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High-Skilled Inventor Emigration as a Moderator for Increased Innovativeness and Growth in Sending Countries

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This study investigates the effect of high-skilled inventor emigration rate on growth rate of the country of origin (COO). Inventor emigrants represent the human capital that can generate highly innovative work. The social network they form spurs knowledge diffusion and technology transfer back to their COOs, which in turn affects innovation and growth in their home countries. We run dynamic panel estimation for 154 countries during 1990–2011, and empirically show that a positive and statistically significant effect exists for the interaction of inventor emigration and trade. The result indicates that the direct negative impact of the brain drain can be mitigated by the positive feedback effect generated by the high-skilled inventor emigrants abroad. When coupled with an active trade policy that reinforces growth, countries can partially recoup the direct effect of the human capital loss. We stress the importance of international trade for successful technology transfer to occur, and offer insights for policies that can utilize the benefits of the rich social network of their high-skilled emigrants.

Keywords: High-skilled Inventor Emigration, Technology Transfer, Innovativeness, Growth Rate, Externalities, Networks
JEL Classification: O15, O33, O50

I. INTRODUCTION

The globalization in recent years has resulted in the collapse of national barriers. This has the positive effect of exposing and exchanging information, and shortening the time for technology transfer and diffusion. The barrier for international migration has also been lowered; as rational individuals, highly educated and skilled citizens of one country are free to migrate to a different country for career opportunities and higher standards of living. The destination countries are typically highly developed countries that are well equipped with high-paying jobs and affluent living infrastructures. Indeed, as of 2006, there were 20 million high-skilled migrants in the OECD countries, with an increase of 63.7% over the previous decade, while the unskilled immigration only experienced a 14.7% increase (Docquier et al., 2006). As a result of this lopsided migration, the OECD countries have enjoyed the economic and social benefits from high-skilled human resources ("brain gain"), while on the other hand, the sending countries have suffered from the loss of such valuable assets ("brain drain"). Since the role of the human capital is critical to technological development, the international migration of high-skilled workers is considered disadvantageous to the country of origin (COO) in general (Nelson and Phelps, 1966).

The purpose of this study is to investigate the effect of high-skilled emigrants on technology transfer to the COO, while taking into account the externalities created by the network of high-skilled workers. The migration of high-skilled citizens to other countries is itself an obvious national loss of human capital for the COOs. In a democratic society, no reasonable policy can forbid its citizens from migrating to a better place of living and opportunities. Hence, instead of focusing on how much *loss* this brain drain implies for the sending countries, we focus on the potential *benefit* that can be generated when high-skilled workers indirectly influence technology transfer to their home country.

The majority of scholars who have studied the association between high-skilled migration and technology transfer to their home countries have analyzed the impact of the returnees (Cerase, 1974; Dos Santos and Postel-Vinay, 2003; Kuznetsov et al., 2006; Agrawal et al., 2011). It is evident that technological development of the COO is possible through the re-entry of the high-skilled workers, who bring with them the technical know-hows that they have learned from the country of destination (COD). This study is different from the previous studies in that we focus on the role of the high-skilled emigrants living in the CODs. Our study investigates the feedback role of the externalities created by the high-skilled migrants living abroad, and find that they can have a positive impact on the promotion of the technology diffusion to the COOs.

The main channels of the technology transfer include international trade and foreign direct investment (FDI) (Gould, 1994; Rauch and Trindade, 2002; Rauch and Casella, 2003; Kugler and Rapoport, 2007; Docquier et al., 2009). We recognize the role of the human capital in effectively stimulating technology transfer through trade or investment (Nelson and Phelps, 1966; Eaton and Kortum, 1996). Countries with relatively rich human capital benefit from attracting multinational subsidiaries, and thereby they are able to facilitate the process of technology diffusion. The role of the high-skilled emigrants (who are working and living abroad) are assumed to be no less important. The personal and professional relationships and the social solidarity they establish in the CODs are very strong and abundant, when compared to those formed by the unskilled migrants. In particular, they can use their ethnic network as a means of promoting technological development to the COO, through international trade and FDI (Kapur, 2001; Rauch and Trindade, 2002). For example, the professional network formed by the high-skilled Indian engineers that moved to Silicon Valley enabled the establishment of branch offices in India, for companies such as Yahoo, Hewlett-Packard and GE, and successful technology transfer was achieved through those multinational subsidiaries (Chacko, 2007).

This study uses the dynamic panel data estimation to empirically demonstrate the positive feedback effect of high-skilled workers abroad on technology transfer leading to growth of the COOs. Using the annual stock of inventor emigrants during 1990-2011, which represent a very specific group of extremely high-skilled human resource that spurs innovation, we study its effect on the growth rate of COOs while considering the interaction with the channels through which it can influence the COOs. We find a significant positive effect of the interaction between the high-skilled inventor emigration and trade. This indicates that the inventor emigrants, who file for international patent protection for their creations while residing abroad, can interact positively with trade in reinforcing the technology transfer process to the COOs. This positive feedback effect can mitigate the negative effect caused by the brain drain phenomenon alone. The interaction of inventor migration with FDI does not have a significant effect on the growth in the following year. In fact, the FDI requires some time to see the positive effect of the investment; its effect on growth rate is significantly positive for +5 year, but the FDI negatively interacts with the inventor emigration. It appears that the diaspora effect works well in a social setting with human-to-human interactions, but not necessarily in business settings involving hard contracts. This also provides support that the FDI is a substitute to international hiring of the high-skilled labor. We offer our interpretation more in detail in subsequent sections.

