Local Gains From Global Minds: The Impact of Collaborating with Foreign-Educated Researchers on Non-Mobile Researchers' Performance

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ABSTRACT

Foreign-educated researchers who cross national borders for training can play an important role in contributing to research in their country of origin. Relying on a unique dataset of Colombian researchers, our study explores how researchers with Ph.D. training abroad affect the performance of researchers who do not work or study abroad (non-mobile researchers) through direct collaboration. Combining Propensity Score Matching and Difference-in-Differences estimations, we find that non-mobile researchers who co-author with foreign-educated researchers experience a significant improvement in their research performance. Co-authoring boosts the number of publications, citations, publications in top journals, and the share of publications in English. Interestingly, the extent of these improvements differs across scientific macro fields.

Keywords: International Scientific Mobility; Co-authorship; Colombia.
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1. Introduction

Foreign-educated researchers who cross national borders for training are often acknowledged as an important source of scientific and innovation capabilities for their origin and host countries (Gibson & McKenzie, 2014; Lissoni, 2018). Their role in diffusing knowledge (Agrawal et al., 2006, 2011; Ganguli, 2015; Kahn & MacGarvie, 2016), advancing the internationalization of innovation activities in their origin countries (Miguélez, 2018; Saxenian, 2005), and connecting national scientific systems (Baruffaldi & Landoni, 2012; Velema, 2012) is well documented. Scholars have focused on understanding what distinguishes these researchers in the academic literature. Previous studies have shown that spending periods abroad allows foreign-educated researchers to absorb frontier knowledge, access infrastructure, develop skills, and expand social networks, all of which increase researchers' human capital and performance (Cañibano, 2017; Jonkers & Tijssen, 2008; Netz et al., 2020; Petersen, 2018; Scellato et al., 2015).

Although there is extensive documentation on the impact of international mobility experience on foreign-educated researchers' performance, the literature offers a limited understanding of the effects of these experiences on non-mobile colleagues – those who have never worked or studied abroad. Fortunately, scholars have attempted to address this gap in recent years. These scholars have explored how foreign-educated researchers contribute to non-mobile researchers' foreign social capital (Fry, 2023; Müller et al., 2023) and performance (Franzoni et al., 2018; Fry & Furman, 2023; Yang et al., 2022). However, the focus has been on the aggregate impact of co-location with foreign-educated researchers at a department level rather than on direct collaborative interactions, such as co-authorship. Also, those scholars have mainly investigated scientists within specific Science, Technology, Engineering, and Mathematics (STEM) fields. By contrast, our study first aims to explore the extent to which researchers who have obtained a Ph.D. abroad influence non-mobile researchers' performance through direct co-authorship channels. Second, we extend the study to all research fields and compare STEM to other Social Sciences and Humanities (SSH) fields.

We focus on a sample of Colombian researchers active between 1990 and 2021. We build a unique dataset, reconstructing mobility patterns and scientific performance from national centralized CV repository data and national funding agencies' records, combined with bibliometric data from OpenAlex. Our empirical strategy combines two methods – Nearest Neighborhood Matching (Rubin, 1973) and a Difference-in-Differences with multiple time periods estimator (Callaway & Sant'Anna,

2021). Establishing a causal link between co-authoring with a foreign-educated researcher and scientific outcomes (if any) for non-mobile researchers is challenging because these foreign-educated researchers do not randomly select their co-authors. We leverage Propensity Score Matching (PSM) to build comparable groups of non-mobile researchers who co-authored with foreign-educated researchers at least once (treated) and who never co-authored (control). We use variables on common performance and socio-demographic characteristics (Jones et al., 2008; Yadav et al., 2023). We next use a Difference-in-Differences estimator to assess the dynamic effects (i.e., an aggregation scheme to observe how the effect changes given the exposure to the treatment for a period of time) of such co-authorships, with the first co-authorship with the foreign-educated researcher as the treatment year. Our analysis focuses on four outcome variables: the number of publications, the cumulative number of citations per publication, the number of publications in top journals (all logged), and the share of publications in English.

Results show that co-authoring with foreign-educated researchers significantly improves the performance of non-mobile researchers. Specifically, we observe a 22% increase in the number of publications and a 19% rise in the number of citations once a non-mobile is exposed to at least one co-authorship with a foreign-educated researcher. Non-mobile researchers in the treatment group also experience an increase of 4% in the number of publications in top journals and 6 percentage points in the share of English publications. Disaggregating non-mobile researchers by macro fields, SSH, and STEM, we observe that researchers benefit similarly in terms of the number of publications. In contrast, STEM researchers benefit from more citations, a larger share of English publications, and a higher number of publications in top journals. However, the event study results indicate that frequent collaborations with foreign-educated researchers are essential to sustain these benefits.

