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Abstract

Students around the world who choose to pursue higher education abroad quadrupled from 1.3 million in 1990 to 5 million in 2004 (University of Oxford, 2017, p. 14). Considering the ever-increasing trends of migration, especially the migration of students who seek education abroad, and the potentials in the line of research on the economic impact of this sub-type of international migrants on origin countries, my study will investigate the relationship between students seeking tertiary education abroad and the number of patents applications as an indicator of innovation in origin countries. For this purpose, I will utilize more recent data sets from the UNESCO's Institute for Statistics (UIS) and the World Bank's World Development Indicators (WID) and employ Ordinary Least Squares (OLS) estimation of regression coefficients to analyze the degree of linear association between the two variables. Control variables will also be added following previous research on patenting activities and the determinants of the number of patent applications.

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I. INTRODUCTION

On September 25, 2015, international migration officially became a part of the United Nations' 2030 Agenda for Sustainable Development, making it the first time for the topic to be included in a global development framework (United Nations Development Programme, 2015). Adopted by 150 world leaders, 6 out of 17 development goals in the agenda wove migration issues into their targets of protecting labor rights of migrant workers, increasing the number of scholarships for study abroad, facilitating "orderly, safe, regular and responsible" migration, among other issues (United Nations, 2015, p.3). The inclusion of migration in the newest set of development goals is crucial, considering the magnitude and trends of migration around the world. In 2017, there were approximately 257.7 million international migrants, up 50% compared to 2000. About 34.5% of those migrated from less developed regions (used interchangeably with "the South", or "developing countries") to more developed regions ("the North", or "developed countries"), reflecting 60% of the increase in international migrants in the North (United Nations, 2017, p.1).

These trends raise important questions about migrants' economic impact. In studying this impact, researchers have looked at the positive relationship between migration and labor force growth in major destination countries (McKinsey Global Institute, 2016, p.1-5), as well as GDP growth rates of destination countries over long time periods (Bove and Elia, 2015, p.227). On the side of origin countries, migrant workers' remittances have been shown to be effective in reducing poverty in less developed regions, especially in rural areas (Taylor et al., 2005, p.103; Bertoli and Marchetta, 2014, p.1067). However, there are other aspects that are important to development besides poverty levels. Thus, it is necessary to look at relationships beyond the one between poverty and migrants' remittances in assessing the effect of migration on the economic development of origin countries. Considering that innovation is an important ingredient in long-term growth, the link between migration outflows and innovation cannot be left out in the discussion of migration's impact on the origin countries (Grossman and Helpman, 1990, p.86-91).

Some researchers have looked at this link in terms of migration outflows and the Economic Complexity Index as a measure for the amount of productive knowledge in origin countries (Vallette, 2016, p.3), as well as international student flows and R&D spillovers to origin countries (Le, 2010, p.315, and Park, 2004, p.315). These studies are built on the rationale that international migrants residing in more developed countries, especially international students who seek education there, are more in touch with the resources and technology in the developed world. Thus, they can bring back useful networks and knowledge to their home countries in less developed regions. For these reasons, this line of research is especially important, due to the policy implications regarding international collaboration on migration and tertiary education, as well

as programs designed to effectively utilize returning migrants' knowledge and resources to promote development in origin countries.

Students around the world who choose to pursue higher education abroad quadrupled from 1.3 million in 1990 to 5 million in 2014 (University of Oxford, 2017, p.14). Considering the ever-increasing trends of migration, especially the migration of students who seek education abroad, and the potentials in the line of research on the economic impact of this sub-type of international migrants on origin countries, my study will investigate the relationship between students seeking tertiary education abroad and the number of patents applications as an indication of innovation in origin countries. For this purpose, I will utilize more recent data sets from the UNESCO's Institute for Statistics (UIS) and the World Bank's World Development Indicators (WID) and employ Ordinary Least Squares (OLS) estimation of regression coefficients to analyze the degree of linear association between the two variables. Control variables will also be added following previous research on patenting activities and the determinants of the number of patent applications.

II. LITERATURE REVIEW

In the line of research focusing on the economic impact of migration, early theoretical works, summarized by Docquier and Rapoport (2012, p.681-730), paid particular attention to the "brain drain", a type of migration characterized by the permanent relocation of high-skilled labor from one country to another. Seminal theoretical contributions such as those of Grubel and Scott (1966) and Bhagwati and Hamada (1974) mainly analyzed the effect of the brain drain on the welfare of non-emigrants in the countries of origin. On the surface, Grubel and Scott (1966) concluded a decrease in the welfare of the people who were left behind within the neoclassical economic framework, given that (i) the emigrants' contribution to the origin economy (or the social return to their education) was larger than their marginal product (or the private return to their education), and (ii) the education of high-skilled emigrants was partly funded by taxes collected from citizens. However, they also argued that compared to the losses in welfare, which was "likely to be small", benefits from the emigrants' contribution to international knowledge and the remittances sent back to the origin countries could be substantial and sufficient to compensate for the negative effects (Grubel and Scott, 1966, p.268-274).

Bhagwati and Hamada (1974), on the other hand, emphasized the negative consequences of the brain drain under the fixed-wage framework with the presence of publicly-funded education and progressive taxation. Under the assumptions related to certain externalities, the emigration of high-skilled labor imposed a net fiscal loss on the non-emigrants in the origin countries (Bhagwati and Hamada, 1974, p.19-42). The negative impact emphasized by Bhagwati and Hamada (1974) was also shown within the endogenous economic growth model by the works such as those of Miyagiwa (1991) and Haque and Kim (1995). These theoretical contributions illustrated a decrease in the long-run growth rates of the origin economies as a result of high-skilled emigration.