In summary, this study's contribution to the literature is threefold: 1) we highlight the importance of the network externality created by high-skilled emigrants while residing abroad; 2) we show that technology transfer to the COOs is enhanced by the exceptionally innovative emigrants, using the database on emigrant inventor stocks; 3) we demonstrate the effect of such interaction on a general economic measure, the growth rate, in the COOs. To the best of our knowledge, this work is the first that empirically studies the role of the high-skilled emigrants in the technology transfer to the COOs, and links the interaction effect to the economic outcomes in the COOs.

The remaining sections are organized as follows. Section 2 reviews the related literature on technology transfer and high-skilled migration. Section 3 explains the data used in the analysis. Section 4 outlines the estimation model, whose results are shown and interpreted in Section 5. Section 6 concludes.

II. LITERATURE REVIEW

1. High-Skilled Migration and Technology Transfer

Researchers are increasingly moving beyond simply considering the international migration of skilled labor as a loss of human capital, giving rise to the studies that examine the positive effects of the skilled labor migration (Gould, 1994; Rauch and Trindade, 2002; Rauch and Casella, 2003; Kugler and Rapoport, 2007; Docquier et al., 2009). The migration of high-skilled labor to developed economies provides access to the knowledge created in those countries, and destinations that offer better resources, colleagues and innovative incentives reinforce the accumulation of knowledge (World Bank, 2008). These externalities create positive synergies with trade and foreign investment to their COOs, resulting in transfer of technology.

The externalities of high-skilled migrants take effect via the networks they form, and accumulate within the CODs first. After arriving at the COD, high-skilled migrants seek out other skilled compatriots, forming and strengthening networks based on a communal sense of nationality (Kim, 2017). They then broaden their networks by interacting and sharing knowledge with other skilled colleagues from the local area as well as from around the world. Such relational networks spread to markets, affording opportunities for businesses in the destination and the origin countries. According to Kapur (2001), firms from developing nations that have relatively little experience of trading in international markets may benefit from overseas networks of the high-skilled migrants originally from that country who can promote the firms' goods or services. Thus, networks of high-skilled migrants function as a pipeline linking the COOs and the CODs, providing a route through which technology transfer to the COOs can occur (Samers, 2010).

International trade and FDI are the two channels through which technology transfer can take effect. The participation of high-skilled migrants in their home country's international trade leads to reductions in transactional costs and other forms of information costs (Gould, 1994). In other words, international migration and trade interact in a complementary, rather than a substitutive manner. Furthermore, by promoting FDI by firms in the CODs, high-skilled migrants stimulate the transfer of technology to their COOs (Rauch and Trindade, 2002). Particularly, networks of high-skilled migrants in North America and Europe promote trade and foreign investment to less-developed nations, thus contributing to the technology transfer (Rauch, 2003). Bosworth (1984) has also identified that technological transfer occurs via investments by multinational corporations or the opening of the subsidiaries.

Many studies on the relationship between international migration and trade examine the bilateral flow of trade between migrants' COO and COD. Gould (1994) studies how migrants to the United States influence the trade between the U.S. and their home countries. Examining the mechanism of immigrant links between the U.S. and the migrants' COOs, he finds that the networks between the two countries positively influence the bilateral flows of trade. First, immigrants tend to prefer goods from their home countries, resulting in the increase of the imports. In doing so, the migrants who possess both the access to the networks in their home country and the information on the foreign markets have the advantage that allows them to save on transactional costs, thus leading to growth in bilateral trade.

Another example is a study on the Korean migrants to the U.S. and their influence on the U.S.–Korea trade. Min (1990) finds that ever since the mass migration of Koreans to the U.S. during the early 1970s, the volume of the U.S.–Korea trade has grown significantly. Owing to the reasons of language and national affinity, Korean migrants largely have imported goods from Korea. This has led to an increase in the number of the Korean migrants to the U.S. working in the trade business as well. Exports from the destination countries can also be increased. Saxenian (2002) analyzes the link between immigration and the U.S. exports. She finds that a 1% increase in the number of first-generation immigrants from a country is associated with a roughly 0.5% increase in exports from California to that country. The evidence of this relationship between migration and trade is not limited to the U.S. examples. Head and Ries (1998) examine the relationship between immigrants to Canada and trade flows from 1980 to 1992. They find that a 10% increase in the number of migrants is associated with a 1% increase in exports to the migrants' home country, and a 3% increase in imports by Canada. Migrants to Canada who have access to market information of both countries find it easier to engage in trade, thus contributing to more opportunities for trading between Canada and their home countries.

Findlay et al. (1998) focus on the effects of the migration of skilled labor from emerging economies, such as Singapore, Taiwan, Korea, and Hong Kong that have grown since the 1980s. These countries are highly dependent on trade, and actively invite foreign investment. The authors derive three implications from their findings. First, the migration of high-skilled labor presents important opportunities to promote the COOs in the international capital markets. Second, the economic growth seen in the emerging economies since the 1980s has led to an even greater emigration of skilled labor. Third, for countries to retain competitiveness in the international trade markets, while transitioning from production- to service-based industries, still further emigration of skilled labor is necessary. It is evident that the migration of skilled labor can reinforce foreign investment to the COOs as well as increase international trade, both of which enable technology transfer to the COOs.