We contribute to existing literature and policy-making in several ways. First, we expand the literature by highlighting the effects of foreign-educated researchers on their non-mobile peers. We investigate these effects by analyzing direct collaborations instead of focusing on the impact at a department level. Second, we explore heterogeneity in the performance among researchers from different macro fields. On the policy side, our results emphasize the relevance of international scientific mobility policies. We demonstrate that the influence of collaborating with foreign-educated researchers extends to the local scientific community, particularly those who have never moved abroad. This finding is significant for countries with limited financial resources that aim to improve their scientific indicators. By financing

the mobility of some of their researchers, they can also guarantee benefits for those who stay in the country.

The remainder of the paper is organized as follows. Section 2 discusses the literature background, sets the theoretical arguments, and identifies gaps in the literature. Section 3 provides background information on the Colombian scientific system. Section 4 details the data sources and sample, defines the outcome variables, and explains the process of identifying researchers. Section 5 describes the empirical strategy used for the analysis. Section 6 illustrates the regression analysis results. Section 7 further investigates our results. Section 8 repeats the same analysis with data on Brazilian researchers to test the external validity of our results. Finally, Section 9 concludes the paper by discussing the results and offering policy implications.

2. Co-authorship and peer-effects in academic research: Why collaboration matters

2.1 Co-authorship as a means to improve researchers' performance

Teamwork has become science's most frequent knowledge production mode in recent decades. The shift from solo-author to teamwork has been observed in the increase of co-authored papers across nearly all scientific fields (Ribeiro et al., 2018; Wagner, 2018; Wagner & Leydesdorff, 2005; Wuchty et al., 2007). Teamwork appears to benefit researchers. For instance, co-authored papers are more likely to receive more citations (Adams, 2012; Gazni & Didegah, 2011; Uzzi et al., 2013) and advance more significantly the scientific and technological frontiers (Jones, 2009; Wu et al., 2019; Wuchty et al., 2007) than single-authored papers.

Acknowledging the role of teams in science, prior work has explored the drivers and advantages of direct collaboration. Knowledge production has increased sharply in recent decades, making science more complex and expensive (Jones, 2009). Consequently, there is an increasing need for labor division and resource pooling (Bozeman & Corley, 2004; Katz & Martin, 1997; Ponomariov & Boardman, 2016). Scientists specialize and team up, joining their complementary competencies to complement their tasks. Individual-level incentives are also relevant. Among them, scientists co-author with their peers to acquire new knowledge and skills that would be otherwise expensive to obtain independently (Laband & Tollison, 2000). Moreover, researchers co-author to benefit different aspects of their careers. For example, to gain credibility by working with renowned peers (Kumar & Ratnavelu,

2016) and to develop a component of academic training (e.g., PhD students co-authoring with supervisors) (Price et al., 2000).

Co-authoring also allows researchers to explore different combinations of existing knowledge pieces to create new knowledge (Fontana et al., 2020; Wang et al., 2017). Scholars often argue that researchers have bounded rationality, making it challenging to explore new combinations alone (Li et al., 2013; Nelson, 2008). To overcome this and create new knowledge, researchers often collaborate with their peers as teams of researchers with different backgrounds (including knowledge bases, cognitive processes, and learning from previous experiences) (Franzoni et al., 2018).

One important aspect of collaboration with other researchers is the peer effect, which often affects researchers' performance in quantity and quality (Ductor, 2015; Hart, 2000). For instance, previous evidence has shown that highly productive researchers (star scientists) have a positive impact on the productivity of their co-authors (Azoulay et al., 2019; McHale et al., 2023), also stimulating publications in high-ranked journals (Oettl, 2012).[1]

Altogether, empirical evidence highlights that co-authorship is essential for researchers to access resources and learn from their peers, potentially influencing their performance. Building on this argument, we explore the co-authorship between researchers who have completed Ph.D. training abroad (henceforth foreign-educated researchers) and those who have not (henceforth non-mobile researchers).[2] Notably, we examine how co-authoring with foreign-educated researchers influences the performance of non-mobile researchers. We also perform a heterogeneity analysis across macro-scientific fields. In fact, the extent to which co-authoring affects researchers' performance varies across macro-scientific fields, such as STEM and SSH. Each macro field has specific collaboration patterns, dynamics, and routines when producing science (Stephan, 2012; Wuchty et al., 2007). For instance, STEM researchers often require large-scale equipment and precision instruments, which are less common in other fields (Fortunato et al., 2018; Stephan, 2010). Additionally, the average number of

[1] The referenced literature on star scientists often investigates the death of these scientists as a shock to the performance of their co-authors. Results show that, after star scientists death, there is a negative effect on the performance of their co-authors. In this sense, while alive, the peer effects are positive.