In the late 1990s, a wave of economic papers shifted their focus to the aspects that could prove the positive effect of the brain drain on origin countries. Theoretical developments such as those of Mountford (1997) and Vidal (1998) demonstrated that the prospect of migration could serve as an incentive to invest in human capital and increase education enrollment in the source economies. Whether studied

under an economic framework with heterogeneous (Mountford, 1997, p.287-303) or homogeneous agents (Vidal, 1998, p.589-600), the expected return of education (with education as an endogenous decision) was shown to be positively impacted by the possibility of emigration and thus would create a benefit to the formation of human capital. Beine, Docquier and Rapoport (2001), using cross-sectional data for 37 developing countries and OLS estimation, found that this positive relationship was especially true for origin countries with low initial levels of GDP per capita (p.275-289). Using the World Bank-sponsored Docquier and Marfouk (2006) data set, with OLS and IV estimation, they were able to confirm similar results in 2008, even when using alternative estimates for the brain drain, as well as alternative definitions of human capital and other functional forms (2008, p.631-652).

The second kind of theoretical development, which had previously been conjectured in Grubel and Scott's seminal work in 1966, was formalized in the works like that of Özden and Schiff (2006). This line of development focused on remittances that were sent back to the origin countries by emigrants, showing that the higher income earned by high-skilled emigrants could increase remittances and benefit the origin economies. Empirically, however, early studies which used a cross-sectional macroeconomic approach found that countries sending relatively more high-skilled migrants received less remittances than those sending less skilled migrants (Faini, 2007, p.177-191; Niimi et al., 2010, p.123-141).

The third theoretical development turned away from the assumption of permanent relocation of high-skilled emigrants. Instead, works such as those of Stark et al. (1997) and Domingues Dos Santos and Postel-Vinay (2003) focused on temporary migration and how the knowledge accumulated while abroad of returning migrants could benefit the origin economies. In testing this theoretical development, mixed results were found due to the understudied nature of the tendency to return of migrants (Docquier and Rapoport, 2012, p.707). In general, studies which looked at immigrants from the UK (Dustmann and Weiss, 2007, p.236–56), and migrants from Eastern Europe to Western Europe (Mayr and Peri, 2009, p.1-52) pointed to a potential benefit to the origin country when wages and economic growth at the origin were expected to rapidly increase, incentivizing the return of migrants.

The last but most important theoretical development to this study detailed how migration could impact innovation in the origin countries. Summarized in Docquier and Rapoport (2012), theoretical works falling under this category showed that migration could positively impact source countries' innovation through the diaspora network effect (p.707). Specifically, the presence of migrants in countries different than their homeland could reduce transaction costs and ease the transfer of goods, factors of production, and knowledge from these countries to their homeland, which would benefit not only FDI, trade, and political institutions, but also technology diffusion and innovation in the source economies (Docquier and Rapoport, 2012, p.707). This theoretical development was formalized in the works such as those of Gaillard and Gaillard (1997) and Meyer (2001) and served as a foundation for a number of empirical works looking at the link between migration and innovation in origin countries, including this study.

Using the NBER Patent Data File over the 1985–1997 period in the US, Kerr (2008) empirically tested this theoretical development by first filtering for inventors with ethnic surnames, which yielded a total of 9 distinct ethnicities: Chinese, English, Eu-

ropean, Hispanic, Indian, Japanese, Korean, Russian, and Vietnamese. This patent data was then analyzed under a model where the origin countries were "technology followers", who would become more innovative through the imitation of certain innovations of the destination countries. Within this model, Kerr placed a large significance on the diaspora network effect in the technological imitation/diffusion process. He found that technology diffusion through ethnic channels was empirically significant, especially for the case of Chinese diaspora networks. Strong evidence was also found regarding the direct positive impact of the ethnic diasporas on manufacturing productivity, especially in the high-tech sector, of the origin countries (Kerr, 2008, p.518-537).

Agrawal et al. (2011) empirically tested the same theoretical development through a model that used the number of patent citations with last names belonging to Indian migrants as an indication of knowledge flows from destination countries to India. This measure for knowledge flows was formulated to depend upon the co-location of Indian inventors and their diaspora networks. To quantify such a measure, they constructed a novel sample from patent data which linked with last name data during the period of 1981–2000 in India. The results found that while the co-location effect was empirically more significant than the diaspora network effect, the latter played the more important role in the case of most-cited patents, which "might actually represent a large fraction of the productivity gains that result from innovation" (Agrawal et al., 2011, p.43-55).

This study will extend the theoretical development detailed in the works of Gaillard and Gaillard (1997) and Meyer (2001) by looking into the impact of migration on innovation in source economies. Similar to empirical works by Kerr (2008) and Agrawal et al. (2011), patent data will be employed in the analysis as a measure for the transfer of knowledge and the degree of innovation in origin countries. My study will, however, extend the said empirical works through the use of more recent data on international student flows as a sub-type of migration. This data is available for 211 countries in the year of interest (2015) and thus will be suitable for a cross-sectional analysis that would extend beyond just one source country or a few ethnic origins. Lastly, instead of building a model that incorporates the diaspora network effect of migration like the mentioned empirical works, my study will employ OLS estimation to directly show the degree of the structural relationship between international student flows and patent applications in origin countries.

