TALENT ON THE RUN: GLOBAL INNOVATION IMPACTS OF BRAIN DRAIN

By

Aleksandra Krasnokutskaia

Submitted to
Central European University
Department of Network and Data Science

In partial fulfillment of the requirements for the degree of
MSc in Social Data Science

Supervisor: Prof. Martin Kahanec

CEU eTD Collection

Vienna, Austria

2025

Author's Declaration

I, the undersigned, **Aleksandra Krasnokutskaia**, candidate for the MSc in Social Data Science declare herewith that the present thesis is exclusively my own work, based on my research and only such external information as properly credited in notes and bibliography. I declare that no unidentified and illegitimate use was made of the work of others, and no part of the thesis infringes on any person's or institution's copyright. I also declare that no part of the thesis has been submitted in this form to any other institution of higher education for an academic degree.

Vienna, 22 May 2025

Aleksandra Krasnokutskaia
Signature

CEU eTD Collection

Copyright Notice

Copyright ©Aleksandra, Krasnokutskaia, 2025. Talent on the Run: Global Innovation Impacts of Brain Drain - This work is licensed under Creative Commons Attribution-NonCommercial-ShareAlike 4.0 International (CC BY-NC-SA 4.0)

CEU eTD Collection

Abstract

As international migration continues to grow and change receiving and sending countries, its understudied effects on the sending countries have become increasingly relevant. The long-standing brain drain versus brain gain debate remains unresolved, largely due to fragmented, industry-specific or country-specific studies that dominate the existing literature. I aim to contribute to the debate and investigate the global impact of emigration on innovation, using the number of resident patent applications per million as a proxy for innovation. To investigate this relationship, I develop a panel OLS model with country fixed effects that accounts for various important predictors of innovation and investigate the difference in this relationship across various regions and income groups. The results are mixed and indicate heterogeneity in the relationship between emigration and innovation across contexts. The relationship is not uniform, suggesting that regional or structural differences play an important role. These findings contribute to a more comprehensive understanding of how the emigration influences global innovation trends.

CEU eTD Collection

Acknowledgements

I would like to express my gratitude to Prof. Martin Kahanec for his continuous guidance, constructive feedback and support throughout the course of this thesis. His expertise and encouragement were essential in shaping this study.

I am also sincerely thankful to Prof. Ljubica Nedelkoska for introducing me to the topic of diaspora and knowledge transfers, which led me to develop the focus of this research, and for her valuable advice on the methodological aspects of this research.

Special thanks to Prof. Anand Murugesan for his valuable input on addressing endogeneity issues, which helped strengthen the methodological foundation of this study.

Lastly, heartfelt thanks to my cats Shesh and Olivia, whose silent presence and unwavering moral support made the long writing days more comforting.

CEU eTD Collection

Contents

CEU eTD Collection

List of Figures

CEU eTD Collection

List of Tables

CEU eTD Collection

Chapter 1

Introduction

Migration is often studied from the perspective of receiving countries with research ranging from studying economic effects to policy impacts to sociopolitical migration-related issues. A wide pool of evidence suggests that migration has significant positive effects for receiving countries, particularly in the case of high-skilled migration. Migrants bring valuable skills and expertise, which increases the receiving country's labor productivity (Fassio et al., 2020) and has a positive effect on technological innovation (Fassio et al., 2019; Peri, 2014). High-skilled migrants often fill critical gaps in labor markets, alleviating labor shortages (Guzi et al., 2018). Some evidence shows that migrants make net positive fiscal contributions (Martinsen et al., 2017). Beyond direct contributions, high-skilled migration also generates spill-over effects (Winters, 2018) and the creation of professional networks (Rauch & Trindade, 2002). These benefits underscore the multifaceted value of migration in shaping the economic and social landscapes of host countries.

However, for every arriving migrant that one country gains, another country loses a potential contributor. In the 1950s and 1960s when the United Kingdom saw a large out-migration of scientists and technologists to the United States and Canada, the British Royal Society described it with the term "Brain Drain" (Sajjad, 2011). Today, it is commonly used to describe a significant outflow of talent from a sending country.

The research of migration's impact on sending countries is limited in terms of the breadth of measurements and fragmented by economic sectors or industries of interest. World Bank's 2023 World Development Report highlights the positive impact of remittances on poverty and income in sending countries, the ability to tackle high unemployment and the potential benefits of knowledge transfers from diasporas and returning migrants.

Other research points out several problems that sending countries face due to emigration with challenges like fiscal revenue losses in India from high-skilled emigration to the U.S. (Desir et al., 2009), substantial training investment losses in Kenya's healthcare sector (Kirigia et al., 2006), mixed evidence on healthcare outcomes like child mortality (Quamruzzaman, 2020), labor shortages in poorer nations (Crush et al., 2005), and negative effects on metrics like patent applications and scientific citations (Labrianidis et al., 2023).

CEU eTD Collection

The available evidence highlights both positive and negative effects, but lacks a cohesive framework to assess the broader implications of emigration on the development. Given this fragmented research and the conflicting narratives surrounding brain drain, the lack of a broader exploration is clear. This study aims to address this gap by posing the following research question: what global impact does emigration have on innovation?

To investigate the impact of emigration on the growth of innovation output, I 1) build the model of innovation as a function of emigration and 2) explore the differences in the relationship across regions and income groups.

I use the number of resident patent applications per million as a measure of innovation, sourced from World Intellectual Property Organization. The rest of the variables are found in various sources. Migration data comes from World Bank's World Development Indicators, which itself is compiled from several nation-level sources. Economic and political variables are also pulled from World Bank Development Indicators.

While this study aims to provide a robust analysis of the developmental impact of emigration on innovation, there are several limitations that must be acknowledged related to data availability and quality, endogeneity, the choices of proxy variables and other methodological decisions. Despite these limitations, the study's methodological approach, aims to mitigate some of these issues.

I arrive at mixed results that show no strong universal link between emigration and innovation and indicates heterogeneity across contexts like regions and developmental level. This contributes to a more comprehensive understanding of how the emigration influences global innovation trends and outlines several potential directions for future research.

CEU eTD Collection

Chapter 2

Brain Drain vs. Brain Gain in the Literature

Attempts at conceptualizing, quantifying and estimating brain drain stretch across time and have been contradicting in approaches and findings. Docquier and Rapoport (2012) describe several waves of brain drain research. The first wave of research on brain drain appeared in the late 1960s. These early economic studies mostly used traditional trade theory to analyze how emigration affects the well-being of countries and found that brain drain had little to no negative effect on the countries people were leaving. Instead they highlighted the overall advantages of allowing people to move freely across borders for the global economy and additionally found remittances a positive force for the local economies, which helped offset the losses caused by emigration. Within the context of global economy, early studies also highlighted the idea that skilled migrants contribute to global knowledge, which benefits everyone.

A second wave in the 1970s introduced alternative models that challenged this optimistic view, arguing that high-skill emigration harmed the economies of sending countries. Researchers focused on exacerbating global inequality, concerns for domestic labor markets of the sending countries, fiscal issues and information asymmetries, concluding that rich countries benefited from migration at the expense of poorer nations.

Since the late 1990s, a third wave of research has aimed to balance these perspectives by examining both the positive and negative effects of brain drain. Theoretical models now explored conditions under which emigration could ultimately benefit source countries, with this phenomena being termed ”brain gain” in contrast to ”brain drain”. New evidence showed that under certain conditions, brain drain could help countries of origin (for example, by encouraging education or through technology and financial transfers) while still addressing earlier concerns like lost tax revenue. Meanwhile, better migration data made it possible to test these hypotheses with more precision. This led to a growing body of empirical research and helped shift the debate towards a more data-driven and evidence-based basis.

Today, various evidence-based effects of emigration are recognized. To begin with, emigra-

CEU eTD Collection

tion has several positive effects.

Remittances account for about one-third of the total recorded capital inflows to low- and middle-income countries (World bank, 2023). They also represent a significant portion of gross domestic product (GDP) in many countries across Central America and Central Asia, as well as in small low-income economies and nations with large diaspora populations, i.e. Lebanon (ibid.).

Remittances help combating poverty in many ways, as evidence from various countries shows. First, remittances increase household income. For example, in Bangladesh remittances from low-skilled migrants double their families' income (Melander & Öberg, 2006). In Albania, remittances nearly double the daily per capita income of households in the bottom 30th percentile (World Bank, 2017). In some Somalia, remittances are essential for displaced people; they receive an average of 876 USD a year in international remittances, or almost twice the level of GDP per capita (Clemens, 2011).

Second, remittances increase consumption and spending on various purposes. For example, Indonesian households receiving remittances spend about 16 percent more on food than they would without remittances (Frieden, 2019). In Ethiopia, farm households receiving remittances are less worried about procuring sufficient food and are at lower risk of malnutrition (Abadi, 2018). In Colombia households receiving remittances spend 10 percent more on education (World Bank, 2018).

The ability to spend more on education results in better educational outcomes. In Malawi, migration to South Africa has increased the educational attainment of children in rural communities (OHCHR, 1951). In many other countries, children in households that receive remittances tend to stay in school longer and reach higher levels of education and lifetime income.

Finally, remittances reduce poverty even in households that do not receive them. Households that receive remittances increase their spending, which boosts local economic activity, the incomes of other households in the community (Cortés, 2015).

Economically, emigration contributes to the increasing international trade, especially as the demand for products from the sending countries grows in the receiving countries (Lucas, 2014). Moreover, direct foreign investment significantly grows with the increase of emigration (Javorcik et al., 2011).

Among the most prominent positive impacts of migration is the transfer of knowhow and innovation between the countries, that tends to benefit the country with the lower development level more. These transfers are primarily possible through returning migrants and diasporas, who bring technological and entrepreneurial knowledge into the home country (Docquier & Rapoport, 2012).

Besides applied knowledge and innovation, World Bank (2023) highlights that transfers also happen in social norms. This effect is strongest when migrants maintain close ties with their origins, particularly through participation in economic and social activities. Migrants can improve institutional quality in the sending countries by transferring knowledge and experiences,

CEU eTD Collection

but large-scale emigration might hinder progress by depleting skilled professionals (Anelli & Peri,2017). Households related to emigrants tend to be more politically active (often with the support of remittances), demand better governance and reduce corruption in their communities of origin (Tusalem, 2018). Emigration has the potential to influence gender roles with migrants to liberal societies promoting equality back home, however, those moving to more conservative regions can reinforce traditional norms (Ferrant & Tuccio, 2015).