The role of high-skilled migrants between the prospective investors and the partners from the COOs is highlighted in other literature as well. The barriers faced by a multinational corporation when considering opening a subsidiary in a foreign country include the uncertainty of its success and the transaction costs (Kugler and Rapoport, 2005). In such situations, high-skilled migrants can aptly serve as a connective link. This presents opportunities for the developing countries to successfully attract FDI through the networks of the high-skilled migrants working in developed economies. In fact, statistical evidence suggests that a 10% increase in the number of skilled immigrants to the U.S. is associated with a 4% increase in the FDI to the COOs (Mattoo et al., 2008). This indicates that the flow of the U.S. FDI is linked to the number of skilled migrants.

The emigration of the high-skilled Indian labor, particularly to Silicon Valley, and the networks they have formed in multinational corporations have led to the opening of the subsidiaries in India for companies such as Yahoo, HP and GE. Chacko (2007) interprets these developments as the result of a “reputation enhancement” via the role of the high-skilled Indian workers employed in those corporations. In fact, during the 1990s, various multinational corporations working on new technologies—many of them among the Fortune 500—looked to India to open and operate R&D centers for software development, in addition to call centers and back offices. Furthermore, major corporations such as Microsoft and Dell greatly increased hiring within India (Chacko, 2007). As a result of such investment by multinational corporations, knowledge and technology have been transferred to India. In fact, Agrawal et al. (2011) conduct a statistical analysis based on the number of patents registered in India from 1981 to 2000, and find that high-skilled Indian migrants contributed significantly to the knowledge and technology transfer to India.

China was no exception to such developments. China is the largest origin of the emigrants historically. However, foreign investment in China has only become noticeable in recent years. In the case of China, the institutional reform of the FDI regulations coincided with the increase in international trade and investment. Gao (2003) states that the Chinese immigrants played a major role in promoting FDI to China. Unlike foreign firms that were faced with the institutional obstacles in gaining a foothold in China, firms that were headed by Chinese immigrants were able to invest in China by taking advantage of their informal networks, such as the Bamboo Network. In particular, businesses owned by Chinese immigrants in Singapore, Malaysia, Thailand, Indonesia, Philippines, and other Southeast Asian countries account for roughly 70% of the private corporate sector of these countries (Weidenbaum and Hughes, 1996). These migrants have been able to successfully pursue investments in China while expanding opportunities overseas. According to Wei (2004), Chinese migrants accounted for roughly half of the 4.1 billion USD in the FDI to China in 2000. In addition, Gao (2003) links the FDI in China to the number of Chinese migrants based on an empirical analysis and concludes that a 1% increase in the number of Chinese migrants is associated with a 3.8% increase in the volume of FDI in China.

As the above cases indicate, migrants form strong cohesive bonds while working in other countries. The role played by such migrants merits attention. High-skilled emigrants working in other countries generate foreign network externalities, which positively interacts with trade and investment to their COOs. Furthermore, technology is seen to spread more efficiently via networks that are formed through cultural or national connections.

2. Technology, Innovation and Growth

In this subsection, we briefly review related literature linking technology diffusion to innovation and economic growth. From the evidence in previous literature, we have hypothesized that high-skilled emigrants foster technology transfer to their COOs, together with trade and FDI. Then, how would we measure this diffusion of technology in the COOs? New technologies, with appropriate industrial application, contribute to the economy. A direct measure such as the number of patents within each COO can serve as a proxy for innovation. While patents serve as a concrete way to measure the overall level of innovation (Furman et al., 2002), the standards of patenting procedures vary widely across developing and developed nations. In order to control for these potential differences, instead we opt for a more general measure that can be objectively obtained across all nations in the world: economic growth.

The importance of the technological innovation as a contributor for economic growth is not new. Scherer (1986) tests the Schumpeterian proposition on the capability of the technological progress to increase real income in Western nations. Freeman (1995) argues that industrial innovation is key to national and corporate competitiveness. In a more recent work, Jalles (2010) empirically demonstrates that economic growth depends on innovation and technological diffusion, and shows that patents, which serve as a proxy for technological progress, explain the growth rates of income per capita across different countries around the world. Another recent study by Maradana et al. (2017) finds that various measures of innovation lead to economic growth in 19 European countries. The positive link between innovation and growth rates in income needs to hold for multiple countries for us to be able to use growth rates as a measure of technology transfer and innovation.

3. Implications

Previous research on the link between high-skilled migration and technology transfer has focused mainly on the COD, rather than the COO. The economic gains to the developed economies have been demonstrated. Countries such as the U.S., the U.K., and Canada were some of the first nations to accept high-skilled immigrants in order to boost the national competitiveness. Such national policies, and the concerted effort of the industrial and the academic community, have brought benefits to these advanced countries by recognizing the substantial influence of the human capital on national competitiveness.

Lessons for the developing countries should go hand-in-hand with recognizing the value of such high-skilled human resources. Instead of focusing on the loss implied by the outflow of those citizens, the developing nations can utilize the high-skilled workers from their country who are working abroad in more developed nations. When they can contribute to the economic development of the origin countries, the emigration of high-skilled workers should no longer be regarded as a simple “brain drain.” Instead, the networks formed in other countries are capable of reinforcing the flow of information and knowledge critical for technology development in the COOs. We identify international trade and FDI as the two channels through which technology and knowledge transfer can accelerate.

III. DATA

1. High-Skilled Inventor Emigration Rate

The emigration rate used in this study represents a very specific workforce of highly capable individuals. Unlike other broadly defined “high-skilled” human capital, which in general indicates at least college-educated human resource, our emigration rate captures *inventors* who have filed for patents under the international patent cooperation treaty (PCT). This represents the international movement of highly creative and technically educated individuals, who create new inventions that potentially represent a valuable industrial application across many countries. Because of the substantial cost involved in filing under the PCT, the inventor or the applicant would only seek such protection if the intellectual property were expected to be of a substantial value internationally.

