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Elieth Diez
Yajaira Freites
Mónica García-Pérez
Luis Ordóñez
José Pineda
Jaime Requena
Sully Romero

Migration Unit

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OPTIONAL: Type address for correspondence

OPTIONAL: Type Authors name and eMail

Venezuelan research community migration: impacts and public policy implications¹

Elieth Diez, Yajaira Freites, Mónica García-Pérez, Luis Ordóñez, José Pineda, Jaime Requena
and Sully Romero²

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Abstract

Venezuela has lost through migration 16% of its research workforce, mostly in the last few years. This paper utilizes BIBLIOS- a database of Venezuelan publications- a survey, and open-ended interviews, to provide evidence on the relationship between migrated researchers and researchers in Venezuela. Several indicators of researchers' productivity were used, together with their attitudes towards professional and social ties. Preliminarily, the survey shows that researchers' initial decision to migrate is motivated by basic family needs and better opportunities. Meanwhile, the extended interviews show evidence of the interest of recent emigrants to maintain connections in Venezuela. Even among researchers not planning to return to Venezuela, there was evidence of their desire to collaborate with local partners in academic, professional, or business organizations and to engage in community work. Further, researchers migrate with an initial destination country in mind that changes over time (mostly to Latin America, North America, and Europe). With the increasing trend on researchers' emigration, their desire to maintain connections with the country, and their changes in migration destination patterns, it is important to evaluate the impact of these factors on the local research productivity of knowledge. Analysis of the BIBLIOS database reveals that research productivity tends to decrease initially when there is a recent migration while quality research productivity increases. In the long run, migration negatively relates to local research productivity, especially among local research groups where no researcher has ever migrated. Our research sheds light on the relevance of data-driven policies that incentivize professional connections between migrated and local researchers.

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² Elieth Diez, Fundación InterConectados. Email: eliethdiez@gmail.com; Yajaira Freites, Asociación Venezolana para el Avance de la Ciencia. Email: yfreites@gmail.com; Mónica García-Pérez Department of Economics, St. Cloud State University. Email: migarciaaperez@stcloudstate.edu; Luis Ordóñez, Fundación InterConectados. Email: lordonezv@onterconectados.org; José Pineda, University of British Columbia and DevTech Systems, Inc. Email: jose.pineda@sauder.ubc.ca; Jaime Requena, Academia de Ciencias Físicas, Matemáticas y Naturales, Caracas, Venezuela and The Institute of Biodiversity, Animal Health and Comparative Medicine, University of Glasgow, Scotland: Email: requena.j@gmail.com; Sully Romero, Fundación InterConectados; Email: sullyromero@gmail.com

Introduction

The migration of scientists as a consequence of the political and economic instabilities in Latin America is not a recent phenomenon. It somehow reflects the close relationship between the development of scientific capabilities and the adequacy of national public policies. Among those migrating, there are a significant number of individuals with the highest levels of educational attainment and professional training. They represent the highly skilled workers of the country's scientific workforce, such as university teaching staff, research scientists, and technologists. They are responsible for training future professionals, producing, and transferring knowledge through its creation via research, innovation, and managing laboratories/research centers, among other professional activities that add value to their disciplines and the economy as a whole.

The persistent negative effects caused by the exodus of high-skill individuals has motivated both research and public policies designed to mitigate impacts and, in the best case, turn them into positive issues to the economy of the country of origin (Lozano-Ascencio and Gandini, 2012). In the particular case of Venezuela, it is estimated that the country has lost 2,482 researchers from 1960 until July 2020. This number represents 16% of the stock of researchers the country created during the last 60 years. Remarkably, 26% of all research scientists and technologists that have left the country have done it in the last three years (Requena, 2019).

This paper explores the linkages between members of the research community who have migrated and those who remain in the country. Specifically, it studies the relationship between local research productivity —measured as the number of publications and ‘quality’ of the publications— and coauthors migration. Also, the paper explores the role of social capital and policies that facilitates the effective participation of migrated researchers in the country's future. Further, the paper documents the main characteristics of the migrated researchers by analyzing a database containing detailed information of the publications records of Venezuelan researchers, their immigration status, and basic personal information of the researcher (BIBLIOS database), and by the analysis of an ad hoc survey and an open-ended survey.

The relationship between Venezuelan researchers emigration and the overall scientific productivity in the country is studied in-depth. It is revealed that having an ever-migrated coauthor relates to two outcomes on Venezuelan researchers' productivity. First, a composition effect on the publication portfolio, by increasing the number of publications in international journals while reducing those on national journals. Second, an increase in the overall quality of the publications,

measured in terms of indexed publications and the journal impact factor. However, if the coauthor has recently emigrated, there is a negative relationship between average publication and the quality of the publications in journals (*disruptive short-term time effect*).

From a more general perspective, the results from the survey show that the age at which researchers migrate and their destinations (mostly Latin America, North America, or Europe) have changed over time. Also, the choice of the destination country seems to be related to the existence of previous contacts in the receiving country. In terms of the drivers of migration, the survey shows that it is related to work and family issues. The extended interviews show evidence of the interest of the latest emigration wave of Venezuelan researchers to maintain connections with their colleagues in Venezuela. Even though results indicate that linkages with national academic institutions have declined with time, half of the migrated researchers have kept some sort of connection, and over 90% of them are interested in having contact with Venezuelan academic institutions.

The paper is organized as follows: a background section presenting a conceptual framework to understand the role of research networks and social capital in scientific production. The data section describes the BIBLIOS database and settings for analysis. The results section presents the main stylized facts of the Venezuelan researchers (both migrated and non-migrated) as obtained from the survey or open-ended interviews conducted to a sample of migrated authors or from BIBLIOS, followed by the results from an *ad hoc* econometric approach. Finally, relevant experiences dealing with the issue of talent loss in Latin America are reviewed, and ensuing policy implications are noted.

Background: *the social-ecological systems for scientific productivity*

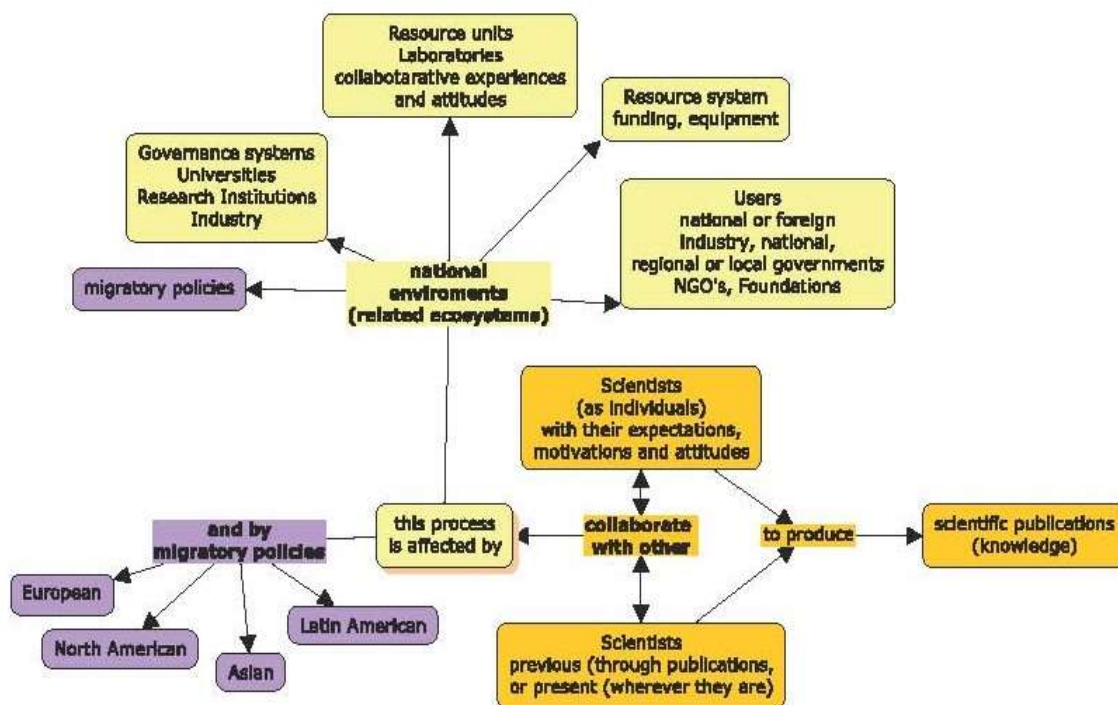
Using the lens of the social-ecological systems (Ostrom, 2007), the overall problem of knowledge mobilization and the role of talent could be understood and managed by analyzing:

- (a) the national environments where scientists work;
- (b) the scientific and other general government policies and;
- (c) the scientists' attitudes and characteristics for collaborative work.

In this framework (see Figure 1), the final objective is to achieve a “homeostasis-like” state, (*a tendency toward a relatively stable equilibrium between interdependent elements*), in such a way that, despite the mobilization of scientists, a working system based upon emigrated and non-

emigrated scientists and professionals may be achieved to guarantee the generation and/or mobilization of knowledge required for the country's development. According to this perspective, the first level of analysis would be whether or not migration affects the quantity and quality of the research output of scientists in the country, and how collaboration patterns for the realization of the scientific activity are affected both in the parting professionals and those remaining (Lee and Bozeman, 2005; Gonzalez- Brambila and Veloso, 2007; Aref, Zagheni and West, 2019).