Other research points out several problems that countries face due to emigration. Despite the benefits that remittances bring, they have mixed effects on inequality. For communities with existing inequalities where richer households are more likely to send out migrants and receive remittances, the richer households receive even more money. For example, remittances were found to increase inequality in Kosovo (Pekkala et al., 2016).

Emigration might lead to direct and indirect fiscal losses. Regional evidence from India shows that emigration leads to huge losses of fiscal revenue: because of high-skilled emigration to the U.S., India is estimated to lose 2.5% of total fiscal revenues annually (Desir et al., 2009). Indirectly, public investment in education and training incurs serious losses in case the professionals migrate abroad after the fact. A research focused on doctors from Kenya shows the significant loss of public investment in the training of healthcare professionals who leave: it costs US$48,169 to train a doctor, while the average Kenyan makes about US$1.30 per day (Kirigia et al., 2006).

Higher emigration levels can result in labor shortages in the country of origin. In the region of Sub-Saharan Africa, skilled emigration resulted in relaxed migration policies in more developed African economies like South Africa, which in turned resulted in skilled labor shortages for poorer countries, i.e. Zimbabwe (Crush et al., 2005).

As for skill-related effects of emigration, there are regional studies highlighting the potential problem of brain drain. The studies on effects of brain drain in the field of healthcare in particular have been contradicting with some suggesting a negative effect of emigration on child mortality (Quamruzzaman, 2020). Quamruzzaman's findings indicate that countries with moderate levels of medical brain drain experience higher infant and child mortality rates. For very low and very high medical brain drain the relationship is less pronounced. Additionally, while medical brain drain has a negative impact on upper-middle-income countries, it appears to have a beneficial effect on low-income countries.

Scientific outcomes are also shown to suffer due to emigration. The case of Greece shows a negative effect of emigration on the number of scientific citations and the number of patent applications (Labrianidis et al., 2023).

CEU eTD Collection

Chapter 3

Innovation & Emigration

Innovation is widely recognized as an important driver of economic development, fostering productivity growth, technological advancements and the creation of new industries. Hence, innovation plays a central role in shaping a country's long-term development, making it an effective proxy for measuring national progress. Given its significance, understanding how emigration affects countries' innovation capacities and whether brain drain or brain gain is observed becomes crucial. When it comes to brain drain/gain literature, a large and growing share of it is focused on innovation outcomes. The following section reviews key studies on this topic, exploring how emigration influences the generation of new ideas, technologies, and industries in both sending and receiving countries.

While recent literature has increasingly acknowledged the potential benefits of emigration and the mixed impacts, the negative consequences are substantial and well-documented, particularly for countries with limited capacity to retain, return or replace their talent. The most immediate and direct effect of emigration is the departure of the most educated and, hence, innovative individuals in society. Innovation is sustained through the availability of skilled labor, particularly in fields requiring high levels of expertise, such as science, engineering, and technology. When a country loses a significant share of its highly educated population, its stock of knowledge workers shrinks, which can reduce national productivity and the ability to conduct research and development. Migration of skilled workers can leave public and private institutions without enough talent, especially in developing countries where education systems may not produce a surplus of skilled professionals (Lowell & Findlay, 2001).

The negative effects are even more severe when the emigration rate of tertiary-educated individuals is high and when the country lacks the infrastructure to absorb or re-train replacements. For example, for some sub-Saharan African and small island nations, more than half of highly educated workers from the country live abroad (Docquier & Rapoport, 2007). In such contexts the departure of even a few key individuals (i.e. professors, scientists, or engineers) can significantly impair country's ongoing innovation projects and, hence, the capacity to innovate (ibid.).

Though, the effects of emigration are not limited to talented individuals, they also impact

CEU eTD Collection

the institutions that support innovation. Universities, research labs, technology startups and public agencies depend on skilled staff to function effectively. When experienced professionals leave, institutional structures often erode, leaving organizations with weaker structures. This ”brain drain of institutions” leads to scientific productivity decline not only because of fewer researchers themselves, but also due to an overall worse academic environment (Gaillard and Gaillard, 1997).

Empirical studies have attempted to estimate the impact of skilled emigration on innovation outcomes, often using patent data, publication counts or R&D investment as proxies. The evidence shows that some countries experience a decline in domestic innovation output that can be attributed to high-skilled emigration. As mentioned in the previous chapter, Greek evidence shows the decrease in the number of scientific citations and the number of patent applications associated with emigration (Labrianidis et al., 2023). Using the data from the US-based migrants, Kerr (2013) suggests that emigration might reduce innovation in the origin country, if emigrants do not maintain ties with their country of origin or if local capacities are not replenished in other ways. In the same vein, developing countries might lack the institutional and financial capacity to turn emigration into a positive and leverage knowledge transfers, hence, it tends to result in a one-way transfer of innovation potential to richer nations (Lucas, 2005).

Furthermore, the sectoral composition of emigration matters. The departure of workers in strategic sectors such as health, education, IT and engineering can disproportionately impact innovation. Bhagwati and Hamada (1974) pointed out the fiscal and developmental problems that arise from losing such professional individuals, particularly when the public has invested in their education and training. More recent evidence shows similar issues persist in some context. Regional evidence from India shows that emigration leads to huge losses of fiscal revenue: because of high-skilled emigration to the U.S., India is estimated to lose 2.5% of total fiscal revenues annually (Desir et al., 2009). The studies on effects of brain drain in the field of healthcare in particular have been contradicting with some suggesting a negative effect of out-migration on child mortality (Quamruzzaman, 2020). A research focused on doctors from Kenya shows that the public investments in training health professionals incurs serious losses in case they leave: it costs US$48,169 to train a doctor, while the average Kenyan makes about US$1.30 per day (Kirigia et al., 2006).

This props another concern is that brain drain can disincentivize investment in higher education, both by individuals and governments. Governments, recognizing the risk of losing their most educated citizens, may shift priorities away from expensive higher education towards other services. Meanwhile, if students perceive that the only way to achieve returns on their education is to leave the country, it may reduce the incentive to invest in local institutions. Over time, this can weaken national education systems, reduce enrollment in advanced programs, and further undermine domestic capacity for innovation. This dynamic is closely related to what Mountford (1997) and Stark et al. (1997) describe as the no return problem: the idea that the prospect of emigration might encourage human capital formation only when

CEU eTD Collection

the probability of emigration is not too high. When emigration becomes the norm, and return migration is unlikely, the benefits of educational investment are lost.

Much of the early literature on emigration and innovation emphasized the problems, a lot of other research has drawn attention to its potential benefits —particularly, for knowledge transfer, as discussed in the previous chapter. The concept of brain circulation, the role of diaspora networks and the stimulating impact of remittances have proved to be important mechanisms through which emigration can stimulate innovation in sending countries as a complex and reciprocal process. Importantly, beneficial brain drain, when emigration can lead to positive development outcomes, occurs if the prospect of migration incentivizes greater educational investment at home and if a portion of skilled individuals return or contribute from abroad (Beine et al., 2008).

The concept of brain circulation emphasizes that the movement of talent is a two-way exchange. Skilled migrants often retain strong personal and professional ties to their countries of origin, which can lead to both temporary and permanent returns, bringing back enhanced skills, global experience, and access to international networks. For example, in the case of Indian and Chinese engineers in Silicon Valley, these migrants contributed significantly to the development of high-tech clusters in Bangalore and Shanghai (Saxenian, 2005). Similarly, there is evidence from US-based ethic research communities that return migration of skilled workers enhances patenting and innovation capacity in origin countries by raising the domestic stock of human capital and embedding international standards into local institutions (Kerr, 2008).

Moreover, even temporary return migration or circular migration, where individuals split their time between countries, can promote knowledge spillovers. Dustmann and Kirchkamp (2002) show that migrants who return home often engage in entrepreneurial activities, benefiting from both financial capital and skills acquired abroad, and this economic activity can contribute to innovation.

In addition to physical returns, diaspora networks (the informal and formal connections maintained by emigrants with their countries of origin) play a crucial role in facilitating knowledge exchange. These networks can provide access to global markets, partnerships, expertise and funding, all of which are critical for innovation.

Diaspora members often act as knowledge intermediaries, transferring information and facilitating collaborations between scientists, entrepreneurs and institutions across borders (Agrawal et al., 2011). The evidence on patent citations showed that U.S. patents by Indian and Chinese inventors frequently cited work from their home countries, indicating active intellectual exchange (ibid.). Similarly, countries with larger skilled diasporas tended to have stronger scientific collaboration with high-income countries (Docquier & Lodigiani, 2010).

Furthermore, ”social remittances”, meaning the ideas, behaviors, and knowledge that migrants transmit home (Levitt, 1998), while being less measurable than financial remittances, significantly shape the culture around innovation, attitudes toward entrepreneurship and the adoption of new technologies in origin countries.

CEU eTD Collection

Though not directly tied to knowledge, remittances can also have important effects on innovation by easing financial constraints. In many developing countries, limited access to financial resources is a major barrier to entrepreneurship, research activity and development. Remittances can help fill this gap, enabling investments in education, research, technology adoption, development etc. Remittances help boost economic growth by relaxing liquidity constraints, particularly in countries with weak financial systems (Giuliano & Ruiz-Arranz, 2009). In the similar vein, regional evidence from the Philippines showed that Filipino households receiving remittances were more likely to invest in education and entrepreneurship, both of which contribute to long-term innovation potential (Yang, 2008).

As evidenced above, much of the literature on brain drain and its effects has polarized into narratives of either loss or gain with nuanced conditions that enhance or damage the outcomes, but a significant body of research presents more nuanced or conditional findings. These studies emphasize that the effects of emigration on innovation in sending countries are context-dependent and influenced by a variety of economic, institutional and demographic factors.