We provide a summary of how this measure is constructed and its source, while the full information can be obtained from Miguélez and Fink (2013). PCT is an international treaty offered by the World Intellectual Property Organization (WIPO), and offers some benefits for those seeking a patent protection across multiple countries. PCT has been widely adapted by many countries, and the inventions of likely significant commercial value are common to be filed under the PCT. Also, this uniform filing standard provides consistency for cross-country econometric analysis. Since each country and jurisdiction has different standards for its local patent filing system, attempting to compare the patent data filed in multiple countries would be prone to errors.

This database of patents filed under the PCT provides key information necessary to track the migratory patterns of inventors: the application records each inventor’s country of residence as well as the nationality of origin. When the two countries differ, this indicates the inventor has migrated to the country of residence. Miguélez and Fink (2013) map these flows of inventors to calculate the emigration rate of inventors as follows:

$$\text{emigration rate of inventors} = \frac{\text{number of emigrant inventors}}{\text{num. of resident (national + immigrant) inventors + num. of emigrant inventors}}.$$

Throughout this paper, we call this *inventor emigration rate*. From the view of the COO, this represents the stock of the emigrant inventors who currently reside abroad, relative to the total inventors including the resident inventors in that country. Miguélez and Fink (2013) acknowledge that there is no unique identifier for each inventor, and the numbers are counted for each patent application; hence, the aggregate measure for each country incorporates the productivity of the inventors. This actually helps our case, because we are interested in the innovative feedback effect created by these individuals. Using their capability/productivity as weights would provide a more relevant measure for our study, instead of using the actual number of inventors (which standardizes and treats all inventors as having an equal impact).

Using the self-reported nationality of origin is more accurate than some of the disambiguation effort reported in the literature using the last names (Raffo and Lhuillery, 2009; Li et al., 2014). Due to a change in regulation in 2012, the quality of data for the residence address and the nationality information is only good until 2011. Hence, we set our study period to be from 1990 to 2011, which captures the good quality data for inventor emigration.

2. Other Variables

Other variables come from the World Bank's World Development Indicators, one of the most comprehensive and reliable databases across all countries in the world. Our dependent variable is the annual growth rate in gross domestic product (GDP). The rate of change in the national GDP for the following year captures the effect of the innovative activity that occurs during the current year. Other variables include two other explanatory variables, trade and FDI, which affect the growth of the nation by itself as well as in coordination with the emigrants. Trade is the sum of imports and exports as a percentage of the total gross GDP of each country, and represents openness to other countries. We consider the net inflow of FDI as appropriate in our context, as it implies the potential for growth as evaluated by the foreign investors. The investment into the COO is poised to spur growth and to be potentially influenced by the emigrants of the same origin. The FDI is also expressed as a percentage of the total GDP.

The control variables included in our model are: GDP per capita, gross fixed capital formation, urbanization, and secondary school enrollment. GDP per capita is often used in models predicting innovative performance since it controls for the resource of each country. While the rest of the variables are share (i.e. percent) variables, the level GDP per capita offers to control against the raw amount of wealth as well as changes in population in each country. Hence, we use GDP per capita in units of constant 2010 US dollars, to provide consistent scaling across all countries. Gross fixed capital formation includes the infrastructure that can serve to promote economic activity and growth in nations. It represents land improvements as well as plant, machinery, and construction of roads and buildings. Countries with higher gross fixed capital formation are able to use that resource to turn into a value-added outcome. Similarly, urbanization is the percentage of population living in urban areas, and it is included as a control variable since each nation can take advantage of its urban environment to promote economic growth. Lastly, the innovative potential of the human resource is controlled by the percentage of secondary school enrollment in each country. Human capital with at least high school education or equivalent is assumed to positively aid the growth of the nation.

Table 1. Summary of Variables

Variable	Definition
GROWTH	Annual Growth Rate in GDP (%)
EMI	Inventor Emigration Rate based on the Patents Filed under the International Patent Cooperation Treaty (fraction of inventors that have emigrated to other countries)
TRADE	Trade (Imports + Exports, as % of Total GDP)
FDI	Foreign Direct Investment, Net Inflows (% of GDP)
GDPpc	GDP per capita (Constant 2010 US Dollars)
GFCF	Gross Fixed Capital Formation (% of GDP)
URBAN	Urbanization (% of Population Residing in Urban Area)
SSE	Secondary School Enrollment (Gross % of Enrollment in Secondary School, based on the Age Group for Secondary Education)

Variable	Obs	Mean	Std. Dev.	Min	Max	Source
GROWTH	5190	3.772	6.460	-64.047	149.97	World Bank WDI
EMI	3000	0.529	0.383	0	1	WIPO (Miguélez and Fink)
TRADE	4912	80.425	52.502	0.021	860.80	World Bank WDI
FDI	4913	4.374	14.580	-82.892	466.56	World Bank WDI
GDPpc	5132	11373.94	16854.48	115.79	144246.40	World Bank WDI
GFCF	4478	22.259	9.673	-2.424	219.07	World Bank WDI
URBAN	5742	54.481	23.631	5.416	100	World Bank WDI
SSE	3923	70.161	29.979	5.210	161.02	World Bank WDI

The scope of the study covers all countries in the world, and we examine the effect of the independent variables during 1990–2011. A total of 154 countries are included in our study, which is the exhaustive list of countries with available statistics. On average, there are a little over 12 years of data for each panelist, and this is because the data for some variables are missing for some of the earlier years. Definitions of all variables used in this study, along with the summary statistics, are shown in Table 1.