Figure 1.- The Social-ecological Systems for Scientific Productivity

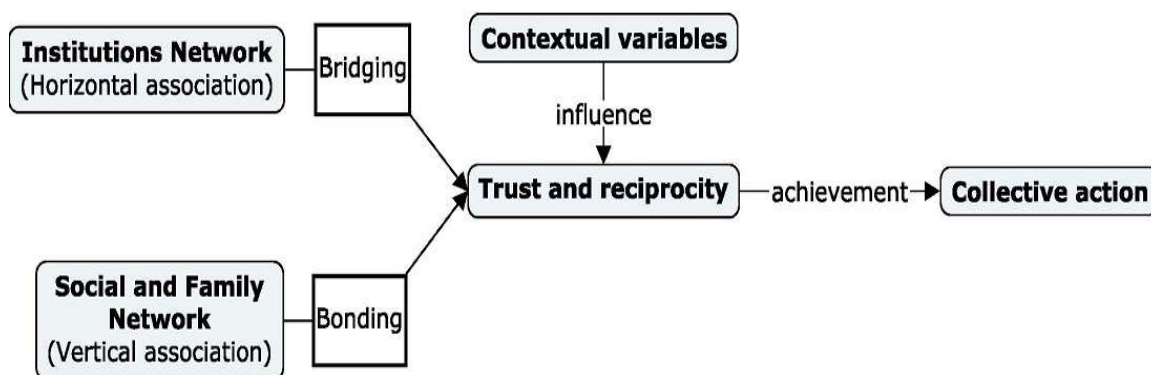


Source: Authors' design based on Ostrom(2007).

Another perspective indicates the importance of networking attitudes in the development of social capital among the academic and scientific diaspora. In this context, the role of two sources of networking is relevant in the analysis: the role played by professional and/or academic associations and the role played by informal networks, such as the family and friends environment of emigrated scientists. These sources of networking could also play a role in determining whether connections with Venezuela are maintained or not, given the network effects it produces, and the

attachments and connections that it generates. The question of how to develop social capital that facilitates the effective participation of migrated scientists in the country's reconstruction process corresponds more to what can be done when designing public policies that work at the second level of the independent subsystems mentioned above.

Figure 2. Forms of Social Capital and their Relation for the Achievement of Collective Action



Source: Based on Ostrom and Ahn (2003), Woolcock and Narayan (2000) and Gittell and Vidal (1998).

In this context, the work of Ostrom and Ahn (2003); Woolcock and Narayan (2000), and Gittell and Vidal (1998), take a broad stance in using the theory of collective action as a key organizing framework. These authors define social capital as “*an attribute of individuals and their relationships, which increases their ability to solve problems of collective action*” through the development of trust and standards of reciprocity between individuals, all forms of social capital contribute to trust and this, in turn, allows the achievement of collective action. (see Figure 2).

General patterns of emigrated researchers

This study uses the database BIBLIOS to analyze the production of knowledge from Venezuelan researchers living in Venezuela and those that have emigrated. BIBLIOS³ is a database that compiles the bibliographic information of almost all research works done in Venezuela and published in local or foreign academic peer-reviewed journals of significance from 1893 up to date. Entries in BIBLIOS comprises publications as journal articles or reviews, patents, proceedings of professional (but excludes abstracts and summary documents). Many of its registered publications are indexed in global databases such as Web of Science of Thompson-Reuters' Institute for Scientific Information (WoS/ISI) or PubMed (life and biomedical sciences database of the US National Library of Medicine of the National Institutes of Health, NIH) or Scielo (database of the Scientific Electronic Library Online). Overall, until year 2018, BIBLIOS comprises 230,638 entries for 71,798 unique publications by 69,346 researchers, of which 46,007 are recorded as Venezuelan nationals. BIBLIOS also includes, in an auxiliary database, background information of researchers such as date of birth, identification number, gender, nationality, academic affiliation(s), level of higher education⁴, and discipline according to the UNESCO coding system⁵. Basic demographic characteristics, such as age, sex, and educational attainment, researchers' discipline, and system type (institutional workplace) is presented in Table A1 in Appendix 1.

The unit of observation in BIBLIOS is the publication. For our purposes, we translate this to researcher-level unit of observation. This change means that researchers will appear in a year as many times as they publish in that particular year. In BIBLIOS, for a given paper, each coauthor is given the same weight in the realm of authorship by a distinct entry in the database. Because of this the study does not intend to identify the actual research-level responsibility per author. Despite the differences across disciplines in the rules behind authors' names ordering, given the data

³ BIBLIOS is administered and maintained by Jaime Requena.

⁴ Information mostly derived from various sources. The first source comes from the late "Programa de Promoción del Investigador" (PPI) researcher-submitted resumes that were once available online and now kept in the files of one of us (JR, manager of BIBLIOS database). The second source comes from the 1983 national census of researchers conducted by CONICIT. Third, CV of researchers posted online, researcher-level communications and few personal communications. BIBLIOS has been used to characterize the Venezuelan research community by different components. For instance, gender at the university (Caputo, Vargas and Requena, 2016), gender in science (Requena, Vargas and Caputo, 2016), dynamics of the national science and technology system (Requena, 2005), descriptions of the biological community (Caputo, Requena and Vargas, 2012) or the health community (Requena, Caputo, Apitz, Soyano and Vargas, 2018).

⁵ The UNESCO code is a six-digit numeration that describes the domain and knowledge specialties. The first two digits correspond to the overall scientific (STEM) and humanistic areas.

limitation regarding the identification of this ordering, an equal level of authorship across researchers was assumed.

The terms “researcher” or “author” include scientific or humanistic professionals (as used in Spanish for “*investigadores*”) working in a university (university teaching staff or scholar), as well as those working for a health system hospital or a public research institutions⁶ with or without teaching load. It also includes researchers working for a private enterprise or by their own, that has published something that is registered in BIBLIOS. Thus, BIBLIOS does not register information about professionals that qualify themselves as researchers but who have not authored a publication that is recorded in BIBLIOS. Hence, the nature of the dataset used in this study is not purely longitudinal, and because of this limitation, the data source is treated herein as pooling cross-sections.

Despite its richness, BIBLIOS goal is not to represent the population of researchers in the country. Given the sources that generated BIBLIOS (see note #4), the sample has a more accurate representation of researchers in biomedical and STEM-related fields than in social sciences. This discipline-specific possible source of bias in the analysis conditions the work at the discipline level. Nevertheless, the dynamics of the research community is still valid when the source of measurement errors is not due to time-related omissions nor the specific individual’s performance level.

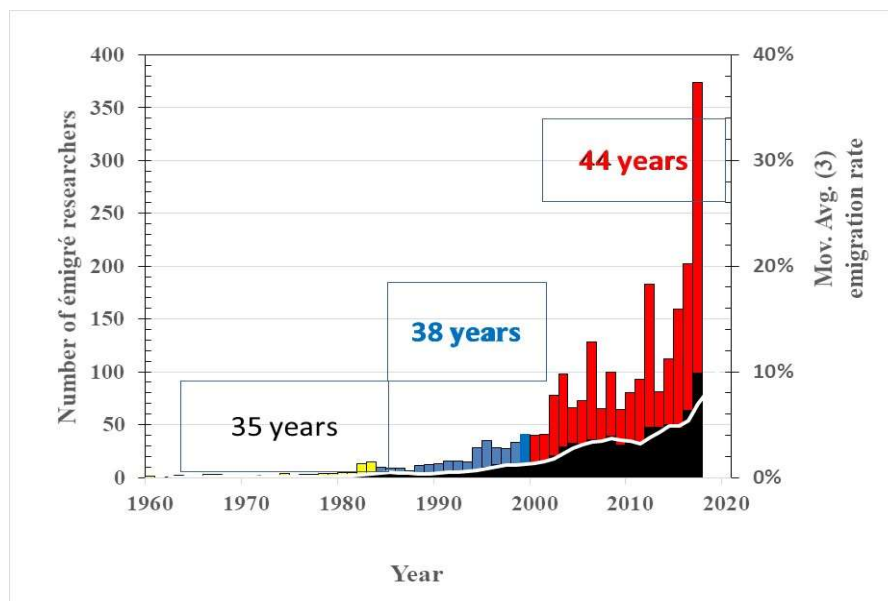
Who migrates. *General Characteristics:*⁷

Our attention is focused on Venezuelan researchers publishing from 1960 to 2018 as recorded in the BIBLIOS database, the number of Venezuelan researchers that have non-emigrated in the chosen period accordingly to BIBLIOS is 29,844, while the number of Venezuelan researchers that have migrated between 1960 up to 2018 is 2,235.

⁶ In energy - INTEVEP, in agribusiness - INIA, in technology - FII or in basic sciences -IVIC or IDEA.

⁷ See Tables 1-6 on Appendix 3 for the specific results from the Survey analysis.

Figure 3. Historical series for absolute number (left ordinate, colored bars) of Venezuelan emigres and relative trend (right ordinate, black bars)



Source: BIBLIOS database and authors' calculations.

Figure 3 depicts the historical series of the absolute number of Venezuelan researchers migrating (left ordinate, colored bars) and the moving average (3 years) of the internal rate of migration, and its trendline, from 1960 up to the year 2018. It shows that up to the end of the century, the absolute number of emigres, year after year, was small. Contrarily, for the last 18 years, the number of emigres escalated to larger figures, 2.084 scientists, representing 85% of all accounted emigres, which ought to be contrasted with the corresponding figure calculated between the years 1960 and 1983, and which barely reached 2% of all emigres. The migration data, when expressed as the moving average (3 years) of the internal relative rate of migration (right ordinate, black bars and white dots trendline), shows that up to 1994, emigration rate was small in magnitude and relatively stable (less than 1%). After 1994, the rate started to grow until it reached 4% by 2008. From then and up to nowadays, the emigration rate spiked out of control, particularly in the last 3 years.

According to BIBLIOS, the group of migrated researchers from 1960 to 2018 constitutes a sizable part (16%) of the academic research community of the country. They are responsible for the production of roughly one-quarter of all academic publications registered in Venezuela. The

loss of talents has affected all academic institutions in the country, but especially the autonomous public universities that manage the production of 80% of research work undertaken in Venezuela. While the loss of talent is similar in magnitude for all fields of knowledge, the group of émigrés engaged in bio-health or energy/petroleum research stands out.