[2] We define foreign-educated researchers as those who have completed their Ph.D. studies entirely abroad (Kahn & MacGarvie, 2012, 2016; Liang et al., 2022; Turpin et al., 2008). Some individuals return to their home countries, while others remain abroad. Although researchers might become mobile at various stages of their careers, we consider only those who have studied abroad.

co-authors in SSH fields is typically lower than in STEM teams (Wuchty et al., 2007). These particular dynamics inevitably create heterogeneities in researchers' performance (Larivière et al., 2015).

2.2 Peer effect in the context of international scientific mobility

Extant work on international scientific mobility has acknowledged the importance of fostering the training of researchers abroad. Drawing on the argument that international mobility allows researchers to access frontier knowledge, develop new skills, and expand networks, scholars point out that these competencies developed abroad can be used to update the scientific system of researchers' country of origin (Bozeman et al., 2001; Corley et al., 2019; Jonkers & Tijssen, 2008; Scellato et al., 2015). Upon their return or even if they remain abroad, foreign-educated researchers are expected to collaborate with other researchers, including non-mobile researchers, and disseminate knowledge in the national scientific systems (Agrawal et al., 2006; Meyer, 2001; Saxenian, 2005). Foreign-educated researchers can also train the researchers in their origin country and contribute to changing the publication behaviors of these latter researchers (e.g., publishing in English to reach an international audience) (Fry, 2023; Hofman & Kramer, 2015; Séguin et al., 2006). These actions can thus affect the performance of other researchers, increase their absorptive capacity, and foster scientific system upgrading (Dahlman, 2010; Velema, 2012).

Nevertheless, the existing literature on international scientific mobility has not given proper attention to the impact of mobility experience on researchers who have never experienced international mobility. Prior studies have shown the direct effects of mobility on foreign-educated researchers' careers (Baruffaldi et al., 2020; Fernández-Zubieta et al., 2015; Franzoni et al., 2014; Netz et al., 2020). Notably, these studies have investigated the impact on mobile researchers' productivity (Baruffaldi & Landoni, 2012; Petersen, 2018), visibility (Jonkers & Cruz-Castro, 2013; Velema, 2012), and foreign social capital (Jonkers & Tijssen, 2008; Scellato et al., 2015). However, research on the benefits extended to other researchers has barely been explored.

A group of scholars has attempted to fill this gap by investigating the impact of foreign-educated researchers on non-mobile researchers' performance and foreign social capital (Franzoni et al., 2018; Fry & Furman, 2023; Fry, 2023; Müller et al., 2023; Yang et al., 2022), but the findings are not convergent. Yang et al. (2022) find that Chinese STEM researchers with experience abroad do not affect their departmental peers' productivity or social capital, except for a marginal increase of 0.2

highly cited papers. Contrarily, Fry (2023) reports a significant rise: a 12% increase in productivity among department peers of African HIV researchers trained in the United States. Fry & Furman (2023) also show that African female mobile researchers contribute to an increase of 3.3% in new foreign connections for department peers. Similarly, Müller et al. (2023) find that researchers in South Africa with foreign social capital help their local co-authors increase foreign ties by 3.6% for every 10% increase in the foreign social capital of the former. With a focus on the extended impact of mobile researchers based in the host countries, Franzoni et al. (2018) demonstrate that teams with researchers from different countries perform better than teams with only non-mobile researchers.

Franzoni et al. (2018), Fry & Furman (2023), Fry (2023), Müller et al. (2023), and Yang et al. (2022) have investigated how foreign-educated researchers affect their non-mobile peers. However, these scholars leave several gaps. First, they predominantly explore the impact of foreign-educated researchers at an aggregate level (i.e., department). In some scientific fields, the peer effect is likely confined to a few individuals, such as co-authors. It is challenging to assert that an entire department experiences this peer effect. Second, their focus has been mainly on researchers from specific STEM fields. However, macro scientific fields have different dynamics, including collaboration patterns (Stephan, 2012; Wuchty et al., 2007). Third, Franzoni et al. (2018), a paper close in spirit to ours, focuses on extended benefits to non-mobile researchers in the host countries, leaving the impact on non-mobile researchers from sending countries unaddressed. Tackling this latter point is crucial as sending countries sponsor the training of their researchers abroad, expecting dissemination of knowledge in return (Cañibano, 2017; Netz et al., 2020). To fill the mentioned gaps in the literature, we ask: *Do foreign-educated researchers influence the performance of their non-mobile peers in their sending countries through co-authorship?* Further, we contribute to the literature by investigating co-authorship effects with foreign-educated researchers on non-mobile peers from STEM and SSH fields.