IV. METHODOLOGY

In this study, we are interested in the interdependency between high-skilled inventor emigration and the factors that can help spur the positive effect into the COO: trade and FDI. Technically, the underlying theory behind the relationship between high-skilled emigration and trade/FDI can occur both in the form of mediation and moderation. In case of mediation, the positive network effect occurs through trade/FDI; in the absence of trade/FDI, the network effect of emigrants does not occur. This would apply to situations when the diasporas initiate and cause the trade and FDI into their COOs, which in turn affect the growth of their home countries. In case of moderation, the degree to which emigrants affect their COOs depends on the level of trade/FDI. This would apply when the diasporas play a role and aid in the process of trade and FDI so that the outcome is more positively achieved for the COOs. In reality, both effects likely exist at the same time (i.e. moderated mediation). However, we focus on the moderated effects only and omit the mediation through trade and FDI for the following reasons. 1. The exact trade and FDI caused by the emigrants abroad is extremely difficult to capture at a global level. It would likely not materialize within the following year; it may come with many years of time lag and the length of these lags may differ widely. 2. Furthermore, the scope of the emigration rate in this study is a small fraction of very high-skilled inventors; the amount of trade and FDI for the COOs, solely generated from these individuals, would represent a miniscule portion of the national trade and FDI if any. Indeed, when we regressed trade and FDI on inventor emigration rates, the effect was insignificant. 3. Other studies have already demonstrated that emigration gives rise to trade and FDI, as explained in the literature review section. To illustrate such effect, a more focused setting is helpful (such as linking the variation in emigrations rates to variation in trade/FDI for a specific country over the years, as in other literature); a global scope is not an ideal setting to study it. Therefore, we focus on the moderated effect to study how the inventor emigrants interact positively with existing trade/FDI to influence the innovation and growth of their COOs. The global dataset enables us to incorporate cross- and within-country effects for the period of time when much technological innovation took place (1990s and 2000s); the large variation in emigration rate, trade and FDI across different countries allows us to study the impact of the emigrants to a wide variety of source countries.

The unit of analysis is country-year. The panel specification with country fixed-effects is shown below:

$$
\begin{aligned}
GROWTH_{i,t+1} = {} & \beta_1 EMI_{it} + \beta_2 TRADE_{it} + \beta_3 FDI_{it} + \beta_4 (EMI_{it} \times TRADE_{it}) \\
& + \beta_5 (EMI_{it} \times FDI_{it}) + \beta_6 GDPpc_{it} + \beta_7 GFCF_{it} \\
& + \beta_8 URBAN_{it} + \beta_9 SSE_{it} + \alpha_i + \gamma_t + \varepsilon_{it}
\end{aligned}
$$

where *GROWTH* is the annual growth rate, *EMI* is the high-skilled inventor emigration rate, *TRADE* is the sum of imports and exports, *FDI* stands for foreign direct investment, *GDPpc* stands for GDP per capita, *GFCF* is gross fixed capital formation, and *URBAN* and *SSE* represent urbanization and secondary school enrollment, respectively. The country fixed effects (α_i) as well as the year effects (γ_t) are included as controls.

The limitation of the fixed-effects model is that some of our variables may be endogenous. Even though the fixed-effects control for the time-consistent country-specific effects, and the year dummies control for the year-specific effects that apply uniformly to all countries, endogeneity remains if there are time-varying shocks to any country (very likely). This may arise, for example, due to some omitted variable related to innovation that affects growth and trade/FDI at the same time. Trade and FDI may cause growth, which in return can cause more trade and FDI into the COOs. In this case, the endogenous variables are correlated with the errors in previous and/or current year(s), which makes the regression estimates spurious. In order to control for the possible endogeneity, we specify a dynamic panel estimation model with the current year's growth rate added as an explanatory variable for the growth rate in the following year:

$$y_{i,t+1} = \beta_1 y_{it} + \beta_2 X_{it} + \beta_3 Z_{it} + u_{it}$$

where the rest of the independent variables are divided into a set of endogenous (X_{it}) and exogenous variables (Z_{it}). Trade, FDI and any interaction terms containing them are the endogenous variables. We treat the inventor emigration rate as exogenous; although there are some precedents to the inventors' decision to emigrate abroad (such as salary gaps, career prospects, distance between the two countries, similarity in culture and languages, etc.), those factors would not be reflected in year-to-year variation in growth rate of the source countries. Furthermore, our inventor emigration represents the current stock of the inventor emigrants at each year, and not necessarily the newly created net flows during a specific year, which might be influenced by growth or GDP of the nation for certain poor countries. Additionally, we also treat the control variables as exogenous, as they are not expected to be correlated with errors or vary a lot from year to year. The time dummies also enter the equation as an exogenous variable; country-specific effects are canceled by the dynamic structure of the model.

The estimation of the dynamic panel model, originally developed by Arellano and Bond (1991), is referenced as difference generalized method of moments (GMM). An extension to the system GMM method, developed by Arellano and Bover (1995) and Blundell and Bond (1998), uses the lagged levels as well as the lagged differences for increased efficiency compared to the difference GMM. The instruments for the endogenous variables, including the previous year's realization for the dependent variable (which is naturally endogenous as the dependent variable is autocorrelated), are estimated GMM style, while the instruments for the exogenous variables are estimated the regular IV style. In all specifications, we used lag 3 to 4 years as instruments (using lag 2 may be risky if variables are strongly autocorrelated). We refer the readers to the improved estimation method developed by Roodman (2009), which is used in this study.