A complementary approach aimed to explore the collaboration between emigrated and non-emigrated researchers and their motivations to migrate was carried out with an *ad hoc* survey. For this survey, the response rate of Venezuelan researchers abroad was higher than the response rate of Venezuelan researchers in Venezuela. One potential reason for this was the loss of contact of BIBIOS database of emails⁸ of its listed authors given the fact that most of the Venezuelan electronic institutional contacts emails have ceased to be valid.

The analysis of the answers of survey respondents among those who migrated shows that most respondents migrated after 2014, (60%), while 21% of them migrated between 2006 and 2013, and only 19% left Venezuela before 2005 (see data in Appendix 3, Table A3.1). The pattern indicates that migration has lately dramatically increased over time, and it is similar to that observed from BIBLIOS data. In terms of destinations, about a quarter of researchers in the survey migrated to North America (the U.S. and Canada), slightly more than half are currently residing in Latin America, and one fifth are living in Europe (see Appendix 3, Table A3.1). Destination regions have also changed over time. A statistically significant larger number of researchers who migrated before 2005, went to North America and Europe instead of going to Latin America. During the period between 2006 and 2013, there are not important differences regarding the destination regions. However, after 2014 Latin America became the main destination region for researchers.

Concerning, age, most migrated researchers that responded to the survey tend to be older than migrated authors: an average age of 43.8 years for authors in Venezuela and 41.7 years for migrated authors (see Appendix 3, Table A3.2). Researchers who migrated to Latin America, not only are migrating later but are also younger than researchers currently living in North America and Europe, where a higher percentage is over 60 years old. In North America, on the other hand, there seem to be two main groups regarding age, about 40% who are under 50 years old, and 47%

⁸ The survey was submitted to a sub-set of the BIBLIOS database registered researchers, valid as update or comparative purposes.

that are over 60 years old. In contrast, most who emigrated to Europe are over 50 years old. This age pattern is similar to the BIBLIOS estimations ((Figure 3) with an average value of 38.5 years for the migrated Venezuela researcher.

Most emigrated respondents used to work in Venezuela as researchers (67.5%) or teaching (51%), and most of them were working on Universities (81%). Of this last group, 91% for non-migrated remains in university posts in Venezuela, while 68% of the migrated group work now in a university post abroad. Most of the migrated researchers are practicing their professions (81.4%). The distribution of maximum grade is biased towards authors with Doctorate (86% of respondents). In the survey, the share of authors with Doctorate is higher for emigrated authors; 93% of the emigrated authors have a Doctorate, while non-emigrated authors with Doctorate represents 72.6%. This data is similar to BIBLIOS, although, in BIBLIOS, these shares are significantly smaller; 28% for the total sample of researchers, 18.8% for authors in Venezuela, and 31.5% for emigrated authors. By the time they migrated, only 27.3% of the migrated researchers had a post-doctorate, but, nowadays, the percentage of migrated researchers with a Postdoctoral degree has increased to 32.7%).

Discrepancies in characteristics between the survey respondents and BIBLIOS researchers are mostly small. Most probably due to the tool used to connect to respondents (email). The initial sample was extracted from the BIBLIOS database, where individual emails were mostly connected to their professional life. Therefore, either we were more likely to find a connection with those who still practice or maintain their connections with their professional networks or, as stated above, lost contact because most of the Venezuelan electronic institutional emails have ceased to exist. Nevertheless, any bias arising from the survey answers would come from the likelihood of those still connected to their institutional emails are also the ones more connected to their networks and their professional research.

Why do researchers migrate?

While the main reasons that trigger migration for the majority of emigrated researchers in the survey are work and family and, to a lesser extent, poor local (Venezuelan) economic reasons or psychological health reasons (emotional stress), the relative importance of these reasons have changed over time (see Appendix 3 Table A3.3). Indeed, work and political factors have recently lost importance; for those who migrated before 2006, work represented by far the main reason to

leave Venezuela, whereas, for those who migrated between 2014 and 2018, there is a statistically significant drop of this factor as a reason to migrate to only (with a total drop of 24 percentage points). On the other hand, economic factors have increased significantly between 2014 and 2018 compared with previous periods (with a total gain of 20 percentage points). A similar trend is found with family reasons as a driver of migration since the percentage of migrated researchers who mentioned as a reason that triggered their decision to migrate before 2005 was significantly smaller than the same percentage found among those who migrated between 2014 and 2018 (with a total gain of 9 percentage points).

In the qualitative approach, the *reasons to emigrate* were explored in-depth, and three general components were found: (a) the limiting conditions of life; (b) obstacles and provisions for professional development and; (c) political situation.

The *limiting conditions of life* is understood as a set of factors that do not meet the minimum requirements for people's survival, denoted by economic limitations, physical insecurity, detriment to the quality of life, lack of medical care, and/or medicines, and socio-economic crisis. *Obstacles and provisions for professional development* refers to both impediments and limitations that affect the stagnation of professional practice, as well as individual strengths and opportunities for the achievement of professional development. For *Political situation*, informants defined that category as a series of adverse government situations that affect the population, summarized in government events and actions that adversely affect daily life.

We note that qualified and unqualified migrants (such as the profile of interviewees) found economic and labor reasons (60%), shortage of medicines (25%), insecurity and violence (12%) political persecution, crisis and others (3%),⁹ coincided with the comments of the informants whose variety of reasons for migrating were called living-limiting conditions and congregate the limitations and deficiencies perceived by them in economic and social aspects (See appendix 4, Tables A4.1 and A4.2).

Life after migration.

Just under half of the migrated researchers have links with research or academic institutions in Venezuela. Furthermore, this percentage increases among those who have migrated more

⁹ These categories are similar to the determinants of the migration crisis mentioned by Marotta (2019).

recently, in comparison with those who left the country in earlier years (with a difference of 20.2 percentage points). (See Appendix 3 Table A3.4). Almost all of those who are still in contact with Venezuelan research or academic institutions have contact with former colleagues and collaborate with them on research activities (95.5%).

Among those who migrated, 43.1% were affiliated to the Venezuelan Association for the Advancement of Science AsoVAC¹⁰ before migrating, being the institution that joined more migrated researchers. As we saw earlier, almost all those who maintain links with the research or Venezuelan academic institutions currently collaborate with non-emigrated researchers. In this sense, it is important to mention that 92.3% of migrated researchers said they were interested in being in contact with AsoVAC, whether they were affiliated or not before migrating.

The three most common drivers for emigrated researchers to collaborate with non-emigrated researchers are to gain more prestige and visibility, to have access to equipment and instruments, and to increase their academic productivity. Besides, mobility is the less frequent potential reasons to collaborate for migrated researchers. For the group of non-emigrated researchers, mobility and visibility are the most frequently mentioned reasons to collaborate with Venezuelan colleagues abroad, which are significantly higher than other reasons, particularly increasing academic productivity. Among those migrated researchers who are collaborating with non-migrated researchers, the most common activity they do is to publish together and work together on joint research projects (See Appendix 3 Table A3.5).

Productivity

The analysis concentrates on the productivity of knowledge done by Venezuelan researchers either in Venezuelan soil or in a foreign country after migrating. Indicators of productivity and networks are created (and transformed) using the information from BIBLIOS to identify the composition of the research publication stock and the collaboration among Venezuelan researchers with Venezuelan and foreign researchers. The originality of the data source allows us to follow individual researchers to the extent of their yearly publication consistency.

¹⁰ AsoVAC is the acronym for the ‘Asociación Venezolana para el Avance de la Ciencia’, is an organization made up mainly of scientists and professionals united in the performance of promoting the progress of scientific research and its applications in Venezuela.

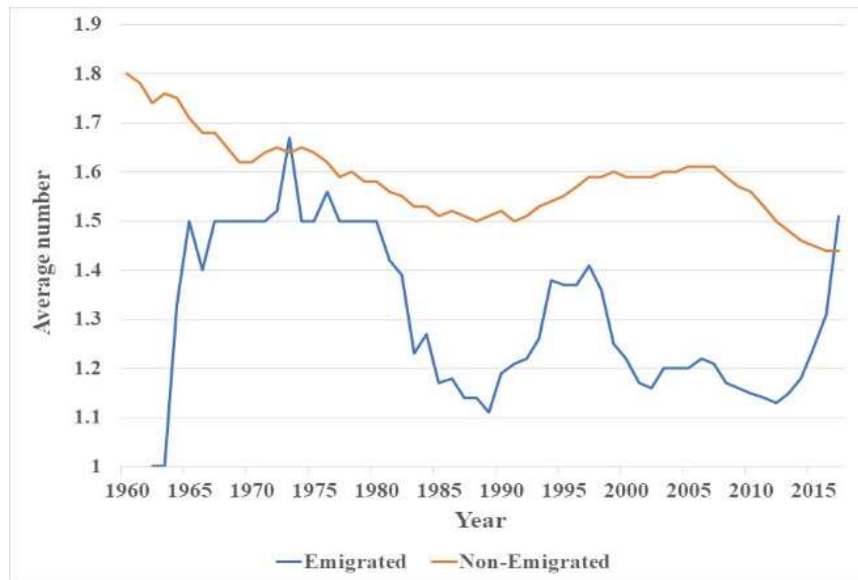
It is pertinent to define the main productivity variables before entering a more detailed discussion of their distributions and trends. The number of publications is used to design a series of indicators that proxy for a researcher's productivity. There are six key indicators of productivity evaluated in this research:

- 1) the average number of published articles per year per author;
- 2) the share of high quality (HQ) of publications per year per author;
- 3) the share of publications in national journals'
- 4) the share publications in high quality (HQ) national journals;
- 5) the share of publications in foreign journals, and;
- 6) the share of publications in high quality (HQ) foreign journals.