III. DATA AND METHODS

In order to investigate the link between migration and innovation in origin countries, data on international students seeking tertiary education abroad has been gathered from the UNESCO Institute for Statistics (UIS). This data consists of the number of students who "have crossed a national or territorial border for the purpose of education" and are now residing in a country different from their country of origin (UNESCO, 2017). Therefore, the data series is appropriate for the purpose of this study, as it reflects a sub-type of international migrants that is controlled for educational attainment (with secondary education completed). The data is available in annual frequency from 2011 to 2017. In 2015, which is the year of interest of this study, data for a total of 211 origin countries were estimated and/or reported by the UIS (UNESCO, 2017).

As a measure of innovation in origin countries, data on patent applications filed by residents and nonresidents by country was collected from the

World Bank's Development Indicators website, whose definition of the data is the number of patent applications "filed through the Patent Cooperation Treaty procedure or with a national patent office for exclusive rights for an invention" from around the world (The World Bank, 2017). This data series is originally reported by the World Intellectual Property Organization. Similar to the data series on international student, this data is available in annual frequency. Although the range of data covers an extended 31-year period from 1985 to 2016, for the purpose of this study, data available for 150 countries and regions in 2015 was obtained (The World Bank, 2017).

Lastly, in order to compare the link between migration and innovation in different countries in a meaningful way, data on each country's population and income group classification in 2015 was also collected from the World Bank. For population data, it is important to note that each country's population is composed of all people who are residing in the country at a certain point in time, regardless of citizenship or legal status. In 2015, data was available for 262 countries and regions. As for the World Bank's classification of countries, there are 4 groups: low-income, lower-middle-income, upper-middle-income, and high-income, categorizing a total of 213 countries based on 4 Gross National Income (GNI) per capita brackets (The World Bank, 2017).

All of the data obtained was compiled in a single Excel spreadsheet. Once the data series from different sources were listed next to each other, it could be seen that there were 118 countries with a data point in each data series. As mentioned above, data on international students and patent applications should be put into the context of each country's population in order to derive meaningful comparisons. Thus, the percentages of outbound international students from each country and patent applications filed by both residents and nonresidents to the country were calculated in terms of population. In this transformation lies a limitation, as outbound international students and nonresidents who file patent applications to a country, by definition, do not belong to the total population of that country. However, the rationale justifying this data transformation is that if there are more of people residing in country at one point in time, there is a higher chance that the number of outbound international students, who in fact originate from the population of the country, will increase as a result. In addition, the impact of international students on patenting activities can extend beyond patent applications filed by residents. This is due to the possibility that the students may file patent applications from destination countries or provide information that facilitates patent filing by residents of destination countries to their countries of origin. Thus, patent applications by nonresidents were deemed to be of interest and are included in the percentages' numerator.

Once the data transformation is performed, it is necessary to examine the data through descriptive statistics. Table 1 in the Appendix provides the maximum, minimum, mean and median values of patent applications and outbound international students both in levels and in percentages of population. China has the largest number of outbound international students and patent applications in 2015 (818,803; 1,101,864), while San Marino holds the largest population-scaled percentages (2.442%; 0.919%). Since San Marino is a micronation with an extremely small population of 32,960 people in 2015, and the data series are scaled by population, the country's top position in terms of the percentages suggests the presence of an outlier (The World Bank, 2017). Looking at the scatterplot with the percentages on both axes

in Figure 1 of the Appendix confirms this suggestion. While most countries (represented by the blue data points) cluster near the lower far left of the horizontal axis, San Marino is exceptionally closer to the upper far right of the horizontal axis. The fact that there is a significant distance between San Marino and the rest of the countries in the scatterplot allows us to treat San Marino as an outlier to be removed from the sample observations. The exclusion of San Marino is expected to affect the maximum and mean values of the percentages.

Table 2 in the Appendix provides the descriptive statistics after the outlier has been removed, with only the maximum and mean values of terms in percentages being influenced in an observable fashion. Some median values also changed, however not significantly. On the other hand, the large distances between the maximum and minimum values found in the patent applications' percentages (Max = 247,658 * Min) and outbound international students' percentages (Max = 281 * Min), as well as the medians being smaller than the means, suggest skewness in the data. The magnitude of skewness can be observed in a histogram. Figure 2 and 3 in the Appendix provide the histograms for patent applications and outbound international students as percentages of population. For outbound international students, 52 out of 117 countries have percentages between 0.009 and 0.117%, the next 27 have percentages between 0.117 and 0.225%. Only 38 countries (32.5% of the total number of countries) have percentages falling in the next 90% of the range. Similarly, for patent applications, only 7% of the countries fall in the higher 80% range. These statistics, along with the shape of the histograms, with an elongated tail to the right, highlight the substantial magnitude of skewness. Therefore, before any regression can be run between the percentage terms, transforming the terms into logarithms is necessary to induce linear behavior. From this point onwards, the study will look at the natural logarithms of percentages of outbound international students and patent applications in terms of the population of each country.

In determining the structural relationship between outbound international students and patent applications in countries, it is beneficial to look at the correlation coefficients of the two variables in logs of percentages. Figure 4 in the Appendix displays the scatterplot for the logs for all 117 countries, while Figure 5 displays the scatterplots for all countries but split into the 4 World Bank's income groups. A positive relationship between patent applications and outbound international students can be depicted from Figure 4, as the data cloud seems to be arranged in an upward fashion. The similar arrangement of data points can be found in the scatterplots for lower-middle-income and low-income countries as well. On the other hand, a negative relationship between patent applications and outbound international student can be observed in the cases of high-income and upper-middle-income countries, as the data clouds seem to be arranged in a downward direction.