V. RESULTS

We report the correlations of the variables in Table 2. Two control variables, urbanization and secondary school enrollment, appear to be positively correlated. This occurs naturally as the countries with higher urbanization tend to have higher level of education. Although the two control variables represent different characteristics of nations, their effects might not be distinguishable from the estimation results due to potential multicollinearity. Hence, we alert the readers to use caution in interpreting the effect of these control variables.

Table 2. Correlations of Variables

	GROWTH	EMI	TRADE	FDI	GDPpc	GFCF	URBAN	SSE
GROWTH	1							
EMI	0.1827	1						
TRADE	0.0729	-0.0557	1					
FDI	0.0420	-0.0228	0.3442	1				
GDPpc	-0.1617	-0.5905	0.1679	0.0573	1			
GFCF	0.2567	-0.0371	0.1765	0.0715	-0.0145	1		
URBAN	-0.1571	-0.5181	0.1254	0.1138	0.5786	-0.0058	1	
SSE	-0.1975	-0.6113	0.1945	0.0876	0.6218	0.0521	0.7284	1

We report the fixed-effects panel estimation results in Table 3, along with the regression results omitting the country effects. The regular ordinary least squares results are helpful in understanding the cross-sectional variations in the data. We briefly discuss the results of the models without the endogeneity control, to offer as a comparison for the dynamic panel estimates.

The inventor emigration is positively associated with growth rates in the OLS estimates. This occurs because the developing countries tend to have higher rates of emigration for high-skilled workers, and these same countries have also experienced economic growth during the 1990s–2000s. It is difficult for already developed countries to keep experiencing higher rates of growth; this saturation effect is also evident in the negative and strongly significant coefficient for the GDP per capita. In the 1990s and 2000s, poorer countries have experienced faster growth, compared to richer countries with higher GDP per capita. On the other hand, the cross-sectional variation in gross fixed capital formation allows us to estimate the positive and significant effect of this variable; the countries with the necessary infrastructure in place have experienced growth. We notice that this effect goes away for fixed-effects panel analysis, probably because there is not enough within-country variation in gross fixed capital formation. The inventor emigration also loses its significance. The coefficient is still positive, but it is weakly significant at best, when the interaction terms are not included. As we allow the effect of the inventor emigration to vary with trade and FDI, the significance goes away. The effect of the GDP per capita stands strong even under the fixed-effects model, and actually the effect is more than 10 times stronger in magnitude. This can be interpreted as that the countries that have achieved economic gains during this period have slowed down its rate of growth. Likewise, there appears to be enough within- and cross-sectional variation in urbanization, which gives us the evidence of some growing countries increasing in urbanization as they gradually slow down their pace of economic growth. Because of the endogeneity problem, we can only make observational statements regarding these results.

The dynamic panel estimates are reported in Table 4 for +1 year effects. We report the estimates using the standard errors (left column) as well as the estimates obtained using the heteroscedasticity- and autocorrelation-robust errors under the two-step estimation (right column). We report the estimates excluding the interaction effects and including the interaction effects, to confirm the robustness of the coefficient estimates. We find that the previous year's growth rate to be highly predictive of the current year's growth rate, as expected. In addition, we find that without the interaction terms, one would arrive at the conclusion that the exogenous effect of inventor emigration is insignificant on the growth of COOs. However, when we add the interaction terms, we notice that in the absence of trade and FDI, the inventor emigration has a significant and negative effect on the growth of the COOs. On the contrary, the inventor emigration positively interacts with trade; this means that the countries with high levels of trade can mitigate the negative impact of "brain drain" to some degree. The negative effect of the inventor emigration is nullified when trade is about 80% of the GDP, which is about its average value across all countries. This is probably why the effect of emigration is not significantly different from zero when the interaction term is not included in the model specification. We find the evidence that the diasporas of high-skilled inventors create a positive network effect through the social and interpersonal relations formed in trading, in ways that foster innovativeness and growth in the COOs. We do not find the effect of the FDI nor its interaction with the inventor emigration meaningful.

Given that innovation often may take over one calendar year to fully materialize into industrial applications and commercial outcomes, we also estimate the effects of the explanatory variables for +3 and +5 year afterwards. These results are reported in Table 5. We find the effect of the emigration and the interaction with trade to weaken for +3 year specification. The weaker significance is only found when the errors are assumed to be standard. The statistical significance disappears under the robust error specification. It is helpful to cross-check that the magnitudes of the coefficients are similar across standard and robust error specifications; however, we believe that errors are indeed subject to heteroscedasticity in our context. Therefore, the results should be trusted only if the significance is found even with the larger robust errors.

We find some other interesting results for +5 year effects. The effect of the positive interaction between emigration and trade is completely indistinguishable from zero.

On the other hand, we start to see the positive effect of FDI. This may indicate that FDI is effective in promoting innovation but it takes time to see that result in terms of growth rates. What is more surprising is the negative and significant interaction between the inventor emigration and the FDI. It appears that the substitutionary effect is greater than the potential complementary effect. In other words, foreign investors interested in hiring the high-skilled workers from the COO has options; they can directly invest in the COO, such as via R&D offshoring or establishing a foreign branch, or they can bring those workers across borders and hire them locally. This finding is in line with the insight from Miguélez (2018).