These different definitions intend to disentangle quantity versus quality in the productivity level of each researcher. It is understood that these indicators have limitations. For example, our quality measure is proxied by whether the journal where the research is published is indexed. The journals' indexation process in and outside the country has changed across the years, especially in earlier years. Further, the quality, as here defined, only considers whether the journal is indexed or not, leaving out measures like impact factor and article's number of citations that are closer to the level of quality desirable to identify.

With this in mind, the study describes the characteristics of the Venezuelan researchers and the trends of the emigration rate of researchers to give context to the analysis. The basic demographic characteristics of the researchers, such as age, gender, and educational level, are also evaluated together with the researchers' discipline and institutional workplace. A clear picture of not only the characteristics of the Venezuelan researchers in Venezuela across the decades but also their productivity as measured by the average number and the quality of publications is provided.

Figure 4. Average Number of Publications. (Emigrated, blue; Non-emigrated, yellow)

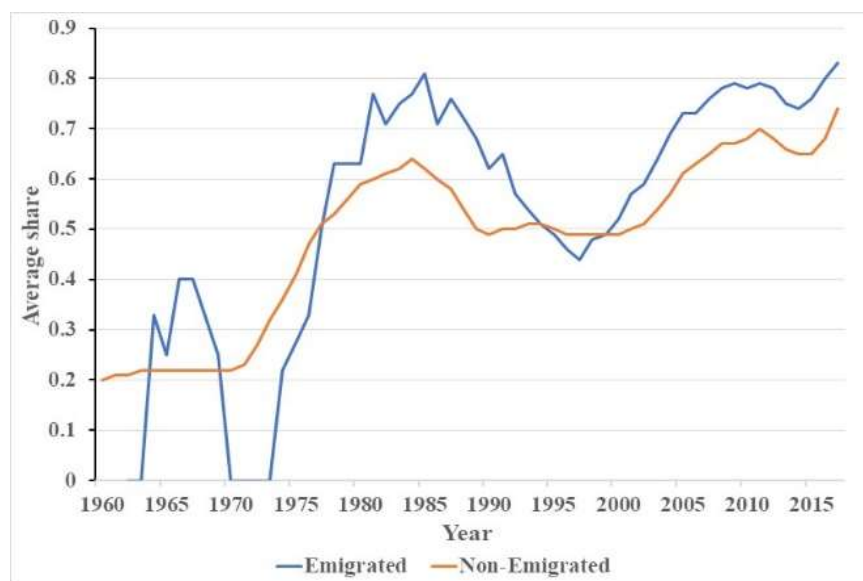


Source: BIBLIOS database and authors' calculations. 3-year moving average.

To study the production of knowledge within the research community, the production of research is estimated as an average of publications per year per author. Figure 4 shows the time series comparison on the productivity level of Venezuelan researchers who have and have not emigrated. The trend of the differences in productivity provides evidence of the productivity-level variability among emigrated researchers compared to never-emigrated counterparts. Some of this variation is due to changes in sample size and actual variation in productivity among researchers. The more telling comparison appears after 2010 when the emigration rate of researchers significantly increases. In particular, Figure 4 shows that the average number of publications per year becomes markedly higher for those Venezuelan researchers that have migrated.

Figure 5 depicts the historic series of the yearly average share of high quality' publications for those that have and those that have not emigrated. It shows a common increasing trend for both sets, although it is more pronounced for those authors that have migrated. For the figures described above, all Venezuelan researchers covered by BIBLIOS in and out of Venezuela were included with the purpose to identify the changes of researchers leaving the country across the years and the average productivity levels.

Figure 5. Average Share of High Quality' Publications per Year



Source: BIBLIOS database and authors' calculations. 3-year moving average.

The following descriptive analysis¹¹ uses BIBLIOS information on authors' characteristics and the features of their publications (coauthors, discipline, type of journal). Table 1 shows the unconditional distributions of the sample based on authors' characteristics, publications' characteristics, and collaborators' characteristics by decade and for the entire period. The age of the average Venezuelan researcher who published has been increasing over time, around 6.5 years when comparing the 1960s with 2010s. Given the cross-section nature of our sample, we are not able to disentangle the cohort and author's age trends. As authors become older, they are at a later time in their life-cycle productivity and, hence, more likely to have accumulated advantages such as more resources, recognitions, and institutional support. On the other hand, a reverse effect comes from the increase in the average age of Ph.D. awardees (Jones, 2005). The average number of publications across the time series is 1.30 per year per author. When compared with similar

¹¹ The total number of observations is 71,798 since we use the entire BIBLIOS dataset to design the indicators referring to coauthors' relevant characteristics such as having migrated, nativity, and discipline.

nature studies¹², this average is relatively high because, by design, we are only considering researchers who publish at least one paper in their lifetime (to be captured by BIBLIOS)

Over the years, the average number of publications has declined, while the quality of those publications has increased (this is true for publications in both national and international journals). The overall share of publications of high quality (in indexed journals) is around 60 percent, which is in line with other Latin American countries¹³. Part of these trends in quality could be due to simple changes in academic journals' indexation process rather than the result of an increase in publications in already indexed journals. However, the indexation process of any journal not previously indexed is also expected to increase its overall quality, since journals by applying key standards for their indexation can increase the reach and impact of their publications. During the same period, the share of papers published in international journals has increased, while the share of foreign coauthors has decreased. This increase could be responding to the expanded research financing policies that were put in place in Venezuela during the 1970s that required the publication of research in HQ journals as well as the large government-sponsored scholarship program to finance studies of Venezuelan researchers abroad implemented by public universities, CONICIT, IVIC and "Fundayacucho".

In addition to creating productivity measures per researcher, research networks indicators at the level of publication per author were constructed. With information about all coauthors per publication, we build the indicators of the share of coauthors who are foreign per publication, the share of coauthors with ever-migrated (*i.e.*, coauthors who at some point in our time series emigrated), the share of Venezuelan coauthors who migrated at the time of publication (Share of Emigrant Venezuelan Coauthor), the share of coauthors from other disciplines (at the 2-digit UNESCO code). The share of coauthors that have ever-emigrated is increasing. The slow upward trend could show that those who have ever-migrated have been researchers who have already published in earlier decades. If we compare this indicator with the share of emigrant Venezuelan

¹² See Gonzalez-Brambila and Veloso (2007) for a study on researchers' productivity in Mexico.

¹³ Vélez-Cuartas, Lucio-Arias and Leydesdorff (2016) show that authors from Latin America and the Caribbean (LAC) tend to publish in regional and local journals. They mention the case of Brazil, which accounts for half of the scientific output of the LAC region in the Science Citation Index publishes approximately 40% of its scientific production outside the Core Collection of the Web of Science. In addition, they also mention the increasing trend on indexation of LAC-edited journals, by their inclusion in Thomson Reuter's and Elsevier's main indexing services (WoS and Scopus).

coauthor, we notice that by the 2010s, the rate of these coauthors has doubled from 1% to 2%. Although small, this share is reflecting the large exodus of researchers after 2014. Meanwhile, the interdisciplinary collaboration (measured by the share of coauthors of other disciplines) has increased, although it has flattened since the decade of the 2000s.

Econometric approach.

At the micro-level, the relationship between the performance of the published researcher and the change in the proportion of coauthors who have emigrated at the time of publication could represent a more direct evaluation of how local researchers in Venezuela see their work impacted by the emigration of coauthors. Because there are components at the individual level that can impact publication trends such as affiliation, discipline, and general individual characteristics, we need a multivariate approach to account for these other relevant elements. Further, we need to account for general macroeconomic conditions that impact the access to resources for research.

Equation 1 shows the baseline model we evaluate:

$$PUB_{it} = \beta_0 + \beta_1 E_{it} + \beta_2 X_{it} + \beta_3 P_{it} + \beta_4 V_t + t + \varepsilon_{it} \quad \text{Equation 1}$$

where i stands for individual author and t time. E represents the emigration indicator(s) we would use. For the first exercise, we will use the share of coauthors who *migrated at the time of publication*. Then, we would add the variable share of coauthors who *migrated at any time* in our period. The first exercise considers a more dynamic setup where coauthors time of departure is compared to the time of the publication. The share that considers the coauthors that *migrated at any time*, looks at the static condition of whether at coauthor left at any point in time. This captures the long run selectivity of researchers preparing their research portfolio to migrate at some point in the future. We cannot identify return migration. Hence, for all authors, once they migrate, we assume that they never return. X is a vector of time-variant individual characteristics such as age and education attainment at time t , and P is a vector of time-variant individual professional characteristics such as type of affiliation, the share of Venezuelan coauthors, the share of non-discipline coauthors, and discipline (2-digit code). V is a vector that contains country-level variables such as the emigration rate of scientists from other disciplines and the real change of the GDP using national-accounts growth rates, for studies comparing (output-based) growth rates

across countries). t is a time fixed-effect component, while ε_{it} represent robust error terms clustered at 2-digit discipline level¹⁴.

A variant of Equation 1 includes the variable Share of Emigrant Coauthors (coauthors who have migrated by the time of publication). The inclusion of this variable accounts for the researchers who have a long-term string of productivity and, hence, are more likely to migrate given the significant and common positive selection among highly skilled emigration (Iredale 2002; Davenport, 2004; Hunter Oswald and Charlton, 2009; Docquier and Rapport, 2009; Constant and D'Agosto, 2010; Edler, Fier and Grimpe 2011). A total of 9 different models, with 3 different definitions of researcher's productivity (PUBit) and 3 different ways of identifying the type of coauthor migrating at the time of the publication relative to all coauthors, were evaluated accordingly to formulas defined in Appendix 5. The definitions of productivity are:

1. The average number of publications per year;
2. The share of publications identified as high quality;
3. The average impact factor of publications per year.

The type of coauthor migrating at the time of the publication relative to all coauthors are:

- a. Any Migrated Coauthor;
- b. Max. Seniority/Productive;
- c. Coauthor's Migration Destination.