3 Institutional context

Colombia is an interesting case to explore whether foreign education benefits can extend to those who never leave the country. Despite being undeveloped, Colombia has devoted increased funds to science to catch up with the scientific frontier. A Science and Technology Ministry was recently created (Dutrénit et al., 2021), and substantial funds were distributed (Salazar, 2017). Those investments

helped to increase Colombia's number of scientific publications from 6,463 publications in 2011 to 12,005 publications in 2019 (Dutrénit et al., 2021).[3]

International mobility policies have contributed substantially to improving the scientific system. Given the few national training programs, various public agencies such as Colombia for the Future (Colfuturo) and the Administrative Department of Science, Technology, and Innovation (Colciencias) have supported researchers' training abroad. In recent years, evaluating the impact of investments in foreign education has become crucial for the country. Nevertheless, despite the improvements, the country faces budget cuts in science (Wade, 2017). A better understanding of the relationship between funding and productivity will allow for a better understanding of the consequences of those budget cuts.[4]

4 Data

4.1 Data sources

To assess the impact of collaborations with foreign-educated researchers on the scientific performance of non-mobile researchers, we combine three data sources: (i) the Colombian centralized dataset recording national researchers (CvLAC), (ii) the lists of Ph.D. scholarship beneficiaries, and (iii) a bibliometric dataset, OpenAlex.

We consider Colombian data in the period between 1990 and 2021. It is since the 90s, Colombia has increased the number of nationals sponsored abroad, and in the last decade, the country has also made an effort to strengthen its scientific system, such as increasing the number of graduate programs (Bedenlier, 2018; Losada, 2016)

CvLAC Data. Established by Colombia's national government in 2001, the CvLAC is an integrated database to track the country's research community progress (de los Ríos & Santana, 2001). It contains self-reported information on researchers' demographic data and educational and professional backgrounds, including publication lists. Since CvLAC data are the main input for national selection processes in academia and research organizations, Colombian researchers are incentivized to maintain up-to-date CVs.

[3] For example, Colombia and Brazil still far from the scientific frontier where China and the United States stand (Scimago Journal & Country Rank, 2023).
[4] Until 2023, more than 3,000 students have been sponsored to study abroad.

For our analysis, we extract data from researchers with a CvLAC profile and use it for two purposes. First, this data source helps identify researchers' nationality and mobility patterns. Second, it facilitates the matching process with OpenAlex. The recorded academic background allows us to identify foreign-educated researchers, i.e., those students who moved abroad for their Ph.D. and those who pursued their education at a national level, i.e., those who have done a Master's or Ph.D. program in Colombia.[5] Using the affiliations of the researchers' working history, we retrieve the mobility pattern after Ph.D. The publications reported in CvLAC allow us to refine the matching with those publications retrieved from OpenAlex.

Ph.D. scholarship lists data. Researchers moving abroad do not have the same incentive to maintain an up-to-date national CV, leading to incomplete or outdated data. To address this issue, we complement the national CV repository with the lists of Ph.D. scholarships maintained by the three main funding agencies in the country: Foundation for the Future of Colombia (Colfuturo), Ministry of Science, Technology, and Innovation (Colciencias), and Fulbright Colombia. These lists provide information on the scholarship holder's name, Ph.D. institution, destination country, discipline, and starting date of doctoral studies.

OpenAlex data. We rely on OpenAlex, an extensive repository with over 200 million scientific publications (Singh Chawla, 2022), to retrieve researchers' bibliometric data. We use matching procedures (e.g., fuzzy matching) to identify Colombian researchers in OpenAlex and attribute bibliometric indicators to each identified researcher. Appendix 1 provides the details of the dataset construction and matching procedure.

4.2 Identifying non-mobile and foreign-educated researchers

To determine the impact of co-authoring with foreign-educated researchers for non-mobile peers, we need to identify the two categories of researchers as the first step.

In our analysis, Colombian researchers are classified as non-mobile if they have completed their graduate studies (both master's and Ph.D.) exclusively in Colombia and have not spent more than a

[5] In Colombia, it is usual that some researchers do not have a Ph.D. For this reason, we also include researchers with a Master's degree in our analysis. Still, we define a three-publication threshold for researchers in Colombia to be part of our sample. In the subsection *Identifying non-mobile and foreign-educated researchers*, we further explain our definitions for Colombian researchers.

year studying abroad. This categorization also includes researchers with only a Master's degree, as Ph.D. programs have only recently been introduced as part of the graduate system in Colombia (Observatorio Colombiano de Ciencia y Tecnología, 2021). Given this context, different educational and research institutes have hired researchers holding only a Master's degree to undertake academic and research activities. To guarantee that researchers are active, we set a three-publication threshold for non-mobile researchers in our dataset, i.e., we include only researchers with at least three publications in our period of observation, 1990-2021.