Several studies argue that the innovation outcomes of high-skilled emigration differ depending on the developmental stage of the country. For instance, Beine et al. (2008) found that countries with a moderate rate of skilled emigration may experience positive feedback effects, such as increased incentives for education and remittances invested in knowledge infrastructure. However, these benefits are typically seen only when the brain drain is not excessive. In contrast, countries with already weak education systems or limited R&D infrastructure may suffer disproportionately from the outflow of talent, as they lack the capacity to benefit from return migration or diaspora knowledge transfers.

The sectoral composition of emigrants plays an important role. As discussed, migration may affect certain professional sectors (like healthcare) more than others and lead to disproportionately harmful outcomes. Also, the loss of highly skilled workers in strategic or demanding industries can harm national innovation capacities more than in mature sectors where knowledge spillovers are already institutionalized (Kerr, 2013).

As established earlier, mixed conclusions are also a theme around return migration. Its size, timing and structure influence the outcomes to a great extent, determining the net positive or net negative effect.

The effect of diaspora communities varies based of the extent and quality of diaspora engagement and should be carefully considered.

Another source of mixed findings lies in the difficulty of measuring innovation accurately across countries. While many studies use patent counts or R&D expenditure as proxies, these indicators may not fully capture the complex and multi-layered nature of innovation. Innovation can take informal forms, especially in developing countries where entrepreneurial knowledge might not be patented but still contributes significantly to economic development (Crescenzi et al., 2013).

Many studies also struggle with issues of endogeneity, specifically, whether high emigra-

CEU eTD Collection

tion causes weak innovation or whether low innovation levels lead to higher emigration among skilled individuals. As a result, findings often depend on model specifications and the robustness of underlying assumptions. Structural models that simulate counterfactual scenarios might offer insights, but they rely heavily on forecasts and assumptions that may not hold universally. Hence, the literature urges caution when generalizing findings across different national and institutional contexts.

In sum, the literature increasingly recognizes the upsides of emigration and also the potential acknowledges the negative effects on innovation, particularly those with fragile institutions and limited human capital. Despite these insights, most studies are country-specific or focus narrowly on return migration. Few attempt to capture the global effect of emigration on innovation using large-scale data. I address this gap to find what impact emigration has on innovation.

CEU eTD Collection

Chapter 4

Methodology

To investigate the impact of emigration on the growth of innovation, I utilize classic econometric methods 1) to build a model of innovation as a function of migration as well as 2) to investigate how this relationship varies across different world regions and income groups of countries by estimating separate models for each subgroup.

4.1 Data

This study uses the number of *patent applications* as a measure of innovation, sourced from World Intellectual Property Organization and ranging from 1990 to 2023. More specifically, the measure is resident patent applications per million inhabitants. *Net emigration* data comes from World Bank's (WB) World Development Indicators database, which itself is compiled from several sources, the data spans from 1999 to 2023. The WB's net migration takes the number of immigrants and subtracts the number of emigrants, meaning negative numbers represent cases where emigration exceeds immigration. For the purposes of straightforward interpretation, I reversed the scale so that in this study a larger number represents a larger amount of net emigrant. Net emigration per million inhabitants is taken to match the dependent variable and to combat potential endogeneity and capture the delayed effect on innovation, it is included as a 3-year lagged variable. The data on *diaspora* is represented with international migrant stock by country of origin from United Nation's Population Division. However, this data spans every 5 years from 1990 to 2024 with remaining years linearly interpolated. Similarly, the measure is recalculated to the number per million inhabitants.

As for control variables, all of them are sourced from World Bank's World Development Indicators and span from 1990 to 2023. However, due to varying data availability and quality across countries, many variables are filled with missing values. Missing values were linearly interpolated if two real data points were available before and after the period and if the gap did not exceed five years. The rest of data points are not taken into the account.

Education Enrollment is represented as the number of people enrolled in tertiary education

CEU eTD Collection

per million inhabitants of all age groups, immediately following secondary school. It covers both academic and vocational programs and serves as a proxy for a country's human capital development. *FDI* is net foreign direct investment measured in current US dollars, where a positive value indicates a net inflow and a negative value represents a net outflow of investment. *GDPpc* represents gross domestic product per capita in purchasing power parity (PPP) terms, measured in current international dollars. This variable typically exhibits a right-skewed distribution, with a few countries having exceptionally high values. Hence, the variable is transformed using the natural logarithm, which helps normalize the data, mitigate the influence of outliers, and compare effects across countries. *Internet* measures the number of individuals using the internet per million inhabitants. *Political Stability* is an estimate of political stability and absence of violence or terrorism in a country, which shows the extent to which the government is perceived as stable, the absence of threats to the established order and the overall security of the environment. Higher values indicate greater political stability and less likelihood of political violence or upheaval, which can create a more conducive environment for economic activity and innovation. *Rule of Law* is an estimate that captures the degree to which agents have confidence in and abide by the laws in the country. It measures perceptions of the extent to which people trust and abide by the legal framework, including the quality of contract enforcement, property rights, the police, the courts, as well as the likelihood of crime and violence. A stronger rule of law, corresponding to a higher number, implies a more predictable and transparent legal environment, which supports business activities, investment and innovation by protecting rights and reducing uncertainty. *R&D Expenditure* refers to research and development expenditure as a percentage of GDP. *Researchers* represents the number of researchers in R&D per million people. *Trade* measures measures the sum of exports and imports of all goods and services as a percentage of a country's GDP. *Population* represents the total population of a country of all ages and, similarly to GDP per capita, the variable was log-transformed to combat right-tail skewness.

In Table 4.1 you can find the descriptive statistics of the dataset.

Table 4.1: Descriptive Statistics

Statistic	N	Mean	St. Dev.	Min	Max
Year	1,521	2,012.972	6.915	1,999	2,023
Patent Applications	1,521	173.651	369.449	0.100	3,053.900
Emigration (3-Year Lag)	1,521	−1,076.545	7,029.288	−90,490.280	37,951.380
GDPpc, PPP	1,521	24,973.280	19,801.170	786.516	141,913.300
Internet	1,521	544,874.500	297,982.000	1,470.000	1,000,000.000
Trade	1,521	85.726	54.405	18.126	442.620
Population	1,521	83,589,691.000	232,731,046.000	1,072,714	1,438,069,596
Enrollment	1,521	518,975.800	273,447.800	20,062.800	1,666,656.000
FDI	1,521	−883,730,004	35,732,132,990	−345,435,000,000	218,323,780,736
Political Stability	1,521	0.132	0.866	−2.810	1.608
Rule of Law	1,521	0.412	0.944	−2.089	2.125
R&D Expenditure	1,521	1.057	0.930	0.005	3.874
Researchers	1,521	2,062.518	1,997.611	13.278	8,130.791

CEU eTD Collection

The total sample consists of 1521 (country-year) observations with 97 counties present in the dataset that have at least 5 years of observations. The breakdown by regions and income groups creates unbalanced samples for different regions and groups with richer countries having higher data availability and quality. The World Bank classifies countries into geographic regions as well as four income groups based on their gross national income (GNI) per capita. As of 2025, low-income countries have a GNI per capita of $1,145 or less, countries classified as lower-middle-income have a GNI per capita ranging between $1,146 and $4,515, upper-middle-income countries fall within the range of $4,516 to $14,005 GNI per capita and high-income countries are those with a GNI per capita of $14,005 or more. These thresholds are updated annually to account for changes in exchange rates and inflation, providing a consistent framework to compare economic development levels across nations.

In Table 4.2 you can see the skewness of the sample.

Table 4.2: Observations by Region and Income Group

Region/Income Group	Observations
Europe and Central Asia	699
East Asia and Pacific	235
Latin America and the Caribbean	193
Sub-Saharan Africa	162
Middle East and North Africa	97
South Asia	72
North America	50
High income	779
Upper middle income	431
Lower middle income	247
Low income	66

4.2 Methods

The analysis is divided into two major steps: constructing a model of innovation as a function of migration and exploring regional and income differences between countries. First, I estimate a panel Ordinary Least Squares (OLS) regression model with robust standard errors to account for potential heteroskedasticity, which occurs when the variance of the error terms is not constant across observations. Using robust standard errors ensures that the estimated standard errors of the coefficients remain valid even if this assumption is violated and, thus, improving the reliability of the results.

Then, I estimate a panel OLS regression with country-fixed effects with robust standard errors. Including fixed effects in the model is important because they allow to control for unobserved heterogeneity across countries (for factors that do not vary much over time but might

CEU eTD Collection

influence both innovation and migration). These time-invariant and unobserved factors, like historical institutions, cultural attitudes, geographic location, the quality of education systems etc., are often difficult to measure directly but can significantly affect the outcome variable. If such factors are omitted and are correlated with the regressors, the estimated coefficients will be biased due to omitted variable bias. By introducing country fixed effects, the model accounts for these unobserved differences by allowing each country to have its own intercept, effectively capturing the influence of all stable characteristics. This approach ensures that the estimated effects reflect within-country variation over time, rather than being confounded by differences between countries. As a result, fixed effects help isolate the true relationship between migration and innovation by singling out any constant cross-country disparities.

The final regression model includes relevant factors in line with the existing literature, taking into account relevant control variables pertaining to innovation from economic, political and social spheres as well as country fixed effects.

$$\begin{aligned}\text{Patents}_{it} = \beta_0 + \beta_1 Emigration_{it-3} + \beta_2 \log(GDPpc_{it}) + \beta_3 Internet_{it} + \beta_4 Trade_{it} + \\ \beta_5 \log(Population_{it}) + \beta_6 Enrollment_{it} + \beta_7 FDI_{it} + \beta_8 PoliticalStability_{it} + \beta_9 RuleOfLaw_{it} + \\ \beta_{10} R\&DExpenditure_{it} + \beta_{11} Researchers_{it} + \alpha_i + \varepsilon_{it}\end{aligned}$$

Throughout, I have to deal with endogeneity arising from the reverse causality between innovation and emigration. Innovation theoretically can be linked to emigration in both ways; as innovation rises, the country produces more skilled workers and, hence, more skilled-workers emigrate. Simultaneously, as emigration rises, innovation is also affected – positively through various transfers in some cases or negatively through reducing the talent pool. I use a lagged variable for net emigration with a 3-year lag to address this problem.