The estimation of Equation 1, and its variant, is highly informative. However, it falls short in being an estimation of the direct impact of coauthor emigration on researchers' performance. For once, emigration and publication decisions are both strategic and time-sensitive processes. The impact of a recent emigration among a professional network could impact this network in two different ways. First, it could increase the publications that are international and better quality because the emigrant researcher has been strategically targeting more prestigious journals to build a better international research profile. Further, this strategy, either intentional or unintentional, due to only having the year of publication and year of emigration for those individuals who published,

¹⁴ In the appendix, we show the results without clustering the errors, but with robust standard errors. We consider that it is still important to see at the two results because the reasoning behind clustering the errors in our exercise is more explorative than theoretical. The sample design of the data was not specifically designed in a clustered way. Further, the clustering approach that we usually see in traditional labor economics literature may not apply to our study (Leahey, Beckman, Stanko 2017). Our theoretical guess here is that researchers' migration patterns are likely to be clustered at the discipline level due to the underline migration incentives of specific skills in destination countries. Then, this would likely correlate with the productivity of local Venezuelan researchers.

it cannot be exactly estimated the timing component of the research process and the pre-emigration performance of each individual. Second, the impact can also be negative if the emigrant coauthors were the engine force of the stream of a research portfolio and their leaving creates a cold stop of the research dynamic. To account for the differences between long-term versus short-term decision strategies the share of coauthors who at some point in the time series emigrated and the share of coauthors who emigrated at the time of publication was included. Incorporating these two indicators differentiates those coauthors who built a research portfolio and emigrated at some point later in life versus those who have recently emigrated.

The analysis intends to shed some light on the relationship between the productivity performance of researchers in Venezuela and a series of indicators capturing the role of their collaboration networks, in particular those with emigrated Venezuelan researchers. The present approach intends to identify direct and indirect relationships between the emigration of researchers and individual's research productivity by not only using the link between the researcher and coauthors who have emigrated (what we called "ever-migrated" coauthor) but also a timely effect of the recent emigration of a coauthor (what we called "emigrant" coauthor) and the rate of emigration of researchers from other disciplines. These different measures are unique to our data source because we can identify these networks through the characteristics of researchers' coauthors. We also consider a diverse way of accounting for the migration of the type of coauthor to account for the heterogeneity in the level of productivity impact due to coauthor's 'quality'.

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Table 2 shows the main results from Equation 1 with different measures of researcher's productivity: the average number of papers (# Papers), percentage of high-quality papers (% HQ Papers), and average journal impact factor (IF); and different ways of identifying the type of coauthor migrating at the time of the publication relative to all coauthors: any migrated coauthor, migrated coauthors with maximum average impact factor (Max. Seniority/Productivity), and coauthor's migration destination. After accounting for individual's characteristics, real GDP, year, institutional sector, 2-digit discipline fixed-effects, and clustered errors, a 10% increase in the share of any-quality coauthors that migrated at the time of publication does not significantly relate to a change in the number of papers nor the average impact factor (columns 1 and 3) statistically speaking, but it does relate to an increase in the quality of the papers published by researchers living in Venezuela by 1.49 percentage points (column 2). If we compare these results to the case where the coauthors migrating at publication are those with the maximum impact factor, the impact is ten times larger in the average number of papers and significant (column 4), but we don't find statistically significant evidence of an impact on quality nor impact factor (columns 5 and 6).

Looking at the same Table 2, when we focus on the coauthors' destination, researchers with coauthors emigrating to North America and Europe show an increase in the average quality of their papers but not on their average impact factor in the case of those moving to North America, while we see an increase in both measures of quality (% HQ papers and IF) in the case of coauthors moving to Europe. However, for those with coauthors emigrating to North America, we see a reduction in the number of papers. The differences in the dynamic of knowledge production between these groups seem to reflect these results. Even with the lack of statistically significant changes, there is a consistency in the sign of the relation that when a coauthor leaves the number of papers to decrease, but the quality of the papers produced increases. Interestingly, researchers with coauthors emigrating to other Latin American countries show no changes in their productivity measures, and this is the only result different from the other destinations. Part of the story behind the evidence is that paper quality is related to having a productive coauthor leaving to 'more productive' regions. However, if the coauthor migrating is the most productive, there is no

evidence of this ‘benefit’. This could be due to a break in the professional network between the Venezuelan researchers and the migrated researchers with the highest impact factors.¹⁵

From Table 2, the coefficient of the migration rate of researchers outside their discipline could show a unique separate relationship with knowledge productivity. The emigration rate outside their discipline could represent a proxy for the state of the research community overall that is not necessarily directly related to the field of affiliation of the researcher. However, the results do not provide evidence of the shift that happens in the scientific community when there is an exodus of researchers that are in the transition from domestic production to international production.

The role of other forms of academic or scientific collaborations on Venezuelan researchers’ productivity was also explored. First, the results in Table 2 show that the share of Venezuelan coauthors is positively related to the average number of papers (columns 1, 4, and 7), but negatively associated with the quality of those publications (column 2,3, 5,6, 8, and 9). This is consistent across all measures of productivity.

Although the significance of the results varies, it seems that having a coauthor migrating at the time of publication is related to a re-composition of the publication portfolio of researchers in Venezuela, by reducing the number of publications (if most productive coauthor leaves or coauthors depart to North America or Other destinations) but concentrating in higher quality work (for most destinations). These differences in the relations could have other underlying mechanisms that we are not exploring in this version of the analysis. The different measures of productivity and the different levels of coauthor migration could be representing the existing diversity behind research and productivity strategies, networks, and connectivity among researchers.

As noted, previous results do not identify the strategy a researcher could use to find high-performance coauthors versus high-performance coauthors (likely to emigrate) finding coauthors who are also highly productive (reverse effect due to double matching). Therefore, our results are not the direct impact of coauthors’ migration, but a relationship between local researchers’

¹⁵ In the appendix, we show the results for the productivity measures distinguishing origin of the journal (national versus foreign) and quality. It appears that the negative relationship with the number of publications is coming from papers on national journals with a reduction on the average number of papers in national journals since the average number of publications on international journal has a positive relationship with the average number of publications in international journals. The positive effect on the quality of the publications cannot be distinguished from the type of publications since for both types of publications, either national or foreign, the effect is not statistically significant.

productivity and coauthors' migration. Despite this limitation, it is interesting that there is a focus on high-quality journals (by being indexed, but not for their IF) when there is a higher share of coauthors migrating at the time of the publication. This is consistent with Gibson and McKenzie (2014)'s findings on the selection of migration among top performance researchers. This selection is exacerbated by return migration because of the likelihood that those returning are likely to be the least productive among the top performers (Roth and Saarela, 2007).

In this analysis, we can explore an alternative explanation. For instance, the emigration of coauthors could incentivize the productivity of those staying in Venezuela but who are also considering emigrate or becoming more competitive internationally. When top performers leave, the network between the emigrant and the locals could strengthen because of that future perspective the locals have about future prospective emigration. Given the structure of the data, we can identify who has migrated at any future time. We call Ever-migrated researchers those researchers who migrated at any time during the data's timeframe. This variable intends to capture the future perspective of the researcher that eventually materialized. Notice that this variable only identifies those who migrate at some point in the future, and not who have intentions to migrate at any other point outside our time frame. Despite this limitation, this variable makes a better case for identifying the strategy of boosting productivity today to increase migration opportunities in the future. It also accounts for some level of selectivity among those who migrate.

Table 3 is similar to Table 2 in all the regressions specifications, but instead of only analyzing the role of coauthors emigrating at the time of the publication, it adds a regressor measuring the share of coauthors who Ever-Migrate in our sample period. That is, authors in a paper are now divided into those who, in our sample period, never migrate, migrated at-year-of-publication, and migrated after publication (ever-migrated). Therefore, the table shows the results of the modified version of Equation 1 that includes all the regressors considered before plus the one that identifies the share of Ever-migrated coauthors. As noted, this version intends to identify whether there are different relational outcomes for Venezuelan researchers having a coauthor that migrates either recently or at some point in the period of analysis.

From the result, we can show that, in fact, there are important differences in the relationships between collaborating with coauthors that migrate in the short term and later in the period—in particular, working with a coauthor Ever-migrated, increases the number and the quality of the papers published by researchers living in Venezuela (columns 1,2 and 3

respectively). So, it seems that having an ever-migrated coauthor increases the performance of researchers in Venezuela related to their publications in high impact journals. The Venezuelan researchers that work with individuals that emigrate at some point in time might get to publish internationally as a strategy for strengthening the ever-emigrant' research profile or they get to work with ever-emigrants that are building their research profile with an international lens.

Contrary, if the coauthor has recently emigrated (Emigrant coauthors), there is a negative relationship between average publication and the quality of those publications (columns 1,2, and 3 respectively). This indicates that keeping the share of Ever-migrated coauthors constant, the departure of coauthors will indeed relate to a decrease in knowledge productivity and quality of what is produced. The increase we saw in Table 2 is coming from the share of coauthors who end up emigrating at some point after publication, either because of their future plans or because they are also the most productive, they increase productivity and quality of the work published. In a hypothetical case where we have only one author leaving at the time of publication, and the rest never emigrating, there is a decrease in the number of publication of -0.02, a decline in the share of high-quality publications of -1.9 percentage points, and a reduction in the average impact factor of -0.06 points. These reductions are more sizeable than what we found before. Notice that the size of the impact is still significant when the top researcher departs at the time of the publication if we account for the share of the Ever-migrated coauthors. However, the share of top Ever-migrated coauthors negatively correlates to the number of papers, identifying top researchers with the strategic behavior of publishing a lower number of papers at better-placed journals. The pattern of quality productivity replicates to the case of emigrant coauthors' destinations. Yet, now that we separate the groups of coauthors into these definitions, the share of Ever-migrated coauthors emigrating to Latin America has a positive and statistically significant relationship with the quality of the papers. Meanwhile, the departure of coauthors at the time of publication relates to a reduction in these measures. Our previous results were not separating these two effects. Finally, not shown in Table 3, the relationships for the other regressors are the same as those found in Table 2, which demonstrates that the relationship of the new component of the share of the new emigrant coauthor relates principally through the short-term event of publications' production.