The observed relationships in the scatterplots can be expressed in terms of correlation coefficients, provided in Table 3. In general, whenever there is a 1% increase in the proportion of outbound international students in terms of population, a 26.8% increase can also be observed in the proportion of patent applications in terms of population. Since the correlation coefficient depicts a symmetrical relationship, it can also be said that the proportion of outbound international students in terms of population increases by 26.8% whenever there is a 1% rise in the proportion of patent applications. Interestingly however, when the countries are split into dif-

ferent income groups, the signs become opposite as we move from the upper-middle-income to the lower-middle-income category. The different signs (and magnitudes) in the correlations suggest that the degree of economic development of different countries might affect the extent of correlation between patent applications and outbound international students. This observation is crucial to the identification of determinants of patent applications besides outbound international student flows, which will be discussed at the end of this part.

In order to study the impact of outbound international student on patent applications, this paper will employ OLS estimation technique to estimate the regression coefficients between the two variables using cross-sectional data in 2015. The regression will be run in the statistical package EViews. In this regression, the natural log of outbound international students as percentages of population will be the independent variable, while the log of patent applications as percentages of population will be the dependent variable. Following past research on the determinants of patenting activities, several independent variables looking at the number of tertiary graduates, the number of scientific and technological journal articles, the R&D expenditures as shares of GDP, the R&D personnel headcount, and the degree of international competition exposure of each country will also be added to the regression estimation equation (Danguy et al., 2010; Huang and Cheng, 2015, p.52). Additionally, since the degree of economic development exerts influence on how outbound international students impact patent applications, as aforementioned, GNI per capita of each country will also be included as one of the independent variables. Lastly, an error term will be included to capture the margin of errors of the model. Table 4 provides the shorthand, definitions, and sources of all the variables. For each country, the estimation equation can be defined as follows:

$$\log(patents/pop) = \alpha + \beta_1 \log(students/pop) + \beta_2 \log(graduates/pop) + \beta_3 \log(articles/pop) + \beta_4 \log(R\&D\ expendtures/GDP) + \beta_5 \log(R\&D\ headcount/pop) + \beta_6 \log(GNI/pop) + \beta_7 \log(Int'l\ competition) + \varepsilon \quad (1)$$

Following the rationale that knowledge attained by outbound international students in destination countries, as well as the academic environment, R&D spending and capabilities, and income levels all positively impact patenting activities, β_1 to β_6 are expected to all have positive signs. Exposure to international competition can encourage or discourage patenting activities depending on the R&D abilities of the country, thus the expected effect is ambiguous. The Results and Conclusion sections down below provide the estimation results.

IV. RESULTS

Due to the skewness to the right of the data series on patent applications and outbound international students, natural logs of the data were taken to induce linearity. Following past research detailing the factors that affect patenting activities and the number of patent applications (Danguy et al., 2010, p.; Huang and Cheng, 2015, p.52), the following independent variables were included in addition to the number of outbound international students in tertiary education: the number of tertiary graduates, the number of scientific and technological journal articles, the R&D expenditures, the R&D personnel headcount, and the degree of international competition exposure of each country.

After all the data series in levels are scaled by

their respective countries' populations, as well as the natural logs were taken, the regression equation is given by the following expression:

$$\log(patents/pop) = \alpha + \beta_1 \log(students/pop) + \beta_2 \log(graduates/pop) + \beta_3 \log(articles/pop) + \beta_4 \log(R\&D\ expendtures/GDP) + \beta_5 \log(R\&D\ headcount/pop) + \beta_6 \log(GNI/pop) + \beta_7 \log(Int'l\ competition) + \varepsilon \quad (1)$$

where ε represents the error term.

Table 5 in the Appendix reports the results of the regression using OLS estimation technique. The p-value for the F-statistic (0.000) eliminates the probability that all coefficients are simultaneously zero. In other words, there is some degree of linear association between the dependent and independent variables. However, in contrast to the expectation that all coefficients would have positive signs, the coefficients for outbound international students and scientific and technological journal articles have negative signs. In addition, only 4 out of the 7 independent variables were statistically significant at a 95% or above confidence level. Therefore, the next step is to remove the statistically insignificant variables from the equation. The regression equation is now given by:

$$\log(patents/pop) = \alpha + \beta_1 \log(students/pop) + \beta_2 \log(graduates/pop) + \beta_3 \log(articles/pop) + \beta_4 \log(GNI/pop) + \varepsilon \quad (2)$$

Table 6 gives the estimation results of the new regression. The new estimation results exhibit similar signs for the coefficients and F-statistic to that of the former equation, with changes in the magnitude of the coefficients and statistical significance for 3 out of the 4 independent variables. Since the coefficient for the scientific and technological journal articles becomes insignificant at the 90% confidence level following the new estimation results, it is necessary to remove the variable entirely from the equation. Thus, the new and final estimation equation is given by:

$$\log(patents/pop) = \alpha + \beta_1 \log(students/pop) + \beta_2 \log(graduates/pop) + \beta_3 \log(GNI/pop) + \varepsilon \quad (3)$$