1. Summary of Results

We find the positive interaction between the high-skilled inventor emigration rate and trade, after controlling for the endogeneity present in the explanatory variables. By using the dynamic panel estimation, we are able to identify the significant effect that is not found under the fixed-effect specification. Trade is a simple exchange of goods and services across borders and represents the general openness of the origin country with other countries. The definition of the trade is not specific to investment into research, development and innovative activities, yet just by having the border more open to exchanges with other countries, this provides avenues for the emigrants abroad to have a positive feedback effect to the home country. Previous literature has noted the importance of trade on growth (Grossman and Helpman, 1990; Dollar, 1992; Sachs and Warner, 1995; Marelli and Signorelli, 2011); trade promotes economic growth through efficient resource allocation and specialization. It can also increase domestic productivity in the face of international competition. Furthermore, trade can also aid the diffusion of knowledge, during which process the emigrants can have a positive reinforcing effect, by reducing the communication cost for a smoother transaction and flow of knowledge.

On the other hand, the network effect through FDI, which represents the actual investment and possible business relations across countries, while having a positive effect on growth for +5 year afterwards, appears to be rather a substitute to high-skilled migration. This result does not preclude that complementary effect between inventor emigrants and FDI is missing; the effect may exist yet it cannot be identified separately and the substitutionary effect seems to be dominant. This insight agrees with the result found in Miguélez (2018); inventor diasporas have stronger effect on co-inventorship and collaboration involving interpersonal relationships, and weaker effect on fostering R&D offshoring and in a setting involving business transactions protected by hard contracts. However, the study by Miguélez (2018) uses the dependent variables from the same database that the inventor emigration rates are calculated from; therefore, the scope is limited to the evidence from the patents registered under the PCT for the WIPO. We extend the scope to study the effect of knowledge spillover on another database, one that measures the economic outcome of the source countries objectively. Hence, we are able to link the aggregate effect of the inventor emigrants on the growth of their COOs. This is the contribution of our work to the literature on high-skilled emigration and the suggested view of it as "brain circulation" (Saxenian, 2006).

Table 3. Cross-Sectional and Fixed-Effects Regression Results

DV=GROWTH	OLS, +1 year effect		Fixed Effects, +1 year effect	
EMI	0.6534**	1.0788*	0.5973#	0.9963
	(0.3166)	(0.5764)	(0.4154)	(0.8138)
TRADE	0.0019	0.0053#	0.0095#	0.0122#
	(0.0022)	(0.0036)	(0.0064)	(0.0076)
FDI	0.0024	-0.0186#	0.0008	-0.0096
	(0.0052)	(0.0139)	(0.0053)	(0.0144)
EMI x TRADE		-0.0074		-0.0055
		(0.0062)		(0.0082)
EMI x FDI		0.0513#		0.0252
		(0.0317)		(0.0334)
GDPpc	-0.000030***	-0.000030***	-0.000366***	-0.000367***
	(0.000006)	(0.000006)	(0.000039)	(0.000039)
GFCF	0.0844***	0.0822***	0.0153	0.0141
	(0.0131)	(0.0134)	(0.0199)	(0.0202)
URBAN	-0.0012	-0.0013	-0.1035**	-0.0998**
	(0.0061)	(0.0061)	(0.0451)	(0.0453)
SSE	-0.0123**	-0.0114**	-0.0155	-0.0156
	(0.0050)	(0.0050)	(0.0129)	(0.0129)
Fixed Effects			Included	Included
Year Effects	Included	Included	Included	Included
Num Observation	1939	1939	1939	1939
Num Panelist			154	154
Avg Obs Per Panelist			12.6	12.6
R^2	0.2042	0.2054		
R^2 (within)			0.2099	0.2103

#, *, **, and *** indicate significance at 0.20, 0.10, 0.05, and 0.01 level, respectively (two-tailed tests).

Table 4. Dynamic Panel Data System GMM Results

DV=GROWTH	Dynamic Panel, +1 year effect (Instruments Lag: min 3 / max 4)			
	One-step System GMM		Two-step System GMM	
	Std. Err.	Std. Err.	Robust Err.	Robust Err.
L1.GROWTH	0.2486***	0.2235***	0.2470***	0.2245***
	(0.0361)	(0.0320)	(0.0558)	(0.0593)
EMI	0.0793	-1.5968*	0.2160	-1.8614*
	(0.3089)	(0.8364)	(0.4315)	(1.1079)
TRADE	-0.0006	-0.0064	-0.0014	-0.0084
	(0.0040)	(0.0055)	(0.0044)	(0.0070)
FDI	-0.0035	-0.0020	-0.0030	0.0024
	(0.0051)	(0.0162)	(0.0035)	(0.0147)
EMI x TRADE		0.0205**		0.0235*
		(0.0098)		(0.0121)
EMI x FDI		-0.0030		-0.0129
		(0.0400)		(0.0363)
GDPpc	-0.000033***	-0.000032***	-0.000030***	-0.000031***
	(0.000005)	(0.000005)	(0.000009)	(0.000011)
GFCF	0.0141	0.0109	0.0154	-0.0084
	(0.0139)	(0.0133)	(0.0244)	(0.0310)
URBAN	-0.0055	-0.0067#	-0.0035	-0.0072
	(0.0050)	(0.0050)	(0.0074)	(0.0092)
SSE	-0.0023	-0.0058#	-0.0029	-0.0088
	(0.0044)	(0.0045)	(0.0063)	(0.0070)
Fixed Effects	Included	Included	Included	Included
Year Effects	Included	Included	Included	Included
Num Observation	1881	1881	1881	1881
Num Panelist	154	154	154	154
Avg Obs Per Panelist	12.21	12.21	12.21	12.21
AR(1) test	0.000	0.000	0.000	0.000
AR(2) test	0.687	0.764	0.831	0.850

#, *, **, and *** indicate significance at 0.20, 0.10, 0.05, and 0.01 level, respectively (two-tailed tests).

