
creates a multiplier effect that leads to lifelong collaboration between countries (U.S. Department of State, 2017). Similarly, developing countries can diversify their approaches to promoting international collaboration by launching more bilateral visiting scholar’s programs with developed countries or holding international conferences to provide more opportunities for researchers from different countries to build up connections. While supporting more students to study in developed countries including the United States, developing countries can also attract students from developed countries and enhance mutual understanding and cooperation.

Moreover, developing countries with a large number of students abroad need to retrieve their talent with intentional efforts. Particularly, developing countries with sufficient financial and academic resources can promote policies to draw expatriate researchers back or encourage collaboration. For example, China has adopted an active posture towards its massive outflow of students to industrialized countries by offering returning scientists huge incentives and abundant resources, such as important positions in universities or research institutions, substantial salaries, research grants, spouse hiring, family relocation and even housing (Recruitment Program of Global Experts, 2017). Joint appointments are also offered to academics in key fields so that Chinese universities can benefit from top scholars who wish to remain abroad (Altbach, 2015). For developing countries that have limited resources and may not be able to implement large-scale plans, it is better to prioritize and focus on the talent they need most for the country’s development of economy and education. Joint appointments or joint research projects will also be an economical and efficient way for such underprivileged countries to utilize expertise from compatriots who live abroad.
For countries that have already benefited greatly from receiving foreign students and researchers, it will become more challenging to attract and retain highly skilled migrants as there is growing competition from both developed and developing countries. For example, Canada and Australia have had an immigration system that favors the entry of highly skilled migrants for years. The European Union has also implemented the “blue card” policy since 2011 to attract highly skilled migrants (Franzoni, Scellato & Stephan, 2015). In addition, fast-developing countries such as Saudi Arabia, China, and Qatar appropriate special funds for attracting return scientists or foreign experts. To retain the advantage in the competition for talent and make good use of international human capital, traditional destination countries for international students, particularly developed countries, may need to adjust or stipulate new immigration policies according to their needs and the changes in the global market in a timely manner.

**Strengths and Limitations**

Compared with previous studies on the topics of “brain circulation” and “brain drain,” this dissertation has a few strengths. In theory, through integrating the analyses of student mobility and international research collaboration, this study essentially has answered three questions: does brain circulation exist? Where does brain circulation exist? How does brain circulation work? The results confirm that brain circulation takes place in the world nowadays. It is more likely to happen to countries that are better off in economy and education. Returning scientists and expatriate researchers can both contribute to their home country while returning scientists can contribute in a more
efficient way. By answering these questions, this dissertation has depicted the mechanism of “brain circulation” in a more accurate way than before.

In method, this dissertation has utilized a variety of data sets and regression analysis to confirm the effect of expatriate researchers on collaborative research that has been mentioned but not quantified by previous studies. Country-level panel data have many restrictions, especially in terms of missing countries, missing years or missing values of important indicators, but this study has strived to integrate data from different sources, select data with good quality, and compile them in a proper way for analysis.

This dissertation has also carefully selected statistical models for advanced analysis. For example, pooled and fixed-effects models have been examined and compared for international student mobility. In some previous studies, researchers have ignored the fixed-effects of year or country (Van Bouwel & Veugelers, 2009; Fernandez-Zubieta, Guena & Lawson, 2015), but this study contends that it is necessary to consider fixed-effects models based on the Hausman test and has provided evidence to support the selection of models. Also, this dissertation has treated dependent variables with caution and has matched them with models that best fit them. Given the excess zero values of collaborative publications, different models have been tested and compared in the analysis process, and negative binomial regression models have been selected to simulate the data of collaborative publications.

Moreover, this dissertation has given proper consideration to the selection and measurement of variables. For example, it has examined the effects of education and research capacity on student mobility by including two different measures, the number of top universities and the number of publications per capita. By comparison, the number of
top universities is found to be a better predictor of student mobility and research collaboration, because it not only reflects the quantity but also the quality of higher education in a country while the number of publications cannot adequately reflect the quality aspect of the academic capacity of a country. The number of top universities also stand for the population of students and researchers who participate in relevant research activities, since universities are generators of highly skilled human capital (Etzkowitz & Leydesdorff, 2000; Schiller & Liefner, 2007; Abel & Deitz, 2011; Schaaper, 2014). In addition, the study has coded discrete variables, such as the number of top universities and polity index, into a series of dummies, so as to detect the change of their effects that can be overlooked when they are treated as continuous variables.

In spite of the strengths stated above, this study falls short in several aspects mainly due to deficiency of data. The foremost drawback is caused by the lack of data on returning scientists. Without this part of data, this study could not separate the group of returning scientists from domestic researchers, and thus fail to compare the role of returning scientists and expatriate researchers. For example, the observed positive correlation between U.S.-China collaborative publications and the growth of Chinese expatriate researchers in the United States could be largely due to an increased number of returning scientists to China, but less influenced by those who remained in the United States. Due to the restriction of data, this study can only view the role of returning scientists as a part of domestic researchers and thus have only a general idea of the extent to which domestic researchers as a whole contribute to international collaboration.