At the second stage, I compare the difference across regions and income groups. As evident from Table 4.2, only a few regions and income groups have a sample large enough to be investigated on their own. For subsamples with at least 200 observations, I estimate separate fixed effects models. This results in five additional models focused on specific groups: Europe and Central Asia, East Asia and Pacific as well as high-income countries, upper-middle-income countries and lower-middle-income countries.

CEU eTD Collection

4.3 Limitations

While this study aims to provide a robust analysis of the developmental impact of emigration on innovation in sending countries, it is important to acknowledge limitations that might affect the results.

First, there are notable challenges related to the availability and quality of data. Both migration and innovation statistics differ significantly across countries in terms of coverage, reliability, and consistency over time. In particular, Global South countries are affected by these problems more, as they tend to have lower capacities for quality data collection. This can introduce measurement errors or biases, particularly in lower-income countries. To address gaps in the data, some values were interpolated, which, while necessary, also introduced an additional layer of uncertainty. In a similar vein, subsamples for regional and income groups are unbalanced because of the data availability and some of the groups, particularly poorer countries, cannot be properly investigated.

Second, while the model offers interesting insights into the relationship between emigration and innovation, it is inherently limited by its reliance on key assumptions. The validity of the results depends heavily on correct model specification, the inclusion of relevant variables and the absence of omitted variable bias.

Third, this study relies on aggregate, country-level indicators of innovation, such as patents per capita. While these measures provide useful cross-national comparisons, they might not fully capture the complexity and context-specific nature of innovation. For example, informal or small-scale innovations, sector-specific dynamics or regional disparities within countries may be overlooked.

Furthermore, the proxy for innovation —resident patent applications—captures only formal and codified innovations and might underrepresent non-patentable technology, informal knowledge or unofficial activities, particularly common in lower-income countries.

Lastly, from a methodological perspective, the use of lagged net migration helps reduce concerns about reverse causality, although the possibility of endogeneity cannot be completely ruled out. It is possible, for example, that more innovative countries are better connected globally and thus have more citizens who emigrate for study or work abroad. However, given that innovation output is influenced by long-term systemic factors, the consistent relationship observed here suggests that migration plays a meaningful role in shaping innovation trajectories for some countries. To further address endogeneity, I tested instrumental variable (IV) models, using two instruments: the stock of diaspora (international migrant stock per million from the UN Population Division) and disaster-related displacement (number of persons displaced due to disasters per million, from the World Bank). Unfortunately, due to weak instrument relevance and limited data availability, the resulting models were of poor quality and, hence, are only reported in the Appendix **??** and A.4 for transparency.

Despite these limitations, the methodological design of the study tries to address and mini-

CEU eTD Collection

mize some of these concerns. Hence, the findings should be interpreted with caution, but they nonetheless contribute valuable insights into the relationship between emigration and innovation, particularly from a global perspective.

4.4 Ethical Considerations

I address ethical considerations such as data privacy and informed consent. Although the study relies solely on secondary data and does not involve direct interaction with individuals, ethical standards remain important. The analysis uses publicly available, aggregated national-level datasets (e.g., World Bank, UN Migration Database), which do not include personal or identifiable information and therefore pose no risk to individual privacy.

Nonetheless, ethical responsibility calls for the accurate representation of findings without bias or misinterpretation that could impact countries or communities of receiving or sending countries. Hence, the results will be presented and framed responsibly without stigmatization of sending countries experiencing emigration or receiving countries accepting immigration.

The findings of this research might carry broader implications for policy debates surrounding migration and global equity. Given the sensitive nature of migration and brain drain/gain discussions, there is a risk that the results could be misinterpreted or misused. To mitigate this, I emphasize that migration is a complex phenomena with a range of positive and negative effects on sending and receiving countries. This balanced presentation ensures that the findings constructively contribute to policy debates.

Finally, transparency is a cornerstone of ethical research. I document all methodological decisions, including the selection of data sources, models and control variables, to allow for reproducibility and peer review. Any limitations that might affect the findings are explicitly acknowledged. The data and the analysis code are publicly available for anyone to replicate the results (see Appendix A.1 and A.2).

CEU eTD Collection

Chapter 5

Innovation as a Function of Emigration

5.1 The model

Table 5.1 shows the results for the panel regression.

The panel regression models aim to estimate the relationship between net emigration and innovation outcomes. As described above, the dependent variable in each specification is the number of resident patent applications per million inhabitants and the core independent variable is lagged net emigration per million population with a three-year lag. Meaning, the larger the number, the more emigration is observed. The analysis includes three model specifications, with the Model 1 and Model 2 incorporating one of highly correlated variables *political stability* or *rule of law* and the Model 3 incorporating both.

Table 5.2 shows Variance Inflation Factor (VIF) for the predictors included in Model 3. In this model, all VIF values are below 10 –a conventionally accepted threshold, and most remain well below 5, suggesting that multicollinearity is not an immediate concern. The highest VIF is for Researchers (8.95), followed by R&D Expenditure (7.60) and Rule of Law (5.93). While these are relatively higher than other predictors and might indicate moderate problems with multicollinearity, they lie within acceptable limits. This indicates that the estimates of the regression coefficients are not likely to be very significantly biased by multicollinearity in the Model 3.

Across all models, the coefficient on net emigration is positive and statistically significant at the 1% level, suggesting that increased emigration is consistently associated with a rise in patent output in the sending countries. This effect remains robust across different specifications, with the magnitude of the coefficient ranging from -0.003 to -0.004. This implies that for every additional ”stayer” per million people, there is a small but significant decrease in patent applications per million.

GDP per capita (PPP) generally shows a positive and highly statistically significant association with patent output. Internet users per million have a negative coefficient in all specifications and this variable is not significant in most. This could reflect several structural differences in

CEU eTD Collection

Table 5.1: OLS Panel Regression Summary with Robust Standard Errors

	Dependent variable:		
	Resident Patent Applications per Million		
	Model 1	Model 2	Model 3
	(1)	(2)	(3)
Emigration (3-Year Lag)	0.004***	0.004***	0.003***
	(0.001)	(0.001)	(0.001)
GDPpc, PPP (log)	39.512***	66.497***	55.113***
	(10.956)	(13.728)	(12.377)
Internet	−0.00003	−0.0001*	−0.0001
	(0.00004)	(0.00004)	(0.00004)
Trade	−0.580***	−0.551***	−0.544***
	(0.121)	(0.122)	(0.122)
Population (log)	20.944***	9.483***	19.747***
	(5.040)	(3.601)	(4.861)
Enrollment	−0.0002***	−0.0002***	−0.0002***
	(0.00003)	(0.00003)	(0.00003)
FDI	0.000***	0.000***	0.000***
	(0.000)	(0.000)	(0.000)
Political Stability	33.267***		61.154***
	(9.567)		(14.033)
Rule of Law		−28.224***	−63.880***
		(9.975)	(15.333)
R&D Expenditure	317.343***	341.892***	332.793***
	(17.532)	(20.206)	(19.237)
Researchers	−0.021***	−0.018**	−0.015*
	(0.007)	(0.007)	(0.008)
Constant	−672.618***	−737.151***	−801.166***
	(115.748)	(123.217)	(132.040)
Observations	1,521	1,526	1,526
R^2	0.613	0.612	0.618
Adjusted R^2	0.610	0.609	0.615
Residual Std. Error	230.620 (df = 1515)	230.932 (df = 1515)	229.297 (df = 1514)
F Statistic	239.868*** (df = 10; 1515)	238.810*** (df = 10; 1515)	222.269*** (df = 11; 1514)
Note:			*p<0.1; **p<0.05; ***p<0.01

CEU eTD Collection

Table 5.2: Variance Inflation Factors (VIF), Model 3

Variable	VIF
Emigration (3-Year Lag)	1.14
GDPpc, PPP (log)	6.37
Internet	3.35
Trade	1.43
Population (log)	2.04
Enrollment	3.14
FDI	1.08
Political Stability	3.59
Rule of Law	5.70
R&D Expenditure	7.15
Researchers	8.05

how digital infrastructure is utilized across countries, or it may be a genuine indicator that increased internet access does not necessarily translate to greater innovation and that relationship is different.

Trade openness, measured as trade as a percentage of GDP, shows a consistently negative and highly significant relationship with innovation. This coefficient is counterintuitive, however, such result might suggest that countries heavily integrated into global trade might rely more on external innovation sources, leading to a reduction in domestic patenting activity. Alternatively, it might reflect the differences in the sectoral composition of countries' economies, with export-oriented industries being less patent-intensive. However, it is also important to consider the possibility of unobserved heterogeneity with systemic differences between countries.

Log of population size is generally significant and positive, highlighting the importance of scale, while foreign direct investment shows a small but consistently positive and highly significant association with innovation, aligning with expectations that global capital flows can support knowledge transfer and technological development.

Institutional quality is captured through two indicators: political stability and rule of law. Political stability has a positive and significant effect on innovation in the models where it is included, suggesting that a secure and predictable political environment encourages innovative activities, likely by reducing risks associated with long-term investment in business ventures, R&D, education etc. Rule of law becomes significantly negative when included on its own or alongside political stability. If the negative effect was observed only in the Model 3 that includes political stability, this might have been an issue of multicollinearity between the two measures, the two variables are highly correlated (0.80), as both reflect aspects of governance quality. Including both in the model might lead to distorted estimation of the coefficients: in this case, political stability might be capturing the primary governance effect on innovation, while

CEU eTD Collection

the residual variation in rule of law (after controlling for political stability) might relate to factors that are less supportive or even restrictive of innovation in some contexts, i.e. overly strict enforcement, overregulation or bureaucracy. However, the Model 2 with only $rule\ of\ law$ included similarly shows a negative effect. This finding might seem counterintuitive, as stronger legal institutions are generally associated with more secure economic environments. One possible explanation can lie in the regulatory rigidity hypothesis (Djankov, 2002), which suggests that environments with high rule of law may impose stricter legal and bureaucratic constraints that inadvertently hinder entrepreneurial risk-taking and innovative activity. In such contexts, legal compliance may be prioritized over experimentation and, thus, hinder the activity required for innovation. Additionally, the negative effect could reflect heterogeneity across countries, where the impact of institutional quality on innovation differs based on levels of development or other structural factors not fully captured in the model. In the similar vein, it is also possible that the observed relationship is influenced by the model design issues like omitted variable bias or endogeneity, warranting a further investigation. This once more highlights the complex role institutional variables play in shaping innovation outcomes for countries and suggest that a stronger rule of law might not universally foster innovation, especially when not accompanied by complementary policies that encourage flexibility and creativity.