Table 5. Dynamic Panel Data System GMM Results, +3 and +5 Year Effects

DV=GROWTH	Dynamic Panel, System GMM (Instruments Lag: min 3 / max 4)			
	+3 year effect		+5 year effect	
	Std. Err.	Robust Err.	Std. Err.	Robust Err.
L1.GROWTH	0.3476***	0.3539***	0.2538***	0.2551***
	(0.0433)	(0.0685)	(0.0404)	(0.0868)
EMI	-1.7788**	-1.9407	-0.7714	-0.5826
	(0.8637)	(1.7212)	(0.8724)	(1.1612)
TRADE	-0.0073#	-0.0076	0.0010	0.0011
	(0.0057)	(0.0086)	(0.0057)	(0.0061)
FDI	-0.0224#	-0.0177	0.0316*	0.0316*
	(0.0170)	(0.0236)	(0.0165)	(0.0180)
EMI x TRADE	0.0138#	0.0160	0.0071	0.0072
	(0.0101)	(0.0183)	(0.0102)	(0.0121)

Table 5. Continued

DV=GROWTH	Dynamic Panel, System GMM (Instruments Lag: min 3 / max 4)			
	+3 year effect		+5 year effect	
	Std. Err.	Robust Err.	Std. Err.	Robust Err.
EMI x FDI	0.0637#	0.0530	-0.0860**	-0.0873*
	(0.0421)	(0.0622)	(0.0403)	(0.0465)
GDPpc	-0.000020***	-0.000019**	-0.000032***	-0.000031***
	(0.000006)	(0.000009)	(0.000006)	(0.000009)
GFCF	0.0503***	0.0432	-0.0090	-0.0054
	(0.0126)	(0.0339)	(0.0126)	(0.0300)
URBAN	-0.0024	-0.0037	-0.0024	-0.0013
	(0.0052)	(0.0076)	(0.0053)	(0.0089)
SSE	-0.0140***	-0.0150*	-0.0112**	-0.0109#
	(0.0046)	(0.0080)	(0.0046)	(0.0071)
Fixed Effects	Included	Included	Included	Included
Year Effects	Included	Included	Included	Included
Num Observation	1887	1887	1884	1884
Num Panelist	154	154	154	154
Avg Obs Per Panelist	12.25	12.25	12.23	12.23
AR(1) test	0.000	0.000	0.000	0.000
AR(2) test	0.958	0.971	0.093	0.184

#, *, **, and *** indicate significance at 0.20, 0.10, 0.05, and 0.01 level, respectively (two-tailed tests).

VI. DISCUSSION AND CONCLUSION

In this paper, we investigate the effect of high-skilled inventor emigration rate on growth rate, in 154 countries during the period of 1990–2011 for which reliable data on inventor emigration are available. We consider a moderating effect of high-skilled inventor emigrants on growth of the countries of origin; in particular, we hypothesize that their network effects play a role depending on the level of trade and foreign direct investment. In order to examine the externality effects, we study the interaction of the high-skilled inventor emigration rate with trade and foreign direct investment.

After controlling for endogeneity by using a dynamic panel data specification, we find that while the high-skilled emigration has a direct negative impact (representing the "brain drain"), this can be mitigated by the positive interaction effect with trade. On the other hand, the foreign direct investment appears to have stronger substitutionary rather than complementary effect, and interacts negatively with high-skilled inventor emigration for +5 year effects. Our study is unique in that the empirical result examines the emigration of the extremely skilled inventors who patent internationally, and links their effect on the economic outcomes in their countries of origin.

The study results highlight the importance of the network externalities created by the high-skilled emigrants abroad. Especially, when coupled with an active trade policy, the high-skilled emigrants are poised to spur technology and knowledge spillover into their source countries. The significance of their effect is expected to be greater for near future, with faster rate of innovation in a world that is no longer flat. The implication is that the outgoing high-skilled emigrants should no longer be viewed as a simple “brain drain”; instead of focusing on their direct negative effect, policy makers should consider taking advantage of the rich social and interpersonal relations they form internationally. Countries with enough absorptive capacity can work with them to increase the flow of knowledge and technology, which benefits the source countries as well.

This paper is not without limitations. We use a broad measure of growth rates as an evidence of innovation. Some other direct measure might prove to be more relevant, if such data are accurate and available for a wide range of countries. The patents filed under the international patent cooperation treaty does not provide a complete coverage for innovation, and some patents may only get filed under each country’s jurisdiction. The system also provides a way to approximately infer the inventions’ industrial value, whose actual value to the society is unobserved and unmeasured.

Nevertheless, this study is meaningful in a number of ways. We discover and empirically demonstrate the positive externality effects of high-skilled inventor emigrants on the growth of the origin countries, and the inventors are central to new technology creation and transfer. This work is one of the fewer studies on the impact on the source countries, highlighting that many of them are developing rather than developed countries. Our result emphasizes the importance of openness and active trade policy. We draw implication for how the sending countries can benefit from the rich network of their high-skilled workers abroad, another important resource for the origin countries nowadays.

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