In addition, this study does not differentiate between master and doctoral students when examining the models of international student mobility. Because the data do not
specify categories of graduate students, the difference between these two groups cannot be detected. It has been shown in this study that graduate students, in general, have stronger correlation with expatriate researchers than undergraduates do; however, master students and doctoral students may also have distinct patterns, because the mobility of doctoral students is supposed to be more relevant to research capacity of origin countries and the group of expatriate researchers than master students.

Moreover, this study does not differentiate between the academic fields of research publications due to the limitations of Web of Science data. Although it is possible to know the fields of study of expatriate researchers from NSCG data, without knowing the number of publications in S&E and non-S&E fields separately, the relationship between expatriate researchers and collaborative publications by fields of study cannot be examined.

Finally, the data on the number of international students report cumulative counts at a time point rather than the flow every year, while the characteristics of countries are yearly statistics. Although there is a certain relationship between origin countries’ time-variant characteristics and a cumulative population of international students in the United States, it will more accurately reflect their relationship if the counts of students are instant annual statistics.

Apart from the limitations caused by data, the interpretation of some of the results may be controversial and needs further discussion. The number of top universities is supposed to indicate the quality rather than the quantity aspect of the competitiveness of a country’s higher education and research. It is also found to have a significant and positive effect on student mobility or research collaboration in this study. However, it is
reasonable to consider that the increase of top universities is just a natural outcome of the
geneneral educational development which simultaneously causes the growth of
international student mobility or collaborative publications. In other words, the growth of
the outcome variables can be simply due to the growing scale of general education rather
than a few top universities in a country. Although the models in this study have
controlled for the population for tertiary education, it is still possible that some
population determinants latently confound the process. This study would avoid this
problem if there were a more proper indicator that can better reflect countries’ academic
competitiveness with population’s influence being excluded.

Consideration for Future Research

Based on the limitations discussed above, future studies with an interest in
examining the phenomenon of brain circulation may consider the following possible
avenues. First of all, data with better quality and more information will help answer
questions more thoroughly. One of the main purposes of this dissertation is to understand
the role of different groups of researchers in research productivity based on available
data. If future studies can obtain data on returning scientists from the United States to
their home countries, both mechanisms of returning and expatriate researchers in brain
circulation can be examined simultaneously. Their effects on research collaboration can
be revealed and compared. Furthermore, it will be meaningful to find out and understand
the different roles of domestically educated, returning, and expatriate researchers in
research productivity and international research collaboration. This requires complicated
and tedious processing of Web of Science data by identifying how many collaborative
publications are created by domestically-educated researchers only, which are produced by returning researchers, which by expatriate researchers, and which by a mixed group of them. With more clear knowledge of their different roles, countries can better prioritize target groups and distribute resources more efficiently.

In addition, given the finding from this study that expatriate researchers are not the only factor that determines research collaboration between country of origin and the United States, future studies may include other variables related to the population involved in academic exchange, such as the number of U.S. researchers who have studied in the other country, the number of bilateral visiting scholars and the number of U.S. students who have studied in the other country, and examine how such groups of researchers contribute to the research collaboration between countries.

Moreover, future studies can verify if country’s homophily in student mobility and research collaboration apply to broader contexts by using bilateral data where the receiving country is not restricted to the United States. This dissertation focuses on the United States as the only destination country and its relationship with all other countries, so the conclusion mainly applies to the student mobility into the United States and the research collaboration that involves the United States. However, international student mobility is, in fact, multiple-directed, and brain circulation does not only involve the United States but all destination countries. The degree of brain circulation can also vary by country. Therefore, the pattern of brain circulation worldwide may be different from what have been found here by using the U.S.-foreign data only.

Another improvement that can be made based on this dissertation is to check the brain circulation by fields of study or by academic levels. With data on research
publications in various fields, for example, S&E fields and non-S&E fields, researchers
can figure out if research collaboration is more likely to happen in S&E fields than non-
S&E fields, or the other way around. Researchers can also examine if domestically-
educated researchers, returning researchers, or expatriate researchers have more impact
on the collaboration in S&E fields or non-S&E fields. Moreover, if a measure of citation
of publications could be acquired, particularly the highly cited publications, the data
would reflect more in-depth information about the quality and competitiveness of the
research output produced by researchers instead of the quantity of research output only.
Some researchers have adopted measures that reflect quality or impact of academic
publications when studying the productivity of mobile researchers by using different data
sets (Franzoni, Scellato & Stephan, 2015; Lawson et al., 2015). The Web of Science data
also include journal article information which can be tapped into to acquire more
information about the quality of publications, but it will need more advanced data mining
skills and efforts. Therefore, more relevant work can be done if the current data resources
can be brought into full play.
REFERENCES


Medicine, 67(11), 1924-1933.