The analysis also explores the role of education in innovation outcomes. Tertiary enrollment per million, included as a proxy for the availability of human capital, appears in all three models with a negative and statistically significant coefficient, though the effect size is small. This unexpected result might suggest that enrollment alone is not sufficient to drive innovation, but instead other issues specific to education might play a more important role, like the quality and relevance of higher education, alignment of education with labor market needs, the capacity of the economy to absorb talent etc. It is also possible that high enrollment figures hint at misallocation of talent in non-innovative sectors. Further research could explore whether quality measures of education or indicators related to STEM specialization provide a more accurate picture of education's role in innovation.

Research and development expenditure is a strong and positive predictor of patent output across all specifications, as expected. The number of researchers per million, on the other hand, surprisingly shows a negative and significant coefficient in all models. This result might be related to a number of factors like various inefficiencies in the research industry, i.e. low commercialization of research outputs, poor integration/collaboration between academia and industry or systemic barriers that prevent research activities from translating into patentable innovation. It can also reflect a simple issue of quality over quantity, where a higher number of researchers does not necessarily imply more impactful or market-oriented innovation.

Overall, the OLS regression results support the conclusion that increased overall net emigration is associated with a rise in innovation performance, or in other words more individuals leaving is associated with more patents. However, counterintuitive coefficients and interpretations along with the theoretical econometric understanding call for including country fixed

CEU eTD Collection

effects in the model.

Table 5.3 presents the results of a fixed-effects regression. Country fixed effects are included to control for time-invariant heterogeneity across countries and robust standard errors are used to account for potential heteroskedasticity. Interestingly, various changes in comparison to the regular model can be observed that add to the understanding of the relationship between the variables.

GDP per capita in this model is statistically insignificant and shows a negative effect. The results also indicate that internet penetration has a negative relationship with innovation, similarly, to the regular OLS model, yet with fixed effects this relationship is statistically significant, confirming that increases in internet usage do not directly translate into domestic patenting activity.

Similarly, trade openness also shows a strong and significant negative effect on innovation, also hinting at a more complex relationship with innovation.

Interestingly, tertiary enrollment has a theoretically expected positive coefficient, once fixed effects are added. The positive coefficient in this specification suggests that, holding all other factors constant, countries that have higher enrollment rate in higher education over time tend to experience gains in innovation, supporting the idea that human capital development contributes to technological progress when looking within countries rather than across them.

Population size shows statistically significant positive coefficients, highlighting the role of the scale.

FDI has a small, negative and statistically insignificant effect, in contrast with the regular model, suggesting that FDI inflows may not directly boost patenting activity in the host country, or their effect is mediated through other channels not captured in this model.

The institutional variables also show mixed results: rule of law has a significant positive effect on innovation, which supports the idea that stronger legal environments encourage innovation (by protecting intellectual property rights, removing uncertainty etc.). Yet political stability is negatively associated with innovation, which is unexpected. This relationship is statistically significant and inverted compared to the previous models. Potentially, it might be an issue of overlapping variance between the variables.

R&D expenditure is, as expected, strongly and significantly associated with innovation, reinforcing its role as a key input into the innovation activity. However, the number of researchers per million does not show a statistically significant relationship (though, the coefficient is still negative), potentially indicating an issue with this variable.

Most importantly, the coefficient for net emigration becomes positive but not statistically significant, suggesting that the hypothesized effect of emigration on innovation is weak or potentially absorbed by fixed effects and other covariates.

Most importantly, the coefficient for net emigration becomes positive but statistically insignificant in the fixed effects specification, suggesting that the hypothesized positive impact of emigration on innovation is weak, inconsistent or potentially confounded by unobserved

CEU eTD Collection

Table 5.3: OLS Panel Regression Summary with Robust Standard Errors and Country-Fixed Effects

Dependent Variable:	Patent Applications
Model:	(1)
Variables	
Emigration (3-year lag)	8.2×10^{-5}
	(0.0002)
GDPpc, PPP (log)	-0.0002
	(0.0004)
Internet	$-8.5 \times 10^{-5***}$
	(1.78×10^{-5})
Trade	-0.4900***
	(0.1428)
Population (log)	$9.83 \times 10^{-7***}$
	(2.46×10^{-7})
Enrollment	0.0002***
	(3.45×10^{-5})
FDI	-1.58×10^{-10}
	(1.59×10^{-10})
Rule of Law	48.75***
	(17.82)
Political Stability	-16.03**
	(6.809)
R&D Expenditure	95.03***
	(20.82)
Researchers	-0.0100
	(0.0082)
Fixed-effects	
Country	Yes
Fit statistics	
Observations	1,521
R^2	0.95777
Within R^2	0.13399

Heteroskedasticity-robust standard-errors in parentheses
*Signif. Codes: ***: 0.01, **: 0.05, *: 0.1*

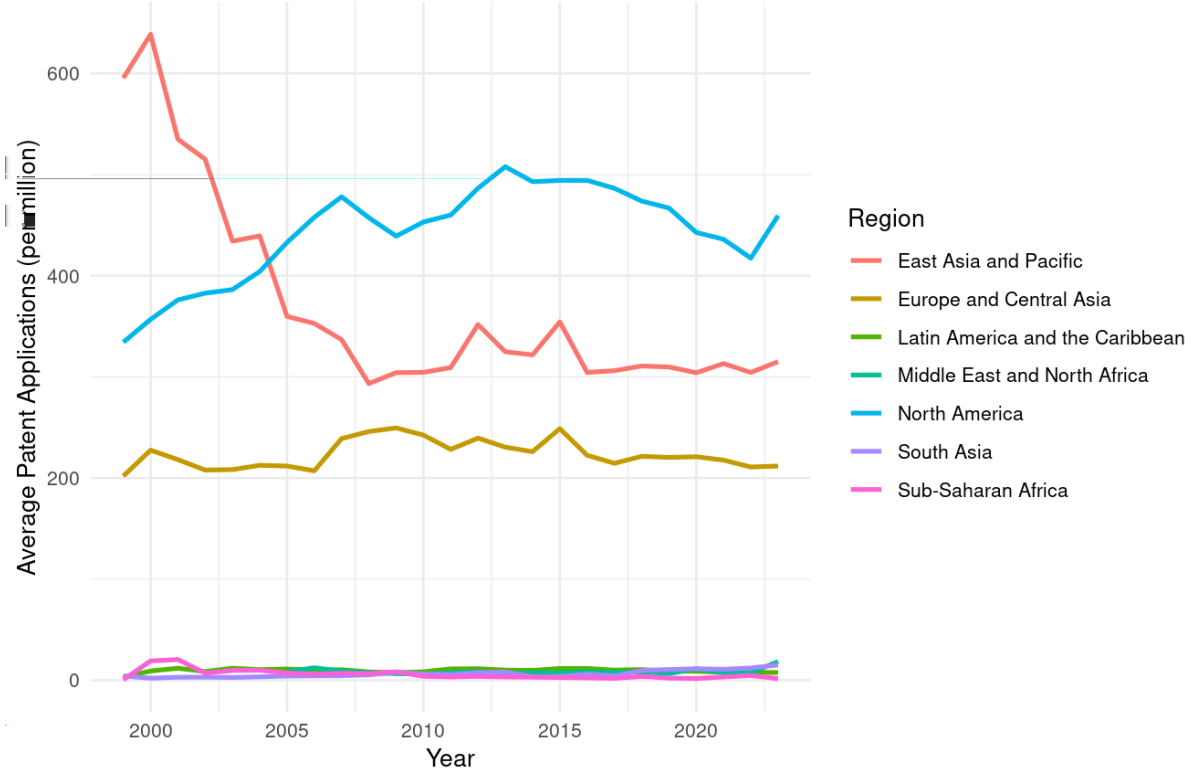
CEU eTD Collection

country-specific factors. Previously the estimates might have been biased because of heterogeneity across countries. As a result, the initially observed relationship between emigration and innovation in simpler models may be driven more by cross-country differences than by a true causal mechanism.

The latter is also supported by the model's metrics. The model has a high overall R^2 of 0.958, indicating that nearly 96% of the total variance in patent applications per million people is explained by the model. However, the within R^2 is substantially lower at 0.134, meaning that only about 13.4% of the variation within countries over time is accounted for. This discrepancy supports the conclusion that much of the explanatory power comes from differences between countries, rather than changes within countries over time. While the model fits the data well overall, the relatively low within R^2 highlights the challenge of explaining temporal variation in innovation outcomes using the included covariates. No definitive conclusions about causal effects can be drawn based on the model.

5.2 Heterogeneity: regional differences

Figure 5.1: Average Resident Patent Applications per Million by Region



Since the within R^2 of the fixed effects model is relatively low, this suggests that much of the variation in innovation is explained by differences between countries rather than by

CEU eTD Collection

changes within countries over time. In other words, the model struggles to capture how innovation changes within a country from year to year. To explore this further, I now examine whether the relationship between emigration and innovation differs across world regions and income groups. By analyzing these subgroups separately, I aim to uncover whether the effect of emigration on innovation is stronger or more visible in certain contexts.

Figure 5.2 illustrates clear regional disparities in average resident patent applications per million people over time. North America consistently leads in innovation output, showing a steady rise from around 320 in 2000 to a peak of nearly 500, before experiencing a modest decline in the late 2010s. East Asia and Pacific initially had the highest average, peaking near 640, but experienced a significant drop in the early 2000s and stabilized around 300–350 thereafter. Europe and Central Asia follow a flatter trend with a relatively stable average between 200 and 250 patent applications. In contrast, other regions such as Latin America and the Caribbean, Middle East and North Africa, South Asia, and Sub-Saharan Africa all maintain much lower levels, generally below 50, showing minimal growth or flat trends over the years. These differences suggest substantial regional gaps in innovation capacity and activity.

In the Table 5.4 two country fixed effects models are presented: one with the data from Europe and Central Asia as well as a model for East Asia and Pacific region, as the other regions do not have a sample substantial enough for regression analysis. It is also important to note that the sample for the chosen two regions is not balanced, since the data quality and availability for the European and Central Asian World Bank region is better than for East Asia and Pacific.