Following the literature on international scientific mobility (Kahn & MacGarvie, 2012, 2016; Liang et al., 2022; Turpin et al., 2008), we label a Colombian researcher as a foreign-educated researcher if they have completed their Ph.D. studies entirely abroad.

4.3 Sample

We consider a sample of non-mobile researchers and compare those who co-author with at least one foreign-educated researcher with those who co-author only with locals. We identify 3,833 Colombian researchers who have not studied or worked abroad and examine their co-authorship networks to make this sample suitable for our empirical strategy. Looking at the co-authorship network of non-mobile researchers, we distinguish those who have co-authored with foreign-educated researchers and those who have not, forming our treatment and control groups, respectively. Appendix 1 provides further details on how we identify our sample of non-mobile researchers and the foreign-educated researchers with whom part of them co-authored.

4.4 Outcome variables

In our analysis, we consider four outcome variables: the *number of publications*, the *cumulative number of citations per publication*, the *number of publications in top journals*, and the *share of English publications*.

The *number of publications* measures the researcher's productivity. To construct the variable, we count the number of publications that a non-mobile researcher has published in a year. We rely on the yearly *cumulative number of citations per publication* (stock of citations over stock of publications) to investigate a non-mobile researcher's citations. The third outcome variable is the *number of publications in top journals*. To construct this variable, we match the journals' International Standard Serial Number (ISSN), where non-mobile researchers have published with the ISSNs in SciMagoJournal Rank indicator – a dataset

with the journal ranking constructed based on the quality of citations a journal receives.[6] After matching the journals with the ranking, we count the non-mobile researchers' publications from journals in the top quartile of the Scimago Journal Rank.[7] For the first three variables, we consider their log transformation. The fourth outcome variable is the *share of English publications*, measured by dividing the number of publications in English by the total number of publications yearly.[8] With the share of English publications, we want to identify whether the non-mobile researcher's publication language patterns change after collaborating with a foreign-educated researcher.

5. Econometric strategy

5.1 Matching

Our analysis aims to assess if a non-mobile researcher's scientific performance changes after co-authoring with a foreign-educated researcher. Ideally, we would need to know how the researcher would have performed without such co-authorship and compare the two scenarios, i.e., with co-authorship and without. This observation is not possible, and to overcome this limitation, we construct a control sample of non-mobile researchers with the same characteristics, differing only for coauthoring with no foreign-educated researcher (Yadav et al., 2023).[9]

We employ nearest-neighborhood matching to create comparable treatment and control groups. This matching employs an algorithm to identify a control unit with the closest propensity score to a treated unit. The main idea involves first calculating the propensity of a unit to be in the treatment based on

[6] This rank considers the number of citations and the source of citations that publications from a journal receive to classify the journals (Falagas et al., 2008).

[7] The number of publications in top journals is constructed by calculating the number of publications a non-mobile researcher has each year in journals ranked in the top quartile according to the Scimago Journal Rank. We have opted for a more conservative approach when matching the ISSNs from journals where non-mobile researchers have published. We particularly use the ISSNs assigned to the papers to match with the journal from Scimago's rank. However, some of these ISSNs might change over the years. We have then conducted a fuzzy matching using the journals' names to overcome this issue. The results of this second exercise are similar to the previous one when we estimate the impact of a foreign-educated researcher on a non-mobile researcher's high productivity (see Appendix 2).

[8] A methodological challenge in calculating the share of English publications arises because non-mobile researchers may not publish any paper in specific years, yielding in an undefined number. To overcome this issue, we took the average share of English publications before and after meeting a foreign-educated researcher for the first time for each non-mobile researcher. Then, we replaced the undefined numbers with the averages accordingly. In the case of non-mobile researchers who never collaborated with a foreign-educated researcher, we use the baseline year from the matching and calculate the shares before and after this meeting year.

[9] In their study, Yadav et al. (2023) investigate how co-authoring with a star scientist impacts the productivity of scientists. This is in line with what we research in this paper: how co-authoring with a foreign-educated researcher affects the performance of non-mobile researchers. Hence, their identification strategy technique provides a benchmark for our study.

observable covariates and, second, matching treated and control units with similar scores. This method reduces the imbalance between treated and untreated units, allowing the comparability between groups (Gertler et al., 2016; Rubin, 1973).