APPENDIX A

Percentage of international students in the United States by academic level each year, 1993-2013

<table>
<thead>
<tr>
<th>Year</th>
<th>Graduate</th>
<th>Undergraduate</th>
<th>Non-Degree</th>
<th>OPT</th>
</tr>
</thead>
<tbody>
<tr>
<td>1993/94</td>
<td>44.70%</td>
<td>47.50%</td>
<td>5.27%</td>
<td>2.54%</td>
</tr>
<tr>
<td>1994/95</td>
<td>42.36%</td>
<td>48.94%</td>
<td>5.79%</td>
<td>2.92%</td>
</tr>
<tr>
<td>1995/96</td>
<td>41.89%</td>
<td>48.18%</td>
<td>6.53%</td>
<td>3.40%</td>
</tr>
<tr>
<td>1996/97</td>
<td>41.54%</td>
<td>47.76%</td>
<td>6.74%</td>
<td>3.96%</td>
</tr>
<tr>
<td>1997/98</td>
<td>43.12%</td>
<td>46.39%</td>
<td>7.05%</td>
<td>3.45%</td>
</tr>
<tr>
<td>1998/99</td>
<td>43.07%</td>
<td>48.03%</td>
<td>5.47%</td>
<td>3.43%</td>
</tr>
<tr>
<td>1999/00</td>
<td>42.40%</td>
<td>46.09%</td>
<td>6.69%</td>
<td>4.83%</td>
</tr>
<tr>
<td>2000/01</td>
<td>43.53%</td>
<td>46.44%</td>
<td>6.18%</td>
<td>3.84%</td>
</tr>
<tr>
<td>2001/02</td>
<td>45.41%</td>
<td>44.78%</td>
<td>5.90%</td>
<td>3.90%</td>
</tr>
<tr>
<td>2002/03</td>
<td>45.69%</td>
<td>44.36%</td>
<td>5.21%</td>
<td>4.74%</td>
</tr>
<tr>
<td>2003/04</td>
<td>47.91%</td>
<td>43.35%</td>
<td>3.61%</td>
<td>5.12%</td>
</tr>
<tr>
<td>2004/05</td>
<td>46.79%</td>
<td>42.34%</td>
<td>5.03%</td>
<td>5.84%</td>
</tr>
<tr>
<td>2005/06</td>
<td>45.99%</td>
<td>41.85%</td>
<td>5.42%</td>
<td>6.75%</td>
</tr>
<tr>
<td>2006/07</td>
<td>45.33%</td>
<td>40.83%</td>
<td>6.69%</td>
<td>7.15%</td>
</tr>
<tr>
<td>2007/08</td>
<td>44.38%</td>
<td>39.01%</td>
<td>7.51%</td>
<td>9.10%</td>
</tr>
<tr>
<td>2008/09</td>
<td>42.19%</td>
<td>40.18%</td>
<td>7.71%</td>
<td>9.92%</td>
</tr>
<tr>
<td>2009/10</td>
<td>42.54%</td>
<td>39.72%</td>
<td>7.93%</td>
<td>9.81%</td>
</tr>
<tr>
<td>2010/11</td>
<td>41.01%</td>
<td>40.30%</td>
<td>8.19%</td>
<td>10.51%</td>
</tr>
<tr>
<td>2011/12</td>
<td>39.30%</td>
<td>40.46%</td>
<td>9.10%</td>
<td>11.14%</td>
</tr>
<tr>
<td>2012/13</td>
<td>37.97%</td>
<td>41.48%</td>
<td>8.97%</td>
<td>11.58%</td>
</tr>
<tr>
<td>2013/14</td>
<td>37.23%</td>
<td>41.84%</td>
<td>8.97%</td>
<td>11.96%</td>
</tr>
</tbody>
</table>

Leading places of origin and change rate of international students in 1993, 2003 and 2013

<table>
<thead>
<tr>
<th>Place</th>
<th>1993</th>
<th>2003</th>
<th>2013</th>
<th>Change rate 1993/2013</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. China</td>
<td>44381</td>
<td>79736</td>
<td>274439</td>
<td>5.18</td>
</tr>
<tr>
<td>2. Japan</td>
<td>43770</td>
<td>61765</td>
<td>102673</td>
<td>1.95</td>
</tr>
<tr>
<td>3. Taiwan</td>
<td>37581</td>
<td>52484</td>
<td>68047</td>
<td>1.19</td>
</tr>
<tr>
<td>4. India</td>
<td>34796</td>
<td>40835</td>
<td>53919</td>
<td>13.49</td>
</tr>
<tr>
<td>5. South Korea</td>
<td>31076</td>
<td>27017</td>
<td>28304</td>
<td>0.25</td>
</tr>
<tr>
<td>6. Canada</td>
<td>22655</td>
<td>26178</td>
<td>21266</td>
<td>-0.43</td>
</tr>
<tr>
<td>7. Hong Kong</td>
<td>13752</td>
<td>13329</td>
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Conference Paper and Publication


Presentation