Table 1. Summary Statistics -Venezuelan Researchers' Characteristics and Publications

CONDITION (as Average per decade)	1960s	1970s	1980s	1990s	2000s	2010s	ALL
Age	37.67	36.61	38.29	41.12	42.11	44.21	41.62
Number of publications	1.40	1.34	1.29	1.34	1.32	1.25	1.30
Share of HQ publications	0.192	0.458	0.495	0.426	0.579	0.681	0.551
Average Impact Factor (IF)	0.685	0.933	1.012	0.987	0.864	0.773	0.878
Share of Emigrant Coauthor	0.003	0.002	0.004	0.007	0.011	0.024	0.012
Share of Ever-migrated Coauthors	0.020	0.044	0.075	0.086	0.088	0.072	0.077
Share of Emigrant Coauthor Max. IF	0.002	0.001	0.003	0.004	0.007	0.013	0.007
Share of Ever-migrated Coauthor Max. IF	0.025	0.046	0.075	0.073	0.066	0.047	0.060
Share of Emigrant coauthor to North America	0.001	0.001	0.003	0.004	0.005	0.006	0.004
Share of Emigrant coauthor to Europe	0.001	0.000	0.001	0.002	0.004	0.006	0.003
Share of Emigrant coauthor to Latin America	0.001	0.001	0.000	0.001	0.001	0.011	0.004
Share of Emigrant coauthor to Other	0.000	0.000	0.000	0.000	0.001	0.001	0.001
Share of Ever-migrated coauthor to North America	0.006	0.022	0.036	0.038	0.028	0.018	0.027
Share of Ever-migrated coauthor to Europe	0.012	0.015	0.023	0.023	0.023	0.016	0.020
Share of Ever-migrated coauthor to Latin America	0.002	0.007	0.013	0.020	0.032	0.035	0.026
Share of Ever-migrated coauthor to Other	0.000	0.000	0.002	0.004	0.004	0.003	0.003
Share of Foreign Coauthors	0.425	0.346	0.294	0.237	0.202	0.218	0.239
Share of other-disciplines Coauthors (2-digit code)	0.055	0.079	0.097	0.118	0.106	0.099	0.102
Emigration Rate (other disciplines)	0.005	0.004	0.011	0.014	0.020	0.044	0.023
GDP growth rate	-0.011	0.029	-0.015	-0.016	0.072	0.002	0.020
Total	861	1,924	3,288	5,721	9,376	8,674	29,844

Source: BIBLIOS (1960-2018) of Venezuelan researchers who have not migrated at the time of the year-publication. Author's calculations. HQ stands for authors' definition of high-quality journals: journal indexed by WoS/ISI publication & Uspto.

Final considerations: *policy implications*

The international mobilization of scientists is one of the imperatives of science. Scientists tend to migrate as part of their idiosyncrasy because knowledge is an individual-managed capital. However, an important part that triggers the migration of scientists in our midst is in the internal conditions of Latin American societies, where economic, political, and social problems entail conditions unsuitable for the performance of these scientists. The various policies/efforts to mitigate the problem of the migration of scientists in Latin America have generated an interesting background of experiences (little studied and with little statistics), possibly because the expectations did not match the goals achieved, but revealing of how these policies have evolved from the vision of considering this population of talent abroad as a loss, to the vision of needing to integrate it in terms of diaspora as an asset of the country.

Efforts to mitigate talent migration have been focused on the national dimension. Little or no consideration has been given to the regional context, or to the global context in which they take place, (Scellato, Franzoni, and Stephan, 2015). There have been at least nine programs in eight Latin American countries aimed at either repatriation or funding of collaborative projects with migrated professionals.

1.- Repatriation: it includes everything from legislation to return programs, with tax incentives, dispensations, and transfer payments, among others: this is the case of Argentina, Colombia, Peru, Chile, Uruguay, Mexico (Barreiro Díaz, 1997; Chaparro, Jaramillo and Quintero, 2014; Chiancone, 1996; Gerard and Grediaga Kuri, 2009; Luchilo, 2007; Marmolejo, 2009; PAR, 2008; Pellegrino, 2003); accompanied by re-entry or reintegration grants in scientific institutions or companies requiring such staff (Argentina, Peru, Uruguay; Vid. Barreiro Díaz, 1997; García de Fanelli 2008. PAR, 2008);

2.- Retention: creating systems of recognition and giving economic incentives to the researchers of the country, improvement of working conditions, as well as fellows abroad, and possibly ensuring their insertion into the occupational system of the country. The processes related to mobility and internationalization of science will also be included here others related to the effort to “retain” it, through programs of economic incentives and recognitions, as has happened in Argentina, Mexico, Venezuela and Uruguay¹⁶ (Aboites and Diaz, 2016; García de Fanelli, 2008;

¹⁶ (CONICET Researcher Career, National Research System (SNI), Investigator Promotion System (SPI), Uruguay retains).

Marmolejo, 2009; PAR, 2008); or creation of working conditions that stimulate return/retention (Brazil. Vid. Baeninger, 2002; Garcia, 2005);

3.- Linking: it is based primarily on the organization of groups abroad with some national counterpart, insertion into the system of recognition of the country, national funds, joint research with groups in the country and participation in teaching tasks and training of human resources, internships or participation in business innovation projects. All of the above is strongly supported by ICT developments. other modalities have been the “creation of links” between national peers and graduates in cooperative projects (Argentina, Mexico, Colombia, Vid. Angulo Pico, 2016; Chaparro et al, 2014; Garcia, 2014; López 2016; OIM, 2016), tutoring and internships for staff training; linking with companies, ventures and businesses (Mexico, Argentina, Uruguay, Chile, Vid. Aboites and Diaz, 2016; López 2016; OIM, 2016).

4.- Finally, some countries applied so-called “scientific diplomacy”, for example, Argentina, Brazil, and Colombia (Chaparro et al, 2014; OIM, 2016; Muntaner, 2017, Pulido, 2018).

These four measures do not always set up a stable public policy or give rise to a specific program, as in the case of Roots in Argentina (Garcia de Fanelli, 2008; López, 2016) Red Global MX in Mexico (Tigau, Pande, and Yan, 2017), or to activities that are maintained over time, since they may change according to the interests of the government of both the country of origin and the migrant participants or mediatic constructs (Tigau, 2013) rather than on evidence-based policies, Therefore, no panaceas have been found so far to ameliorate the perceived damages or benefit for the country of origin regarding the scientific diasporas, and only anecdotal successes have been explored. Our previous results provide more formal explorative evidence on the relation of researchers’ migration patterns and local production of knowledge by local researchers. The migration of coauthors on local groups relates to a loss in quality of production if no local researcher migrates in any future period (doesn’t have a plan to migrate). These may offer the preliminary evidence that without that link-local researchers may be losing the connectivity with those coauthors leaving and, so, losing the human capital accumulated up to that point. The bridge between migrated researchers and local researchers relies on the ‘ever-migrated’ who are likely to have the incentives to maintain connections and quality productivity to compete internationally.

Initiatives to mitigate migration in the countries that undertook such efforts are characterized by the guiding and fundamental role of the State¹⁷ as a driver and support of policies and activities; therefore, such initiatives are an expression of a political will that would have a strong concreteness in their financing. Although there have been other actors, such as universities and scientific societies, the main beneficiaries of those policies, with a much lower degree of participation, as well as almost absolute absence of the private productive sector.

The main results achieved by these countries policies are the following:

- a) The achievements of repatriation efforts have been limited; but in some cases, it allowed the reconstruction of the scientific system (Uruguay) and it has helped revitalize activity in others. However, poor macroeconomic performance has influenced the re-emerging of migration.
- b) The generation of Social Capital by organization in nodes of expatriate researchers in the receiving countries, as part of the networks organized from the State (cases Colombia, Argentina, Chile or Mexico), allowing the realization of joint projects with their counterparts in the country, for teaching, counseling or internships, which allow migrated researchers to have connections with the diaspora has been yielding promising responses.

The experiences succinctly exposed indicate that the prospect of efforts to mitigate talent migration has been focused on the national dimension. Little or no consideration has been given to the regional context, let alone the global context in which it was implemented to solve a problem that was already complex. Scellato, Franzoni, and Stephan, (2015). Thus, taken together the facts exposed and the results obtained, all point to the fact that, if the State of origin wishes to reduce the negative effects of the migration of scientists, it must implement policies that increase the Social Capital of the migrant population, to maintain the links required to promote collaborative efforts that impact the well-being of the country concerned. These efforts could and should be coordinated at a regional and global level to maximize results. This could be valid experiences for the Venezuelan case, since this paper show the existence of important networks effects and a high willingness of migrated researchers to maintain their local contacts.

¹⁷ The mentioned efforts have resulted in structures from which they are managed; ranging from the structures of the Ministry of Foreign Affairs, networks of consulates and embassies, technical secretaries with representatives of migrants, scientific and technology bodies of the country of origin and state officials (Chaparro et al, 2014; Garcia, 2014; IME, 2018; López 2016).

Table 2. Analysis of Coauthor Emigration Profile and Author's Productivity – (ever-emigrated).