The regression results reveal notable differences in how emigration and other factors relate to patent applications. In Model 1, covering Europe and Central Asia, the coefficient for emigration is negative and statistically insignificant, suggesting no clear relationship between emigration and innovation in this region. In contrast, East Asia and Pacific model shows a positive and statistically significant coefficient for emigration, indicating that in East Asia and Pacific, higher emigration is associated with increased innovation. This result may point to beneficial knowledge transfers or return migration effects more present in this region.

Other variables also behave differently across the two contexts. GDP per capita is positively signed but insignificant in Europe and Central Asia, while in East Asia and Pacific it shows a significant negative effect, possibly indicating diminishing returns to income on innovation in higher-growth Asian economies, which is counterintuitive. Similarly, Internet usage and FDI show no significant association in Europe and Central Asia but are significantly negative in East Asia and Pacific, which may reflect regional differences in how digital infrastructure and foreign investment influence local innovation ecosystems.

Trade openness has a positive but insignificant effect in Europe and Central Asia, while the coefficient is negative (though not statistically significant) in East Asia and Pacific. Interestingly, population size shows significant effects in both models but with opposite signs: negative in Europe and Central Asia and positive in East Asia and Pacific. This suggests that in

CEU eTD Collection

Table 5.4: OLS Panel Regression Summary with Robust Standard Errors and Country-Fixed Effects by Region

Dependent Variable:	Patent Applications	
	Europe and Central Asia	East Asia and Pacific
Model:	(1)	(2)
Variables		
Emigration (3-year lag)	-0.0004	0.0079^{***}
	(0.0006)	(0.0029)
GDPpc, PPP (log)	9.43×10^{-5}	-0.0063^{***}
	(0.0004)	(0.0023)
Internet	-2.39×10^{-5}	-0.0003^{***}
	(1.56×10^{-5})	(8.48×10^{-5})
Trade	0.0970	-0.6169
	(0.1070)	(0.3980)
Population (log)	$-7.45 \times 10^{-6***}$	$8.54 \times 10^{-6***}$
	(1.84×10^{-6})	(1.18×10^{-6})
Enrollment	1.42×10^{-5}	0.0003^{**}
	(1.47×10^{-5})	(0.0001)
FDI	1.13×10^{-10}	$-8.19 \times 10^{-10*}$
	(7.45×10^{-11})	(4.82×10^{-10})
Rule of Law	12.53	-133.2^{**}
	(9.099)	(64.49)
Political Stability	-3.106	5.883
	(4.947)	(26.26)
R&D Expenditure	18.49	-4.419
	(11.90)	(67.99)
Researchers	0.0146^{***}	0.0344
	(0.0055)	(0.0333)
Fixed-effects		
Country (N)	Yes (36)	Yes (13)
Fit statistics		
Observations	699	235
R^2	0.98356	0.96949
Within R^2	0.17486	0.56863

Heteroskedasticity-robust standard-errors in parentheses
*Signif. Codes: ***: 0.01, **: 0.05, *: 0.1*

CEU eTD Collection

the European/Central Asian region increases in population might dilute innovation per capita, while in East Asia/Pacific, population growth could be associated with scale advantages and a broader innovation base.

Tertiary enrollment is positive in both models, though only statistically significant in East Asia and Pacific. This suggests that higher education plays a clearer role in supporting innovation in this region. The effect of FDI is near zero and insignificant in Europe and Central Asia, but significantly negative in East Asia and Pacific. This could reflect a scenario where foreign firms dominate innovation activity but do not contribute to domestic patent filings, or where FDI flows into sectors with low patenting intensity.

Institutional quality, as captured by rule of law and political stability, also shows contrasting results. In Europe and Central Asia, neither variable is statistically significant. In East Asia and Pacific, rule of law has a large and negative effect, which is statistically significant —a counterintuitive finding that might point to informal or alternative innovation mechanisms at play in countries with weaker legal enforcement or measurement issues. Political stability remains insignificant in both models.

R&D expenditure and number of researchers are not significant in either model, except for Researchers in Europe and Central Asia, which shows a positive and significant effect. This finding aligns with traditional innovation models that emphasize the role of skilled researchers, at least in more institutionally developed contexts.

The within R^2 values further support the idea that explanatory power varies by region. While the model explains 17.5% of within-country variation in Europe and Central Asia, the same specification accounts for 56.9% in East Asia and Pacific, suggesting that the chosen covariates better capture innovation dynamics in the latter region. These contrasts underline the importance of regional heterogeneity when modeling global innovation drivers and caution against drawing uniform conclusions from aggregate models.

5.3 Heterogeneity: income differences

Figure 5.3 shows that the clear divide in innovation output is also present if you break down the sample by income group. High-income countries dominate the landscape, although their average has slightly declined over time from higher numbers in the early 2000s to below 300 by the 2020s. Upper middle-income countries display a small and steady upward trend, nearly doubling their average from about 30 to over 60 patent applications. In contrast, both lower middle-income and low-income groups remain at very low levels throughout the period, with only modest gains. This stark contrast highlights the persistent innovation gap across income levels.

Table 5.5 shows the models for various income groups with a large enough sample.

The coefficient for emigration is positive but statistically insignificant across all groups, again indicating no robust link between emigration and innovation when controlling for country-

CEU eTD Collection

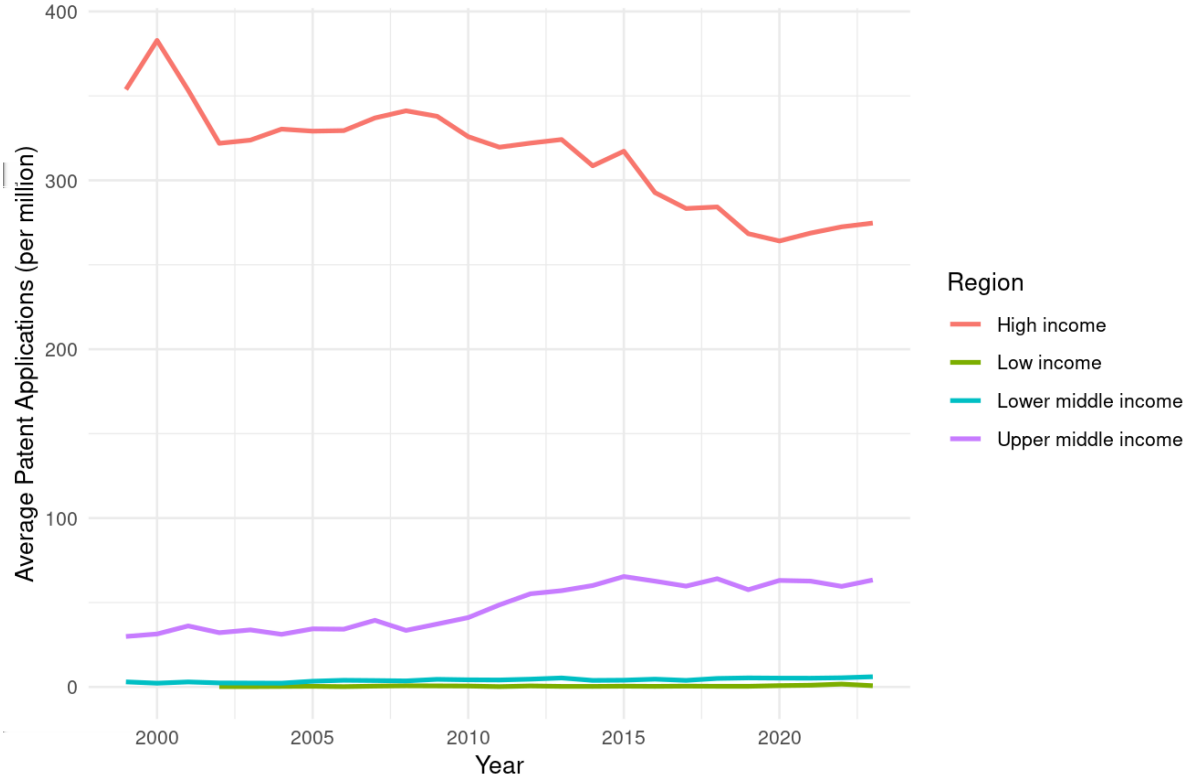
Table 5.5: OLS Panel Regression Summary with Robust Standard Errors and Country-Fixed Effects by World Bank Income Group

Dependent Variable:	Patent Applications		
	High income	Upper middle income	Lower middle income
Model:	(1)	(2)	(3)
Variables			
Emigration (3-year lag)	0.0004	0.0005	4.65×10^{-6}
	(0.0003)	(0.0004)	(1.19×10^{-5})
GDPpc, PPP (log)	-0.0010**	0.0021***	0.0007***
	(0.0005)	(0.0005)	(0.0002)
Internet	-0.0001***	-0.0001***	-3.33×10^{-6}**
	(3.77×10^{-5})	(1.28×10^{-5})	(1.5×10^{-6})
Trade	0.7934***	-0.2862**	0.0195
	(0.1902)	(0.1134)	(0.0124)
Population (log)	5.02×10^{-6}***	6.59×10^{-6}***	4.32×10^{-8}**
	(1.17×10^{-6})	(4.03×10^{-7})	(1.97×10^{-8})
Enrollment	4.5×10^{-5}*	7.73×10^{-5}***	3.37×10^{-6}
	(2.34×10^{-5})	(2.32×10^{-5})	(3.7×10^{-6})
FDI	-3.26×10^{-10}**	8.75×10^{-10}***	8.5×10^{-11}
	(1.32×10^{-10})	(1.39×10^{-10})	(1.38×10^{-10})
Rule of Law	-8.843	58.05***	0.1802
	(20.05)	(12.49)	(1.117)
Political Stability	-2.312	4.812	1.039**
	(13.20)	(5.235)	(0.4403)
R&D Expenditure	-13.00	43.46**	-4.245*
	(16.51)	(19.62)	(2.243)
Researchers	0.0288***	-0.0258**	0.0023
	(0.0101)	(0.0106)	(0.0017)
Fixed-effects			
Country (N)	Yes (39)	Yes (29)	Yes (20)
Fit statistics			
Observations	778	431	247
R^2	0.96668	0.96276	0.82523
Within R^2	0.08797	0.91721	0.64200

Heteroskedasticity-robust standard-errors in parentheses
*Signif. Codes: ***: 0.01, **: 0.05, *: 0.1*

CEU eTD Collection

Figure 5.2: Average Resident Patent Applications per Million by World Bank Income Group



specific factors. GDP per capita has mixed effects: it is negatively associated with innovation in high income countries but positive and statistically significant in the other two groups (upper middle and lower middle). Internet access shows a consistent and significant negative relationship. Trade openness is positively related to patenting in high income countries, but negatively in upper middle income countries, while for lower middle income countries it is insignificant. Population and tertiary enrollment are positively and significantly associated with innovation in most cases, while FDI, institutional quality, and R&D variables show varying significance and directions across income levels, highlighting differences in how innovation is driven in different development contexts. Among the significant effects: FDI is negatively associated with patenting in high income countries, while it shows a positive and significant effect in upper middle income countries, suggesting its role in fostering innovation through technology transfer in developing contexts. Rule of law is only significant in upper middle income countries, where it supports innovation, unlike other less intuitive models where it showed a negative impact. R&D expenditure is positively linked to innovation in upper middle income countries but shows a negative association in lower middle income countries, which might point to inefficiencies. The number of researchers is positively and significantly associated with patenting activity in high income countries, while that effect is negative in upper middle income countries, possibly indicating a mismatch between research capacity and innovation output.