Table 7 reports the estimation results of this regression equation. At first glance, all estimated coefficients are significant at a 99% confidence level. A further look into the residual diagnostic tests eliminates the chance of the residuals being heteroskedastic, with the p-value for Breusch-Pagan-Godfrey test exceeding 10%. However, the p-value of the Jarque-Bera test for normality (0.047) does not allow for the acceptance of the null hypothesis that the residuals are normally distributed at a 90% confidence level. Despite this fact, since the regression has 76 observations and is not used for predictions in this paper, the test results are still reliable. The p-value for the F-statistic ensures the overall significance of the estimation results. The adjusted R-squared of 68% is also reported to show the goodness of fit of the estimation equation, which can be rewritten with the estimated coefficients in the following format:

$$\log(patents/pop) = -19.634 - 0.516 * \log(students/pop) + 0.876 * \log(graduates/pop) + 1.129 * \log(GNI/pop) + \varepsilon \quad (4)$$

As seen in equation (4), a 10% increase in the population-scaled number of tertiary students

studying abroad of a given country decreases that country's population-scaled number patent applications by 5.16% within the same year. This decrease indicates that as students cross their national borders to engage in tertiary education abroad, the amount of innovation measured by patent applications is negatively impacted due to some loss of human capital in terms of student researchers and/or workers in the field. In contrast to outbound international students in tertiary education, the number of graduates from tertiary programs in a country positively impacts that country's patent applications. Specifically, a 10% increase in the proportion of people who just graduated from a tertiary program during the year with regards to the total population leads to an 8.76% increase in the country's population-scaled number patent applications. This increase highlights the importance of post-secondary education and its impact on a country's innovation, through the suitable human capital formation that is created by tertiary education programs.

GNI per capita also moves in the same direction with the population-scaled number of patent applications and exhibits the largest magnitude in the estimated coefficient. This co-movement signifies that as a country becomes wealthier in terms of national income per person, it also witnesses more innovation through the addition of patent applications. However, since there is a potential presence of endogeneity between GNI per capita and patent applications, the direction of causality cannot yet be determined.

To extend this paper beyond the estimation results summarized in Table 7, the lags of R&D expenditures were included to investigate the degree of linear association between past spending on R&D and current patent applications. Although de Rassenfosse and Guellec (2009) and Hall et al. (1986) found that both current and past R&D expenditures can impact current patent applications, with a lag of up to 5 years, since the UIS only provides data on R&D expenditures from 2011 onwards, 4 years is the maximum lag that the estimation equation may have. The 2011-2014 lag terms, along with the 2015 R&D expenditure data, were added to equation (2) to estimate the results summarized in Table 8. Out of the 5 coefficients for R&D expenditure, only that of the 2011 lag has a statistical significance at the 90% confidence level. Thus, the next step in this extension is to remove the statistically insignificant lags.

In contrast with the estimation results from equation (2), the coefficient for the scientific and technological journal articles is significant at a 95% confidence level. Thus, it is not removed but included with the 2011 R&D expenditure lag in the new estimation equation. Two outliers were removed to ensure the homoskedasticity of the residuals. The total number of observations were reduced to 57. The estimation results are reported in Table 9. All of the coefficients are significant at a 95% confidence level and have similar signs with that of equation (1), (2) and (3). Here, however, with the addition of the lag term, every coefficient increased in absolute magnitude, and the goodness of fit measured by the adjusted R-squared also increased. Specifically, a 10% increase in the population-scaled number of outbound tertiary students now decreases the population-scaled number of patent applications by 63.2%. Conversely, the proportion of new tertiary graduates in the total population now has a larger positive impact on innovation. As for the lag term, a 10% increase in the proportion of R&D expenditure in the total GDP from 4 years ago is expected to increase the current population-scaled number of patent applications by 5.21% at a 95% confidence level.

The coefficient for the scientific and technolog-

ical journal articles has a negative sign in the estimation results. Specifically, a 10% increase in the population-scaled number of journal articles leads to a 4.35% decrease in the population-scaled number of patent applications at a 95% confidence level. This result indicates that the contemporaneous relationship between article journals and patent applications is negative. In other words, innovation that is measured by the number of patent applications does not benefit from the addition of newly published research within the same year. In fact, holding all else constant, patent applications fall alongside the addition of newly published journal articles.

V. CONCLUSION

Data on patent applications and outbound tertiary international students in 2015 were retrieved from the World Bank and the UNESCO Institute for Statistics (UIS) to study the impact of migration on innovation, through the relationship between international students as a subtype of migration and patent applications as a measure for innovation (2017). Both data series were scaled by population and then taken as logarithms to induce linearity. Following past research on the determinants of patenting activities, a number of independent variables were added. Ordinary Least-Squares (OLS) estimation technique and statistical package EViews were used to run the regression. By observing the statistical significance of the independent variables, the final estimation equation was determined with patent applications being a function of outbound tertiary international students, tertiary graduates within the country, and the country's GNI per capita.

It is found that an increase in the students seeking tertiary education abroad decreases the patent applications in a country within the same year. This result aligns with the body of literature supporting the "brain drain" argument, for instance, in Beine, Docquier, and Rapoport (2008), and indicates that as students seek tertiary education abroad, there is a loss of human capital in the origin countries in terms of student researchers and/or workers in the fields that generate new patent applications. In the body of empirical research specifically related to migration and innovation, this finding aligns with that of Agrawal et. al (2011), where "the net effect of innovator emigration is to harm domestic knowledge access, on average." In other words, the migration of students exhibits a similar negative co-location effect to the migration of innovators, where the distance between internationally mobile students and students in the origin countries may decrease the countries' net access to knowledge in the short run, hence decreasing the number of patents.