Model	Any Migrated Coauthor			Max. Seniority/Productive			Coauthor's Migration Destination		
Variables	# Papers	% HQ Papers	Avg IF	# Papers	% HQ Papers	Avg IF	# Papers	% HQ Papers	Avg IF
(column)	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
Share of Emigrant coauthor...									
Any	-0.082	0.149**	0.257						
	[0.054]	[0.057]	[0.154]						
Max. Impact Factor				-0.885***	0.035	0.052			
				[0.100]	[0.060]	[0.138]			
to North America							-0.160**	0.219***	0.397
							[0.060]	[0.072]	[0.258]
to Europe							-0.064	0.199*	0.365**
							[0.104]	[0.105]	[0.137]
to Latin America							0	-0.023	-0.179
							[0.058]	[0.075]	[0.127]
to Other							-0.340*	0.341***	0.978
							[0.179]	[0.098]	[1.075]
Emigration (ND)	2.101	-4.663	-2.39	1.551	-4.926	-2.794	3.525	-4.325	-2.235
	[3.977]	[5.207]	[11.330]	[3.963]	[5.253]	[11.331]	[2.798]	[4.930]	[9.835]
Share Vnzla Coauthors	0.049**	-0.173***	-0.825***	0.054**	-0.171***	-0.823***	0.120***	-0.159***	-0.675***
	[0.022]	[0.028]	[0.135]	[0.021]	[0.028]	[0.135]	[0.021]	[0.029]	[0.083]
Share of ND Coauthors	-0.065**	-0.003	-0.073	-0.065**	-0.003	-0.072	-0.051*	-0.008	-0.063
	[0.029]	[0.010]	[0.053]	[0.029]	[0.010]	[0.053]	[0.029]	[0.010]	[0.055]
Observations	71,202	71,202	66,228	71,202	71,202	66,228	63,577	63,577	59,111
R-squared	0.064	0.175	0.051	0.065	0.174	0.051	0.064	0.174	0.047

Note for Tables 2 & 3. Note: Using BIBLIOS data from 1960 to 2018 of Venezuelan researchers in Venezuela. All models control for sex, age, 2-digit discipline, Venezuelan real economic growth at the time of the publication, year fixed-effects, system-specific effect, and author's educational attainment (High School or less, Doctorate, Master, and Technical). HQ High Quality; EM Ever-Migrated; E Emigrant; ND Not the same discipline. IF-Impact Factor. Clustered -Robust standard errors in brackets; *** p<0.01, ** p<0.05, * p<0.1.

Table 3. Analysis of Coauthor Emigration Profile and Author's Productivity (ever emigrated).

Model	Any Migrated Coauthor			Max. Seniority/Productive			Coauthor's Migration Destination		
Variables	# Papers	% HQ Papers	Avg IF	# Papers	% HQ Papers	Avg IF	# Papers	% HQ Papers	Avg IF
(column)	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
Share of ...									
Ever-Migrated (EM)	0.096**	0.357***	0.992***						
	[0.040]	[0.038]	[0.240]						
Emigrant (E)	-0.172**	-0.184**	-0.665**						
	[0.074]	[0.075]	[0.253]						
EM-Max. IF				-0.607***	0.193***	0.437**			
				[0.080]	[0.027]	[0.142]			
E-Max. IF				-0.261**	-0.163**	-0.390**			
				[0.104]	[0.072]	[0.159]			
EM to North America							0.047	0.498***	1.387***
							[0.108]	[0.090]	[0.439]
EM to Europe							0.023	0.387***	1.039***
							[0.032]	[0.041]	[0.158]
EM to Latin America							0.023	0.250***	0.399**
							[0.074]	[0.030]	[0.176]
EM to Other							-0.083	0.262***	0.039
							[0.082]	[0.061]	[0.158]
E to North America							-0.206	-0.273**	-0.976
							[0.149]	[0.126]	[0.598]
E to Europe							-0.086	-0.162*	-0.608***
							[0.090]	[0.082]	[0.176]
E to Latin America							-0.021	-0.247***	-0.514***
							[0.074]	[0.082]	[0.157]
E to Other							-0.256	0.106	1.003
							[0.195]	[0.094]	[1.124]
Observations	71,202	71,202	66,228	71,202	71,202	66,228	63,577	63,577	59,111
R-squared	0.064	0.189	0.057	0.073	0.179	0.052	0.064	0.189	0.052

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Appendix 1. Research's Characteristics

Table A1. Summary Statistics. Venezuelan researchers' characteristics and Publications

Categorical Variables	1960s	1970s	1980s	1990s	2000s	2010s	ALL
(as average decade)							
Female	0.15	0.23	0.35	0.42	0.50	0.53	0.45
Educational Attainment							
Bachelors & Specializations	0.83	0.69	0.58	0.49	0.48	0.59	0.55
Doctor	0.14	0.23	0.31	0.35	0.30	0.24	0.28
Master	0.02	0.08	0.11	0.17	0.21	0.17	0.17
Technical	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Discipline (first 2-digit)							
Agricultural Sciences	0.05	0.16	0.12	0.16	0.16	0.13	0.14
Chemistry	0.03	0.07	0.08	0.08	0.09	0.08	0.08
Earth and space science	0.02	0.02	0.03	0.03	0.03	0.04	0.03
History	0.02	0.01	0.01	0.01	0.00	0.01	0.01
Life Sciences	0.13	0.15	0.16	0.15	0.16	0.16	0.16
Mathematics	0.01	0.01	0.02	0.02	0.04	0.04	0.03
Medical Sciences	0.72	0.48	0.42	0.33	0.28	0.29	0.33
Physics	0.01	0.03	0.04	0.04	0.03	0.03	0.03
Technological Sciences	0.01	0.05	0.09	0.13	0.14	0.13	0.12
Others	0.01	0.02	0.04	0.06	0.06	0.10	0.06
System/Institution type							
Agriculture	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Energy & Oil	0.00	0.01	0.04	0.04	0.02	0.02	0.02
Health	0.14	0.12	0.09	0.07	0.05	0.04	0.06
Others	0.14	0.13	0.12	0.12	0.12	0.11	0.12
S&T	0.09	0.10	0.10	0.07	0.06	0.07	0.07
University	0.63	0.63	0.65	0.70	0.76	0.77	0.73
Total	861	1,924	3,288	5,721	9,376	8,674	29,844

From the Table A1 we can see that the discipline that suffers the most significant reduction in publications is medical science, which is matched by the decline in the analysis by systems on the reduction of the average annual publications for the health system. In terms of other groups, the table also shows a significant increase in the number of publications by female researchers. Finally, it can be seen the increase on publication from researchers with Masters and PhD degrees, which could be associated with the increasing trend in the quality of publications.

Appendix 2. Number of respondents and standard errors of the survey

(for all Tables in appendixes 2, 3 and 4 *Source*: Data obtained from study participants.)

Table A2.1. Distribution of the questionnaire on emigration impacts of the community of Venezuelan scientific researchers.

Period – Dates	Emigrated researcher	Non-emigrated researcher	Total
First - 10/21/19 —11/04/19	129	62	191
Second – 11/05/19—11/21/19	41	21	62
Total	170	83	253
Standard Error	7.35%	14.42%	

Appendix 3. Results from survey to migrated researchers

Table A3.1. Destination Region.

Zone	TOTAL	Before 2005	2006 to 2013	2014 to 2018
North America	25%	37% (*)	24%	39%
LATAM	54%	7%	17%	75% (**)
Europe	21%	27% (*)	27%	45%
TOTAL	100%	19%	21%	60%

Table A3.2. Age by Destination Region.

Age	Total	North America	LATAM	Europe
31 to 40	7%	5%	10%	12%
41 to 50	24%	34%	29%	18%
51 to 60	36%	13%	40%	39%
61 to 70	24%	29%	19%	15%
71 to 80	9%	18%	2%	15%
TOTAL	100%	25%	54%	21%

Table A3.3. Migration Triggers by Date of Migration.

Trigger	Total	Before 2005	2006 to 2013	2014 to 2018
Work	42%	59%	50%	35%
Political	12%	28%	28%	1%
Family	30%	17%	25%	34%
Education	4%	14%	0%	1%
Others	10%	10%	13%	9%
Economic	19%	7%	6%	27%
Social	3%	7%	6%	2%
Emotional stress	18%	7%	22%	20%

Table A3.4. Collaboration with Venezuelan Colleagues.

Collaboration	Total	Before 2005	2006 to 2013	2014 to 2018
Yes	47%	28%	38%	48%(*)
No	53%	72%	63%	52%

Table A3.5. Collaboration with researchers in Venezuela.

Type of Collaboration	Total	Before 2005	2006 to 2013	2014 to 2018
Publish together	62%	25%	64%	72%
Joint research projects	43%	50%	36%	44%
Postgraduate collaboration	36%	13%	18%	44%
Pre-print reviews	15%	0%	9%	19%
None	2%	13%	0%	0%
Other	8%	13%	9%	6%

Table A3.6. Reasons to Collaborate with Migrated and Non-migrated Colleagues.

Reason	Non-Migrated	Migrated
Exchange	64%	82%
Mobility	82%	57%
Visibility	83%	90%
Access	67%	85%
Productivity	43%	83%
Networking	62%	80%

Appendix 4

Table A4.1. Reason to Migrate.