In our identification strategy, non-mobile researchers with at least one co-authorship with foreign-educated researchers are included in the treatment group, using the year of the first co-authorship as the treatment year. Non-mobile researchers without such co-authorships are part of the control group. We employ the following covariates: stock of publications, citations, co-authors, scientific field, educational level, and gender. The treatment group's baseline year is the year before the treatment year (*t-1*). For the control group, we include the current year and year of first publication as exact matching covariates to guarantee that matched pairs have the same seniority and baseline year.[10]

Our sample consists of 3,833 non-mobile researchers (2,532 who have co-authored at least once with a foreign-educated researcher and 1,301 who have never co-authored). After the matching, we obtain 1,656 researchers matched (828 researchers in each group). Table 1 presents the balance of covariates before and after the matching. In Panel A, the three indicators on the balance quality (standardized mean difference, variance ratio, and empirical cumulative distribution function (eCDF)) flag that covariates are unbalanced. Values from the Standardized Mean Difference and eCDF mean are far from 0 – a threshold indicating good balance. Variance ratios are not close to the recommended range between 0.5 and 2 (Greiger, 2023). After the matching, balance quality indicators suggest a good matching, as indicated in Panel B.[11,,12]

[10] We use the MatchIt package in R to conduct our matching. When performing the nearest neighborhood matching with this package, we rely on the exact function to guarantee that matched pairs have the same scientific field, year of first publication, gender, baseline year, and educational level.

[11] The only exception is the stock of co-authors, in which treated non-mobile researchers have a slightly higher average.

[12] Appendix 3 displays a plot of the covariates balance before and after the matching.

Table 1 – Assessing the covariates balance before and after the matching

	Panel A - Unmatched (1)					Panel B - Matched (2)				
	Means Treated	Means Control	Std. Mean Diff.	Var. Ratio	eCDF Mean	Means Treated	Means Control	Std. Mean Diff.	Var. Ratio	eCDF Mean
Distance	0.2215	0.1811	0.4158	1.9621	0.1198	0.1852	0.1851	0.0008	0.9973	0.0019
Year of First Publication	2007.0948	2007.4986	-0.0742	1.0292	0.0144	2009.1522	2009.1522	0	1	0
Education level: Master	0.6619	0.8162	-0.326	.	0.1542	0.8418	0.8418	0	.	0
Education level: PhD	0.3381	0.1838	0.326	.	0.1542	0.1582	0.1582	0	.	0
Gender	0.5806	0.552	0.0579	.	0.0286	0.5519	0.5519	0	.	0
Stock of co-authors	10.2840	6.7625	0.0204	18.3616	0.0015	3.6196	3.0459	0.0033	2.6727	0.0041
Stock of publications	5.0735	5.3216	-0.0294	0.9528	0.0039	3.1787	3.2959	-0.0139	0.8088	0.0027
Stock of citations	10.9139	8.3519	0.0197	5.6755	0.0026	1.6775	1.6002	0.0006	0.345	0.002
Current Year	2012.2129	2012.8001	-0.1202	0.9267	0.0203	2011.9275	2011.9275	0	1	0
Field: Art	0.0667	0.0824	-0.0628	.	0.0157	0.0761	0.0761	0	.	0
Field: Biology	0.1181	0.0775	0.1259	.	0.0406	0.0894	0.0894	0	.	0
Field: Business	0.0731	0.0483	0.0951	.	0.0247	0.0495	0.0495	0	.	0
Field: Chemistry	0.0585	0.0296	0.1231	.	0.0289	0.0326	0.0326	0	.	0
Field: Computer science	0.1035	0.0863	0.0565	.	0.0172	0.1111	0.1111	0	.	0
Field: Economics	0.0071	0.0126	-0.0652	.	0.0055	0.0048	0.0048	0	.	0
Field: Engineering	0.0122	0.0116	0.0061	.	0.0007	0.006	0.006	0	.	0
Field: Environmental science	0.0344	0.0256	0.0479	.	0.0087	0.0266	0.0266	0	.	0
Field: Geography	0.1062	0.1016	0.015	.	0.0046	0.1184	0.1184	0	.	0
Field: Geology	0.0043	0.0042	0.0018	.	0.0001	0	0	0	.	0
Field: History	0.0016	0.0007	0.0213	.	0.0008	0.0012	0.0012	0	.	0
Field: Materials science	0.0225	0.013	0.0638	.	0.0095	0.0121	0.0121	0	.	0
Field: Mathematics	0.0138	0.0168	-0.0256	.	0.003	0.0109	0.0109	0	.	0
Field: Medicine	0.1201	0.1688	-0.1499	.	0.0487	0.1715	0.1715	0	.	0
Field: Philosophy	0.0352	0.0405	-0.0291	.	0.0054	0.0362	0.0362	0	.	0
Field: Physics	0.0099	0.0141	-0.0432	.	0.0043	0.0024	0.0024	0	.	0
Field: Political science	0.1145	0.1303	-0.0495	.	0.0157	0.1292	0.1292	0	.	0
Field: Psychology	0.0608	0.0874	-0.1111	.	0.0266	0.0773	0.0773	0	.	0
Field: Sociology	0.0375	0.0486	-0.0583	.	0.0111	0.0447	0.0447	0	.	0
Number of units	2532	1301				828	828			