It is also found that tertiary graduates play a crucial role in innovation. The significant and positive effect of newly graduated tertiary students on patent application aligns with the empirical works looking at the determinants of patenting activities, such as those of Danguy et al. (2010) and Huang & Chen (2015), where higher education workforce and collaboration with universities significantly contribute to patenting activities. Through an extension of the final estimation equation, it is found that while current R&D spending does not have a statistically significant impact on patent applications, spending on R&D from 4 years ago positively affects current patenting activities. This finding aligns with that of de Rassenfosse and Guellec (2009), who found that past R&D expenditure could impact current patent applications with a lag of up to 5 years.

To further expand on this research paper, one may look at the relationship between outbound tertiary international students as a subtype of migration and patent applications as a measure for in-

novation using panel data over a long time period. While the contemporaneous relationship is negative, it will be interesting to see whether the long-term relationship is that of the opposite, as suggested in the empirical works looking at migration and innovation through the investigation of diaspora networks (Kerr, 2008, p.518-537; Agrawal et al., 2011, p.43-55). As a potential endogeneity is also present between patent applications and GNI per capita, one may wish to expand on this research by conducting a study on the same relationship using Instrumental Variables (IV) or 2-stage Least-Squares (2SLS) estimation technique.

As for this particular research, since only a contemporaneous relationship is found between patent applications and outbound tertiary international students, the opposite directions in movement between the two will not be sufficient to inform any policies affecting studying abroad in the long run. However, to reduce the loss of human capital in the short run, origin countries may increase collaboration with higher education institutions in major study-abroad destinations to provide more knowledge accumulation and research opportunities at the origin, as well as utilizing the human capital that would have otherwise been lost. An example of such collaboration is the Fulbright Scholar program sponsored by the US, which does not only provide opportunities in more than 160 countries around the world, but also requires the return of Fulbright PhD fellows to origin countries and hence, has been found to increase international knowledge flows, especially benefiting countries with weak scientific environments (Bureau of Educational And Cultural Affairs, 2018; Kahn and MacGarvie, 2016, p.1304-1322).

In addition, consistent with existing literature, since the estimation results point to the significance of tertiary graduates in innovation, countries are encouraged to increase the number of tertiary graduates through subsidizing higher education and further integrating research opportunities into higher education. This study also found that while a country's patent applications do not benefit from the addition of published journal article and the R&D spending within the same year, R&D spending from 4 years back significantly increases the number of current patent applications. Thus, countries are also encouraged to increase their spending on R&D activities to foster long term innovation.

APPENDIX

Table 1: Summary Statistics of Variables

Series	Patent applications	Outbound international students	% Patent applications/ Population	% Outbound Students/ Population
MAX	1,101,864.00	818,803.00	0.919%	2.442%
MIN	1.00	355.00	0.000004%	0.009%
MEAN	22,739.87	30,010.10	0.031%	0.248%
MEDIAN	438.50	13,659.50	0.006%	0.140%

Table 2: Summary Statistics of Variables without Outliers

Series	Patent applications	Outbound international students	% Patent applications/ Population	% Outbound Students/ Population
MAX	1,101,864.00	818,803.00	0.419%	2.169%
MIN	1.00	355.00	0.000004%	0.009%
MEAN	22,931.64	30,259.72	0.023%	0.229%
MEDIAN	440.00	13,683.00	0.006%	0.138%

Table 3: Correlation between Patent Applications and Outbound International Students (Logged % of population)

Income Group	Correlations
All income groups	0.268
High income	-0.382
Upper middle income	-0.418
Lower middle income	0.139
Low income	0.558

Table 4: Descriptions and Sources of all Variables

Variable Shorthand	Description	Definition	Source
Patents	Patent applications	Patent applications filed through the Patent Cooperation Treaty procedure or with a national patent office for exclusive rights for an invention	WIPO, WB
Students	Outbound tertiary international students	Students who have crossed a national or territorial border for the purpose of education	UIS
Pop	Population	Number of people who are residing in the country at a certain point in time, regardless of citizenship or legal status	WB
Graduates	Tertiary graduates	People who have completed a tertiary education program in a given academic or school year	UIS
Articles	Scientific and technical journal articles	Scientific and engineering articles published in the following fields: physics, biology, chemistry, mathematics, clinical medicine, biomedical research, engineering and technology, and earth and space sciences	WB
R&D expenditures/GDP	Expenditures spent on Research and Development	Total intramural expenditure on R&D performed as a share of GDP	UIS

Variable Shorthand	Description	Definition	Source
R&D headcount	Headcount of personnels working in Research and Development	All persons engaged directly in R&D, whether employed by the statistical unit or external contributors fully integrated into the statistical unit's R&D activities, as well as those providing direct services for the R&D activities (such as R&D managers, administrators, technicians and clerical staff).	UIS
Int' l competition	Degree of exposure to international competition	Exports as a share of GDP over the sum of imports and exports as shares of GDP	WB
GNI/pop	Gross National Income per capita, PPP (constant 2011 international $)	The sum of value added by all resident producers plus any product taxes (less subsidies) not included in the valuation of output plus net receipts of primary income (compensation of employees and property income) from abroad, converted to international dollars using 2011 purchasing power parity rates and divided by total population	WB

Table 5:

Estimation Results of Linear Regression Model for Patent Applications (2015)
Dependent Variable: log_pats_pop (Patent applications)
Observations: N = 51