CATEGORIES		REGION		
		LATAM	North America	Europe
GENERAL	Particular	#	#	#
1.- Limiting Conditions of Life	Economic limitations	12	5	4
	Physical insecurity	6	1	3
	Detriment quality life	4		1
	Lack medical care & medicines	4		1
	Socio-economic crisis	1		
	Lack of groceries		1	
2.- Obstacles for professional development	Impediments	10		
	Limitations	3		
3.- Political Situation	Government events / actions	6	4	
4.- Future Vision	family future / reunion		5	1
	Opportunities		3	2
	Initial goals		4	
n (informants)=		20	10	8
Age range		40-70 years	30-50 years	50-80 years

Table A4.2. Advantage and Disadvantages

CATEGORIES		REGION		
		LATAM	North America	Europe
GENERAL	Particular	#	#	#
	(Perception)			
1.- Professional / work	Improvement	13	3	5
	Limitations employment (stability/immigration)	10		5
	Academic research	5		1
2.- Economic situation	Favorable	9		
	Unfavorable	5	2	
3.- Socio familiar	Advantage	11	10	7
4.- Socio cultural Barrier	Disadvantage	7		
n (informants)=		20	10	8
Age range		40 - 70 years	30 - 50 years	50 - 80 years

Appendix 5

Table A5.1. Variables' definitions and formulas

Outcome Variables	Description	Formula
Number of publications	Total number of publications p for author i on year t.	$Npapers_t^i = \sum paper_t^i$
Share of HQ publications	Share of publications identified as high quality over the total number publications for author i on year t.	$ShHQpublications_t^i = \sum HQpaper_t^i / \sum paper_t^i$
Average Impact Factor (IF)	Average Impact factor of publications for author i on year t.	$IF_t^i = \sum Impact\ Factor\ of\ paper_t^i / \sum paper_t^i$
Target Control Variables		
Share of Emigrant Coauthors:	share of coauthors who migrated for author i at the time of publication on year t.	$ShEmigrantcoauthor_t^i = \sum Emigrant\ coauthor_t^i / \sum coauthor_t^i$
Share of Ever-migrated Coauthors:	share of coauthors who migrated at any time in our period for author i on year t.	$ShEver - migratedcoauthor_t^i = \sum Ever - migrated\ coauthor_t^i / \sum coauthor_t^i$

Share of Emigrant Coauthors Max. IF:	share of coauthors with the highest Impact Factor (IF) among coauthors who migrated for author i at the time of publication on year t.	$ShEmigrantcoauthor_t^i$ $= \sum Emigrant\ coauthor\ Max.\ IF_t^i / \sum coauthor_t^i$
Share of Ever-migrated Coauthor Max. IF:	share of coauthors with the highest IF among coauthors who migrated at any time in our period for author i on year t.	$ShEver - migratedcoauthor_t^i$ $= \sum Ever - migrated\ coauthor\ Max.\ IF_t^i$ $/ \sum coauthor_t^i$
Share of Emigrant Coauthors to North America:	share of coauthors who migrated to North America for author i at the time of publication on year t.	$ShEmigrantcoauthor\ North\ America_t^i$ $= \sum Emigrant\ coauthor\ to\ North\ America_t^i$ $/ \sum coauthor_t^i$
Share of Emigrant Coauthors to Europe:	share of coauthors who migrated to Europe for author i at the time of publication on year t.	$ShEmigrantcoauthor\ Europe_t^i$ $= \sum Emigrant\ coauthor\ to\ Europe_t^i / \sum coauthor_t^i$

Share of Emigrant Coauthors to Latin America:	share of coauthors who migrated to Latin America for author i at the time of publication on year t.	$ShEmigrantcoauthor\ Latin\ America_t^i$ $= \frac{\sum Emigrant\ coauthor\ to\ Latin\ America_t^i}{\sum coauthor_t^i}$
Share of Emigrant Coauthors to Other:	share of coauthors who migrated to other region for author i at the time of publication on year t.	$ShEmigrantcoauthor\ Other_t^i$ $= \frac{\sum Emigrant\ coauthor\ to\ other\ region_t^i}{\sum coauthor_t^i}$
Share of Ever-migrated Coauthors to North America:	share of coauthors who migrated at any time in our period that migrated to North America for author i on year t.	$ShEver - migratedcoauthor\ North\ America_t^i$ $= \frac{\sum Ever - migrated\ coauthor\ to\ North\ America_t^i}{\sum coauthor_t^i}$

Share of Ever-migrated Coauthors to Europe:	share of coauthors who migrated at any time in our period that migrated to Europe for author i on year t.	$ShEver - migratedcoauthor Europe_t^i$ $= \frac{\sum Ever - migrated coauthor to Europe_t^i}{\sum coauthor_t^i}$
Share of Ever-migrated Coauthors to Latin America:	share of coauthors who migrated at any time in our period that migrated to Latin America for author i on year t.	$ShEver - migratedcoauthor Latin America_t^i$ $= \frac{\sum Ever - migrated coauthor to Latin America_t^i}{\sum coauthor_t^i}$
Share of Ever-migrated Coauthors to Other:	share of coauthors who migrated at any time in our period that migrated to other region for author i on year t.	$ShEver - migratedcoauthor Other_t^i$ $= \frac{\sum Ever - migrated coauthor to other region_t^i}{\sum coauthor_t^i}$

Other variables		
Share of Venezuelan Coauthors:	share of coauthors who are Venezuelan for author i on year t.	$ShForeigncoauthor_t^i = \sum \text{Venezuelan coauthor}_t^i / \sum \text{coauthor}_t^i$
Share of not-the-same-discipline Coauthors (2-digit code):	share of coauthors of author i in disciplines different from her/his own on year t.	$Shotherdisciplinecoauthor_t^i = \sum_{d \neq od} \text{coauthors}_t^{id} / \sum \text{coauthor}_t^i$ <p>Where <i>od</i> is the discipline of author <i>i</i>.</p>
Emigration Rate (not the same discipline (ND) disciplines):	emigration rate for authors in disciplines different from the discipline of author i on year t.	$Emigration\ rate_t^i = \sum_{d \neq od} \text{Emigrant authors}_t^d / \sum \text{authors}_t$ <p>Where <i>od</i> is the discipline of author <i>i</i>.</p>

Table A5.2. Analysis of Relationship between Coauthor Emigration and the Author's Productivity.

Model	Any Migrated Coauthor			Max. Seniority/Productive			Coauthor's Migration Destination		
Variables	# Papers	% HQ Papers	Avg IF	# Papers	% HQ Papers	Avg IF	# Papers	% HQ Papers	Avg IF
(column)	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
Share of Emigrant coauthor...									
Any	-0.082*	0.149***	0.257**						
	[0.043]	[0.024]	[0.106]						
Max. Impact Factor				-0.885***	0.035	0.052			
				[0.034]	[0.033]	[0.101]			
to North America							-0.160**	0.219***	0.397**
							[0.075]	[0.045]	[0.199]
to Europe							-0.064	0.199***	0.365**
							[0.088]	[0.051]	[0.156]
to Latin America							0	-0.023	-0.179
							[0.070]	[0.042]	[0.110]
to Other							-0.340**	0.341***	0.978
							[0.137]	[0.103]	[1.233]
Emigration (ND)	2.101	-4.663***	-2.39	1.551	-4.926***	-2.794	3.525**	-4.325***	-2.235
	[1.562]	[0.473]	[2.220]	[1.562]	[0.470]	[2.205]	[1.543]	[0.494]	[2.294]
Share Vzlan Coauthors	0.049***	-0.173***	-0.825***	0.054***	-0.171***	-0.823***	0.120***	-0.159***	-0.675***
	[0.011]	[0.005]	[0.031]	[0.011]	[0.005]	[0.031]	[0.011]	[0.005]	[0.032]
Share of ND Coauthors	-0.065***	-0.003	-0.073***	-0.065***	-0.003	-0.072***	-0.051***	-0.008	-0.063***
	[0.010]	[0.005]	[0.020]	[0.010]	[0.005]	[0.020]	[0.010]	[0.005]	[0.021]
Observations	71,202	71,202	66,228	71,202	71,202	66,228	63,577	63,577	59,111
R-squared	0.064	0.175	0.051	0.065	0.174	0.051	0.064	0.174	0.047

Note for Tables A5.2 and A5.3: Using BIBLIOS data from 1960 to 2018 of Venezuelan researchers in Venezuela. All models control for sex, age, 2-digit discipline, Venezuelan real economic growth at the time of the publication, year fixed-effects, system-specific effect, and author's educational attainment (High School or less, Doctorate, Master, and Technical). HQ High Quality; EM Ever-Migrated; E Emigrant; ND Not the same discipline. IF-Impact Factor. Robust standard errors in brackets. *** p<0.01, ** p<0.05, * p<0.1.

Table A5.3. Analysis of Coauthor Emigration Profile and Author's Productivity (ever-emigrated).

Model	Any Migrated Coauthor			Max. Seniority/Productive			Coauthor's Migration Destination		
Variables	# Papers	% HQ Papers	Avg IF	# Papers	% HQ Papers	Avg IF	# Papers	% HQ Papers	Avg IF
(column)	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
Share of ...									
Ever-Migrated (EM)	0.096***	0.357***	0.992***						
	[0.021]	[0.010]	[0.054]						
Emigrant (E)	-0.172***	-0.184***	-0.665***						
	[0.047]	[0.026]	[0.117]						
EM-Max. IF				-0.607***	0.193***	0.437***			
				[0.014]	[0.009]	[0.048]			
E-Max. IF				-0.261***	-0.163***	-0.390***			
				[0.037]	[0.034]	[0.112]			
EM to North America							0.047	0.498***	1.387***
							[0.039]	[0.020]	[0.121]
EM to Europe							0.023	0.387***	1.039***
							[0.040]	[0.021]	[0.107]
EM to Latin America							0.023	0.250***	0.399***
							[0.034]	[0.020]	[0.097]
EM to Other							-0.083	0.262***	0.039
							[0.099]	[0.057]	[0.183]
E to North America							-0.206**	-0.273***	-0.976***
							[0.085]	[0.049]	[0.222]
E to Europe							-0.086	-0.162***	-0.608***
							[0.096]	[0.055]	[0.189]
E to Latin America							-0.021	-0.247***	-0.514***
							[0.078]	[0.046]	[0.145]
E to Other							-0.256	0.106	1.003
							[0.170]	[0.118]	[1.254]
Observations	71,202	71,202	66,228	71,202	71,202	66,228	63,577	63,577	59,111
R-squared	0.064	0.189	0.057	0.073	0.179	0.052	0.064	0.189	0.052