Notes: This table displays the covariates used for matching and averages for the treatment and control groups before (Panel A) and after (Panel B) the matching. This table also provides statistics to indicate the quality of covariates balance (i.e., standardized mean difference, variance ratios, and empirical cumulative distribution function (eCDF)). For standardized mean difference and eCDF mean, an absolute value close to 0 indicates a good balance, while for variance rations, values close to a range between 0.5 and 2 are recommended. After the matching, the three statistics are close to the recommended values.

Table 2 provides the descriptive statistics summary of our sample at the baseline year. In our treatment and control units sample, 55% of researchers are male, 46.2% are in STEM fields, and 16% hold a PhD degree. Both groups have a similar stock of publications and citations in the baseline year. A slight difference is found in the stock of co-authors, where the treatment group has an average of 3.619 co-authors, while the control group has an average of 3.045.

Table 2 – Descriptive Statistics

Variables	Treatment group (N= 828)	Control group (N= 828)	p-value
	Mean	Mean	
Number of publications	0.899	0.870	0.623
Cumulative number of citations/publication	0.358	0.270	0.047
Number of publications in highly-ranked journals	0.021	0.019	0.761
Share of English publications	0.253	0.229	0.163
Stock of citations	1.677	1.600	0.833
Stock of co-authors	3.619	3.045	0.027
Stock of publications	3.178	3.295	0.492
Gender (male:1)	0.551	0.551	
STEM	0.462	0.462	
Education level (PhD: 1)	0.158	0.158	

Notes: This table summarizes the descriptive statistics of the treatment and control groups at the baseline year. The variables that we use for matching indicate that both groups are similar. The only exception is the stock of co-authors, in which the treatment group has a slightly higher average than the control group. Most researchers in both samples are male (55%) in SSH fields (53,8%) with a Master's degree (84,2%).

5.2 Difference-in-Differences

We complement the matching with the Difference-in-Differences multiple time period estimator of Callaway and Sant'Anna (2021), which allows units to be treated at different points in time and heterogeneous treatment.[13] An important part of this estimator is the Average Treatment Effect on the Treated (ATT) for a specific group (g) in a specific time period (t), denoted as ATT (g, t). This

[13] In assessing the impact of collaborating with a star researcher on her peers, Yadav et al. (2023) complement the matching with a Two-Way Fixed Effects estimator. Nevertheless, recent developments in the causal inference literature acknowledge that this latter estimation lacks robustness in heterogeneous treatment effects, multiple periods set-up, and treatment timing variation (Callaway, 2020; Cunningham, 2021; de Chaisemartin & D'Haultfœuille, 2020; Goodman-Bacon, 2021). To overcome these limitations we implement the Callaway and Sant'Anna estimator.

parameter differentiates the path for the treated group from the path that group would have had if not treated, assuming this would be similar to the path of the control group:

$$ATT(g,t) = E\left[Y_t(g) - Y_t(0) \mid G_g = 1\right] \quad (1)$$

Where $ATT(g,t)$ is the group ATT; g indicates a group that becomes treated in a specific year; $\mathcal{G}$ is the set of treated groups; and $G_g = 1$ is a binary that turns to one when units are first treated in year g.

Callaway and Sant'Anna (2021) require to satisfy three assumptions for the estimation to be consistent. First, staggered treatment adoption implies that once a unit receives the treatment in a period *t*, the unit remains treated for the following periods. Second, the no-anticipation assumption asserts that the outcome of a unit receiving the treatment should not have any impact before the treatment. Third, and most importantly, the parallel trend assumption requires that the path for the treated units before receiving the treatment is not statistically significantly different. The authors suggest that parallel trends hold among units with similar characteristics.

In our econometric framework, we consider those three assumptions. First, once non-mobile researchers co-author with foreign-educated researchers for the first time, they become treated and remain as such. Second, although a publication is the culmination of an intensive period of research, which cannot be observed with our data, there are opportunity costs and uncertainties in collaborating: a researcher does not know in advance what may be the outcome of a research program, let alone a new collaboration. It is even more difficult to compare the outcomes of a new collaboration with those of investing the same time in existing collaborations. We thus assume no anticipation. Third, our matching guarantees comparability between treated and control groups before the treatment, reinforcing the assumption of parallel trends.