Constant	-19.686 ***
	(-3.401)
Outbound int'l students (of population)	-0.416***
	(-2.669)
Tertiary graduates (of pop.)	0.941***
	(2.918)
Scientific and technical journal articles (of pop.)	-0.562**
	(-2.351)
R&D Expenditures (of GDP)	0.535
	(1.446)
R&D Personnel Headcount (of pop.)	0.197
	(0.487)
GNI per capita	1.161***
	(2.821)
Int'l competition exposure	0.001
	(0.000)
Adjusted R-Square	0.576
s.e equation	0.944
Residual diagnostics tests	
Normality	8.311[a]
Heteroskedasticity	0.405[b]

Significance at the 1% (***), 5% (**), and 10% (*) levels
T-values are parentheses
[a] Values of the Jarque-Bera statistical test for Normality
[b] p-values of Breusch-Pagan-Godfrey's statistical test for Heteroskedasticity

Table 6:

Estimation Results of Linear Regression Model for Patent Applications (2015)
Dependent Variable: log_pats_pop (Patent applications)
Observations: N = 75

Constant	-20.696***
	(-6.500)
Outbound int'l students (of population)	-0.501***
	(-4.480)
Tertiary graduates (of pop.)	0.879***
	(3.665)
Scientific and technical journal articles (of pop.)	-0.038
	(-0.335)
GNI per capita	1.219***
	(5.542)
Adjusted R-Square	0.684
s.e equation	0.953
Residual diagnostics tests	
Normality	5.862[a]
Heteroskedasticity	0.316[b]

Significance at the 1% (***), 5% (**), and 10% (*) levels
T-values are parentheses
[a] Values of the Jarque-Bera statistical test for Normality
[b] p-values of Breusch-Pagan-Godfrey's statistical test for Heteroskedasticity

Table 7:

Estimation Results of Linear Regression Model for Patent Applications (2015)
Dependent Variable: log_pats_pop (Patent applications)
Observations: N = 76

Constant	-19.634***
	(-8.208)
Outbound int'l students (of population)	-0.516***
	(-4.637)
Tertiary graduates (of pop.)	0.876***
	(3.900)
GNI per capita	1.129***
	(7.598)
Adjusted R-Square	0.680
s.e equation	0.953
Residual diagnostics tests	
Normality	6.079[a]
Heteroskedasticity	0.213[b]

Significance at the 1% (***), 5% (**), and 10% (*) levels
T-values are parentheses
[a] Values of the Jarque-Bera statistical test for Normality
[b] p-values of Breusch-Pagan-Godfrey's statistical test for Heteroskedasticity

Table 8:

Estimation Results of Linear Regression Model for Patent Applications (2015)
Dependent Variable: log_pats_pop (Patent applications)
Observations: N = 47

Constant	-20.876***
	(-3.981)
Outbound int'l students (of population)	-0.386***
	(-3.229)
Tertiary graduates (of pop.)	0.759**
	(2.155)
Scientific and technical journal articles (of pop.)	-0.849***
	(-3.425)
2015 R&D Expenditures (of GDP)	0.211
	(2.545)
2014 R&D Expenditures (of GDP)	0.535
	(1.130)
2013 R&D Expenditures (of GDP)	-3.486
	(-1.298)
2012 R&D Expenditures (of GDP)	-1.349
	(-0.646)
2011 R&D Expenditures (of GDP)	3.308*
	(1.968)
GNI per capita	1.219***
	(3.025)
Residual diagnostics tests	
Normality	3.938[a]
Heteroskedasticity	0.109[b]

Significance at the 1% (***), 5% (**), and 10% (*) levels
T-values are parentheses
[a] Values of the Jarque-Bera statistical test for Normality
[b] p-values of Breusch-Pagan-Godfrey's statistical test for Heteroskedasticity

Table 9:

Estimation Results of Linear Regression Model for Patent Applications (2015)
Dependent Variable: log_pats_pop (Patent applications)
Observations: N = 57

Constant	-20.130***
	(-6.544)
Outbound int'l students (of population)	-0.632***
	(-5.783)
Tertiary graduates (of pop.)	1.284***
	(5.193)
Scientific and technical journal articles (of pop.)	-0.435**
	(-2.549)
2011 R&D Expenditures (of GDP)	0.521**
	(2.384)
GNI per capita	1.201***
	(5.308)
Adjusted R-Square	0.722
s.e equation	0.735
Residual diagnostics tests	
Normality	1.018[a]
Heteroskedasticity (no cross)	0.617[b]
Heteroskedasticity (cross)	0.725[b]

Significance at the 1% (***), 5% (**), and 10% (*) levels
T-values are parentheses
[a] Values of the Jarque-Bera statistical test for Normality
[b] p-values of Breusch-Pagan-Godfrey's statistical test for Heteroskedasticity

Figure 1: Patent Applications and Outbound International Students (% of population)

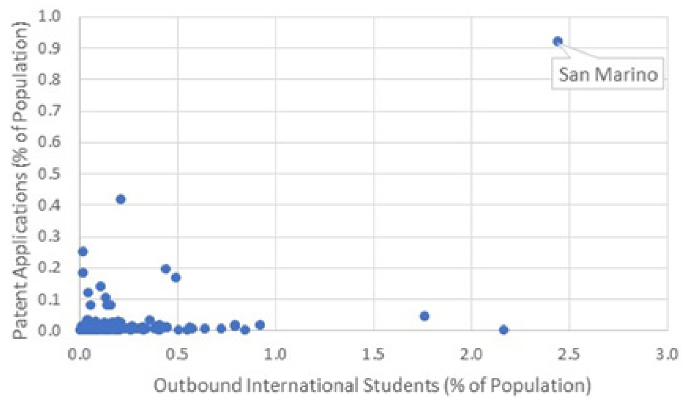


Figure 2: Distribution of Outbound International Student (% of population)