The R^2 values across the three models indicate how well the regressions explain variation

CEU eTD Collection

in patent applications. High income countries model and lower middle income countries model achieve high overall R^2 values of 0.97 and 0.83, respectively, suggesting that the models fit the data well at the country level.

Interestingly, the model performs particularly well for upper middle income countries, with a very high within R^2 of 0.917, indicating that it explains a substantial share of the variation in patent applications over time within countries in this group. Such result is suspiciously high, suggesting that the fixed effects specification might be overfitting the data or capturing noise alongside genuine patterns. This raises concerns about model robustness and warrants further investigation with alternative specifications or validation techniques. For high income and lower middle income countries, the within R^2 values are 0.088 and 0.642 respectively, suggesting a weaker model fit for high income countries and a moderate fit for lower middle income economies.

CEU eTD Collection

Chapter 6

Discussion

The findings on the relationship between emigration and innovation reveal a complex and nuanced picture that, on the one hand, poses new questions and, on the other hand, challenges one-sided narratives about brain drain/gain and its consequences. I find several important insights that contribute to the ongoing research debate on migration and innovation. It is important to note, however, that this study has certain limitations that were addressed in detail in the methodology chapter. These limitations include considerations regarding potential endogeneity concerns, data constraints, methodological design issues and are crucial for properly contextualizing all the findings and their implications.

First, the initial OLS panel regression suggested a positive and statistically significant relationship between emigration and innovation output, indicating that increased emigration was associated with higher patenting activity in origin countries. However, when country fixed effects were introduced to control for time-invariant heterogeneity, this relationship became statistically insignificant, indicating that the apparent positive association might have been driven by cross-country differences rather than within-country variation over time.

The divergence between these results highlights the importance of accounting for country-specific characteristics when analyzing emigration and innovation. This finding aligns with arguments that institutional and structural factors might be more determinative of innovation capacity than migration flows and that highlighted that a more granular breakdown of the phenomenon is needed.

The analysis of heterogeneity by region and income level revealed important contextual variations. In East Asia and Pacific, emigration showed a strong positive and significant association with innovation, while no significant relationship was observed in Europe and Central Asia. This regional divergence suggests that the benefits of emigration for innovation might be connected to the regional context, possibly reflecting differences in institutions, policies or processes around innovation. The East Asian/Pacific result is particularly interesting given that major studies outlining and developing the concept of brain circulation analyzed and drew conclusions from East Asian data (Saxenian, 2005), showing how emigrants to technology hubs like Silicon Valley later contributed to technological development in their home countries

CEU eTD Collection

through knowledge transfer, investment and entrepreneurship.

Similarly to the pooled and European models, when examining heterogeneity by income level, I find no significant relationship between emigration and innovation across high-income, upper middle-income and lower middle-income countries. This also suggests that the relationship between emigration and innovation does not follow a simple pattern based on the development level, but that country-specific institutional and economic factors likely play a much more important role.

The disparate results observed for other variables across regions and income groups further highlight the context-specific nature of innovation drivers. For instance, R&D expenditure shows strong positive effects in the general fixed effects model but varies in significance and direction when examined by region or income group. Similarly, institutional variables like rule of law and political stability demonstrate inconsistent patterns across different contexts, suggesting complex interactions between governance, development and innovation that resist a universal interpretation.

These findings, while mixed, have important policy implications. First, they caution against a universal approach to managing emigration. While some countries might benefit from emigration through diaspora engagement policies that leverage emigrant networks for knowledge transfer and investments, others might need to focus more on strengthening domestic innovation systems and institutions. The observed regional and income-level heterogeneity suggests that policy responses should be tailored to specific contexts rather than derived from global generalizations.

Second, the results suggest that policies focusing exclusively on stemming emigration to preserve human capital may be misguided if they ignore the potential benefits of brain circulation, knowledge transfers and diaspora networks. Instead, in certain cases like East Asia and Pacific policies that facilitate knowledge transfer from emigrants to their home countries, encourage temporary or circular migration and strengthen domestic institutions might better use the potential positives of emigration.

Finally, the finding that much innovation's variation is explained by time-invariant country characteristics suggests that future research should focus on understanding the institutional, cultural and structural factors that create persistent innovation differences between countries. The relatively low within-country explanatory power of the models indicates that many temporal drivers of innovation are yet to be identified.

The regional heterogeneity as well as the varying relationship between innovation and emigration observed in this study suggest that the topic warrants a deeper and more nuanced investigation. A promising direction would be to disaggregate migration data further, in particular to isolate tertiary-educated emigrants or those with STEM backgrounds, to better assess how the movement of high-skilled individuals relates to innovation. More granular data, such as occupation-level flows, institutional affiliations or patenting behavior of migrants, could significantly enhance the precision of such analysis. Such data is not available globally, but could be

CEU eTD Collection

potentially found on a country-level. Country-specific or even subnational studies might help reveal more structural factors that are connected to the effect of migration on innovation. In addition, linking migration databases with bibliometric or patent datasets could illuminate how emigrants contribute to knowledge production abroad or through cross-border collaboration. Longitudinal studies that follow individual career paths, return migration or evolving diaspora networks would also bring to light the temporal dimension of knowledge transfer and brain circulation.

And while quantitative models provide useful general patterns, they might obscure important contextual differences that shape how migration influences innovation outcomes. Future research could benefit from the use of case studies or mixed-methods approaches to explore these dynamics in greater detail. For example, qualitative research on the nature of diaspora engagement, institutional support for return migrants or the role of transnational scientific collaboration might uncover mechanisms that are not easily captured by macro-level data. It would be illuminating to work out how processes and policy mechanisms in specific countries of East Asia and Europe influence the emigration-innovation connection.

Ultimately, this line of research could help policymakers design more targeted strategies for leveraging human mobility to foster innovation at home and bring more understanding of the interconnected phenomena of migration.

CEU eTD Collection

Chapter 7

Conclusion

I explored the complex relationship between emigration and innovation using a panel of countries across different regions and income levels, with a particular focus on resident patent applications as a proxy for innovation output. The central question guiding this study was whether emigration, often framed in terms of brain drain, has a detrimental or beneficial impact on innovation in origin countries. The results are mixed, but they offer several valuable insights that challenge simplistic assumptions and underscore the importance of context in understanding the relationship between these variables.

Accounting for time-invariant country characteristics, the relationship between innovation and emigration has no statistical significance, indicating that much of the observed variation is driven by structural differences across countries rather than by within-country changes over time. This finding highlights the essential role of persistent institutional and economic conditions in shaping innovation capacity, and it suggests that emigration alone does not directly translate into higher innovation output unless accompanied by other important factors.

Further disaggregation by region and income group revealed notable heterogeneity. East Asia and Pacific showed up as a region where emigration maintains a significant positive link to innovation, supporting the idea of pronounced brain circulation in the region. The varying statistical significance of predictors across income groups highlights that the drivers of innovation differ substantially by development level, while the varying within R^2 highlights the different model quality and explanatory power of the models.

The inconsistency in the effects of key variables like R&D expenditure, institutional quality, FDI across regions and income groups suggests that no universal model can adequately capture the relationship, but rather innovation is shaped by a multitude of interacting factors.

As globalization continues to shape both migration patterns and knowledge diffusion, understanding these nuanced relationships remains crucial for developing effective innovation and migration policies. These findings carry important implications for both policymakers and researchers. From a policy perspective, the results suggest that approaches tailored for a specific context might work better. For researchers, this study opens several avenues for future studies. The use of more granular data, the focus on different types of migrants, integrating dif-

CEU eTD Collection

ferent data or methods could bring more understanding of who contributes to innovation, how and where. This is especially important given that the current models explain most variance through fixed country characteristics, suggesting that more dynamic explanatory factors remain underexplored.

In conclusion, this thesis demonstrates that emigration and innovation are interconnected in ways that are shaped by structural and regional contexts. Understanding these interactions more fully requires further research in various directions.

CEU eTD Collection

Bibliography

Abadi, N., Ataklti, T., Girmay, T., Maxwell, D., & Bapu, V. (2018). "The Impact of Remittances on Household Food Security: A Micro Perspective from Tigray, Ethiopia." WIDER Working Paper 40/2018, United Nations University–World Institute for Development Economics Research, Helsinki, Finland.

Agrawal, A., Kapur, D., McHale, J., & Oettl, A. (2011). Brain drain or brain bank? The impact of skilled emigration on poor-country innovation. Journal of Urban Economics, 69(1), 43–55.

Anelli, M., & Peri, G. (2017). "Does Emigration Delay Political Change? Evidence from Italy during the Great Recession." Economic Policy 32 (91): 551–96.

Beine, M., Docquier, F., & Rapoport, H. (2008). Brain drain and human capital formation in developing countries: winners and losers. The Economic Journal, 118(528), 631-652.

Bhagwati, J. N., & Hamada, K. (1974). The brain drain, international integration of markets for professionals and unemployment. Journal of Development Economics, 1(1), 19–42

Clemens, M. A. (2011). The financial consequences of high-skill emigration: lessons from African doctors abroad. Diaspora for development in Africa, 165-182.

Cortés, Patricia. 2015. "The Feminization of International Migration and Its Effects on the Children Left Behind: Evidence from the Philippines." World Development 65 (January): 62–78.

Crescenzi, R., Gagliardi, L., & Percoco, M. (2015). Social capital and the innovative performance of Italian provinces. In The economics of knowledge, innovation and systemic technology policy (pp. 170-199). Routledge.

Crush, J., Campbell, E., Green, T., Nangulah, S. M., & Simelane, T. (2005). States of vulnerability: the future brain drain of talent to South Africa.

Desai, M. A., Kapur, D., McHale, J., & Rogers, K. (2009). The fiscal impact of high-skilled emigration: Flows of Indians to the US. Journal of Development Economics, 88(1), 32-44.

Djankov, S., La Porta, R., Lopez-de-Silanes, F., & Shleifer, A. (2002). The regulation of entry. The quarterly Journal of economics, 117(1), 1-37.

Docquier, F., & Lodigiani, E. (2010). Skilled migration and business networks. Open Economies Review, 21, 565-588.

CEU eTD Collection

Docquier, F., & Rapoport, H. (2007). Skilled migration: The perspective of developing countries. ILO International Migration Papers, No. 89.

Docquier, F., & Rapoport, H. (2012). "Globalization, Brain Drain, and Development." Journal of Economic Literature 50 (3): 681–730.

Dustmann, C., & Kirchkamp, O. (2002). The optimal migration duration and activity choice after re-migration. Journal of development economics, 67(2), 351-372.

Fassio, C., Kalantaryan, S., & Venturini, A. (2020). Foreign human capital and total factor productivity: A sectoral approach. Review of Income and Wealth, 66(3), 613-646.

Fassio, C., Montobbio, F., & Venturini, A. (2019). Skilled migration and innovation in European industries. Research Policy, 48(3), 706-718.

Ferrant, G., & Tuccio, M. (2015). "South-South Migration and Discrimination against Women in Social Institutions: A Two-Way Relationship." World Development 72 (August): 240–54.

Frieden, J. (2019). "The Politics of the Globalization Backlash: Sources and Implications." In Meeting Globalization's Challenges: Policies to Make Trade Work for All, edited by Luís A. V. Catão and Maurice Obstfeld, 181–96. Washington, DC: International Monetary Fund; Princeton, NJ: Princeton University Press.

Gaillard, J., & Gaillard, A. M. (1997). The international mobility of brains: Exodus or circulation? Science, Technology and Society, 2(2), 195–228.

Giuliano, P., & Ruiz-Arranz, M. (2009). Remittances, financial development, and growth. Journal of development economics, 90(1), 144-152.

Guzi, M., Kahanec, M., & Kureková, L. M. (2018). How immigration grease is affected by economic, institutional, and policy contexts: evidence from EU labor markets. Kyklos, 71(2), 213-243

Javorcik, B., Özden, C., Spatareanu, M., & Neagu, C. (2011). "Migrant Networks and Foreign Direct Investment." Journal of Development Economics 94 (2): 231–41.

Kerr, W. R. (2008). Ethnic scientific communities and international technology diffusion. The Review of Economics and Statistics, 90(3), 518-537.

Kerr, W. R. (2013). U.S. high-skilled immigration, innovation, and entrepreneurship: Empirical approaches and evidence. NBER Working Paper No. 19377.

Kirigia, J. M., Gbary, A. R., Muthuri, L. K., Nyoni, J., & Seddoh, A. (2006). The cost of health professionals' brain drain in Kenya. BMC health services research, 6, 1-10.

Labrianidis, L., Sykas, T., Sachini, E., & Karampekios, N. (2023). The impact of highly skilled emigrants on the origin country's innovation performance: the case of Greece. International Journal of Manpower, 44(8), 1605-1621.

CEU eTD Collection

Levitt, P. (1998). Social remittances: Migration driven local-level forms of cultural diffusion. International migration review, 32(4), 926-948.

Lowell, B. L., & Findlay, A. M. (2001). Migration of highly skilled persons from developing countries: Impact and policy responses. ILO International Migration Papers, No. 44.

Lucas, R. (2005). International migration and economic development: Lessons from low-income countries. Edward Elgar Publishing.

Lucas, R. (2014). "The Migration–Trade Link in Developing Economies: A Summary and Extension of Evidence." In International Handbook on Migration and Economic Development, edited by Robert E. B. Lucas, Jr., 288–326. Cheltenham, UK: Edward Elgar.

Martinsen, D. S., & Pons Rotger, G. (2017). The fiscal impact of EU immigration on the tax-financed welfare state: Testing the 'welfare burden'thesis. European Union Politics, 18(4), 620-639.

Melander, E., & Öberg, M. (2006). "Time to Go? Duration Dependence in Forced Migration." International Interactions 32 (2): 129–52.

Mountford, A. (1997). Can a brain drain be good for growth in the source economy? Journal of Development Economics, 53(2), 287–303.

OHCHR (Office of the United Nations High Commissioner for Human Rights). (1951). "Convention Relating to the Status of Refugees." Adopted July 28, 1951, by the United Nations Conference of Plenipotentiaries on the Status of Refugees and Stateless Persons Convened under General Assembly Resolution 429 (V) of December 14, 1950. OHCHR, Geneva.

Pekkala Kerr, S., William R., Özden, Ç., & Parsons, C. R. (2016). Global talent flows. Journal of Economic Perspectives, 30 (4), 83–106.

Peri, G. (2014). Do immigrant workers depress the wages of native workers?. IZA world of Labor.

Rauch, J., & Trindade, V. (2002). Ethnic Chinese networks in international trade. The Review of Economics and Statistics, vol. 84(1). MIT Press, 116–130.

Quamruzzaman, A. (2020). Exploring the impact of medical brain drain on child health in 188 countries over 2000–2015. Societies, 10(4), 73.

Sajjad, N. (2011). Causes and solutions to intellectual brain drain in Pakistan. Dialogue, 6(1), 31-55.

Stark, O., Helmenstein, C., & Prskawetz, A. (1997). A brain gain with a brain drain. Economics Letters, 55(2), 227–234.

Tusalem, R. (2018). "Do Migrant Remittances Improve the Quality of Government? Evidence from the Philippines." Asian Journal of Comparative Politics 3 (4):336–66.

CEU eTD Collection

Winters, J. V. (2018). Do higher levels of education and skills in an area benefit wider society?. IZA World of Labor.

World Bank. (2017). Forcibly Displaced: Toward a Development Approach Supporting Refugees, the Internally Displaced, and Their Hosts. Washington, DC: World Bank.

World Bank. (2018). Moving for Prosperity: Global Migration and Labor Markets. Policy Research Report. Washington, DC: World Bank.

World Bank. (2023). World development report 2023: Migrants, refugees, and societies. Washington, DC: World Bank.

Yang, Dean. "International migration, remittances and household investment: Evidence from Philippine migrants' exchange rate shocks." The Economic Journal 118.528 (2008): 591-630.

CEU eTD Collection

Appendix A

Appendix

A.1 Data

https://github.com/alkrasnokutskaya/ceu/blob/main/talent_on_the%20run_data.csv

A.2 Analysis Code

https://github.com/alkrasnokutskaya/ceu/blob/main/talent_on_the_run_code.R

A.3 Instrumental Variable Models: Correlation Matrix between X, Y and Instruments

Table A.1: Correlation Matrix between X, Y and Instruments

	Patent Applications	Emigration	Diaspora	Displacement
Patent Applications	1.00			
Emigration	-0.12	1.00		
Diaspora	-0.12	0.08	1.00	
Displacement	-0.05	0.06	0.01	1.00

A.4 Instrumental Variable Models: Two Stage Regression Summary with Instrumental Variables

CEU eTD Collection

Table A.2: Two Stage Regression Summary with Instrumental Variables

	Dependent variable:			
	Patent Applications			
	Diaspora	Diaspora Fixed Effects	Displacement	Displacement Fixed Effects
	(1)	(2)	(3)	(4)
Emigration (3-Year Lag)		1.728		0.099
		(6.962)		(0.463)
Emigration (3-Year Lag) (fit)	0.009*		0.058	
	(0.005)		(0.041)	
GDPpc, PPP	0.003**	−0.152	−0.001	−0.082
	(0.001)	(0.586)	(0.002)	(0.118)
Internet	−0.00004	0.255	0.0001	−0.032
	(0.00004)	(1.321)	(0.0001)	(0.072)
Trade	−0.683***	−0.457	−0.942*	−0.094**
	(0.152)	(1.479)	(0.488)	(0.040)
Population	0.00000***	0.756	0.00000	0.862***
	(0.00000)	(0.786)	(0.00000)	(0.295)
Enrollment	−0.0002***	−0.499	−0.00004	0.349***
	(0.00004)	(2.528)	(0.0001)	(0.116)
FDI	0.000***	0.035	0.000***	0.017
	(0.000)	(0.251)	(0.000)	(0.013)
Rule of Law	−57.587***	0.063	11.986	0.123
	(19.159)	(0.286)	(69.245)	(0.135)
Political Stability	51.933***	−0.220	1.962	−0.044
	(14.353)	(0.818)	(45.406)	(0.099)
R&D Expenditure	359.681***	0.168	386.948***	0.147*
	(22.118)	(0.371)	(36.835)	(0.079)
Researchers	−0.027**	0.403	0.017	−0.153
	(0.013)	(1.777)	(0.044)	(0.220)
Constant	−19.298		−129.577*	
	(22.394)		(66.023)	
Observations	1,369	1,369	530	530
R^2	0.595	0.0003	0.296	0.220
Adjusted R^2	0.592	−0.079	0.281	0.065
Residual Std. Error	237.896 (df = 1357)		303.416 (df = 518)	
F Statistic		5.238		146.917***
Note:				*p<0.1; **p<0.05; ***p<0.01

CEU eTD Collection