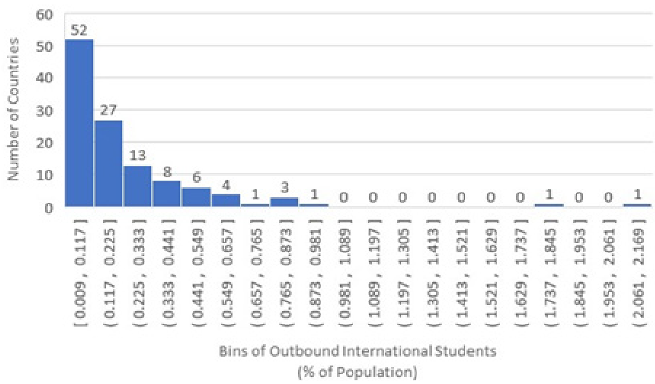


Figure 3: Distribution of of Patent Applications (% of population)

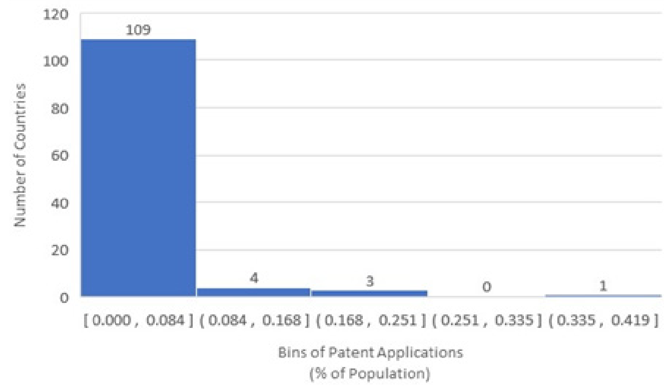


Figure 4: Patent Applications and Outbound International Students (Log of % of population) - All

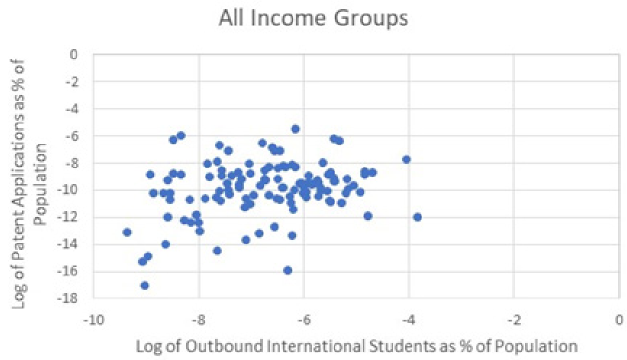
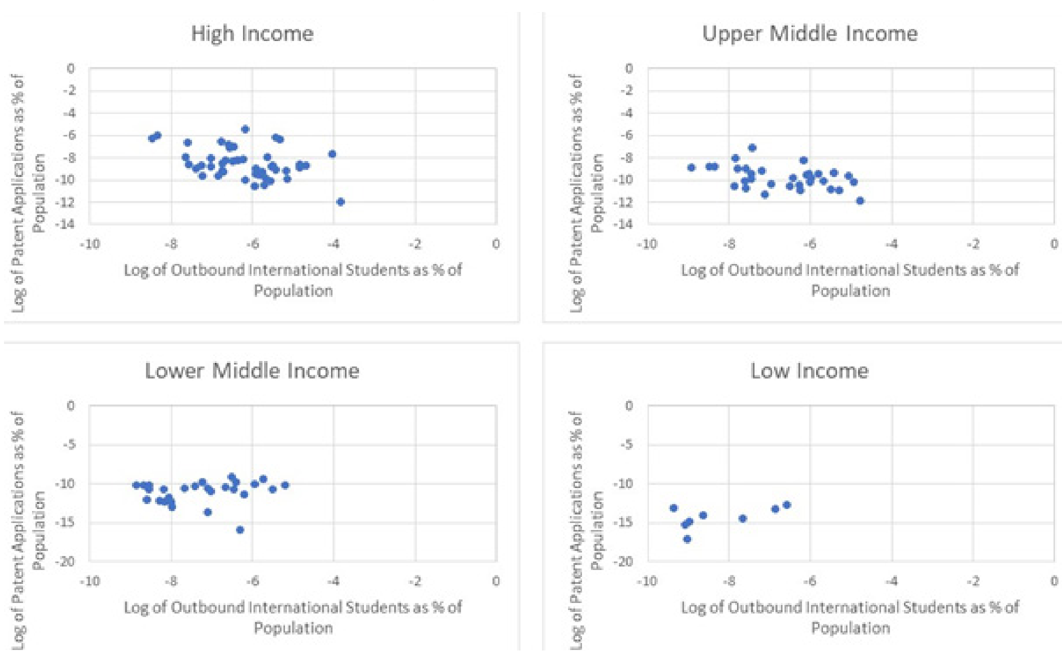


Figure 5: Patent Applications and Outbound International Students (Log of % of population) - By Income Group



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