Initially, we estimate dynamics effects (i.e., an aggregation scheme to observe the effects given the exposure to treatment during an elapsed time) for each outcome variable (number of publications, cumulative number of citations per publication, number of publications in top journals, and share of English publications):

$$ATT^{ES}(e) = \sum_{g \in \mathcal{G}} w^{ES}(g,e) ATT(g, g+e) \quad (2)$$

Where e is the number of periods exposed to the treatment. Our analysis includes the five years before and after the treatment.[14]

By estimating the dynamic effects, we first obtain an Aggregate ATT to capture the average effect of participating in the treatment during an elapsed time. Subsequently, we obtain an event study to investigate the effect over the years and to verify parallel trends at pre-treatment periods.

In the Event Study, we first consider the impact of co-authoring with at least one foreign-educated researcher. Then, we explore whether diversifying the collaborations with foreign-educated researchers has an impact. To do that, we examine a variety of scenarios. We consider scenarios in which non-mobile researchers have co-authored with an increasing number of distinct foreign-educated researchers, i.e., from one to three different researchers.

As a robustness check, we present Event Study figures using alternative estimators (Sun & Abraham, 2021; Two-way Fixed Effects).

Finally, we explore heterogeneity across fields, distinguishing between STEM and non-STEM fields.

6 Results

6.1 Co-authoring with at least one foreign-educated researcher

Table 3 displays the estimated Average Treatment Effects on the Treated (ATT) from Equation (2) for all outputs. The ATT compares the performance of researchers who co-authored with foreign-educated researchers to the performance of individuals who did not but who were otherwise similar in all relevant aspects, i.e., the assumption is that treated researchers would have followed the same trend as the control group in the absence of the treatment. Our findings show a positive association between co-authoring with foreign-educated researchers and non-mobile researchers' scientific performance. Notably, Column 1 shows that non-mobile researchers' productivity (number of publications per year) increases by 22% relative to the control group. Column 2 provides the point estimate on the citations, showing a rise of 19% in the number of citations for the treated group compared to the control group. In column 3, an examination of publications in top-tier journals shows a small yet positive impact: on average, researchers in the treatment group have 4% more publications

[14] We have chosen this window frame to have considerable data points to observe the parallel trends before the treatment and the effect over the years after the treatment.

in top journals than researchers in the control group. Column 4 investigates changes in publication language patterns. The results indicate a 6 percentage-point upward shift in the share of English publications among researchers in the treatment group after co-authoring with foreign-educated researchers.

Table 3 – Aggregate results: non-mobile researchers' performance

	Number of publications (in log)	Cumulative Number of citations per publications (in log)	Number of publications in top journals (in log)	Share of English publications
	(1)	(2)	(3)	(4)
Co-authoring with foreign-educated researchers	0.2193***	0.1906***	0.0393***	0.0645***
	(0.0231)	(0.0177)	(0.007)	(0.0149)
Observations	16,866	16,866	16,866	16,866
N non-mobile researchers	1,656	1,656	1,656	1,656

Notes: This table provides point estimates for various performance indicators. In Column 1, the data show a 22% increase in publications among non-mobile researchers following co-authorship with foreign-educated researchers. Similarly, Column 2 presents a 19% rise in citation counts per publication. Column 3 shows that non-mobile researchers have a slight yet positive increase of 4% in the number of publications in top journals. Column 4 indicates a positive shift of 6 percentage points in the share of English publications. The levels of statistical significance are: * $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$. Standard errors in parentheses are clustered at the individual level.

6.2 Event Studies results

We adopt an event study framework to investigate the effect over the years and test the assumption of parallel trends in the pre-treatment period. Figures 1 to 4 present the event study graphs, each corresponding to one outcome variable (i.e., number of publications, cumulative number of citations per publication, number of publications in top journals, and share of English publications).

In Figures 1-4, the point estimates for the pre-treatment period confirm the parallel trend assumption for our matched sample: they are close to zero and statistically insignificant. This indicates that there are no discernible pre-trends between treatment and control groups for all four outcomes, suggesting that these groups do not have different scientific performances and publish the same share of English publications before the implementation of the treatment.

With respect to the year of the treatment and the following five years, we observe two main patterns when we examine the effects of co-authoring with foreign-educated researchers on the number of publications of non-mobile researchers (Figure 1). First, we notice a marked increase in non-mobile researchers' productivity coinciding with the year in which they publish with the foreign-educated researchers (year 0). Second, we identify a positive reinforcement as the stock of foreign-educated researchers expands (from Panel 1 to 4). These results suggest that the increase in productivity in the treatment year results from a publication with a foreign-educated researcher (Panel 1). Subsequently, a gain in productivity is maintained as the non-mobile co-author with more foreign-educated researchers. Nevertheless, whether productivity is sustained through increasing collaborations with foreign-educated researchers or by indirect effects such as spillovers and learning processes remains an open question. We further explore these results in Section 7.

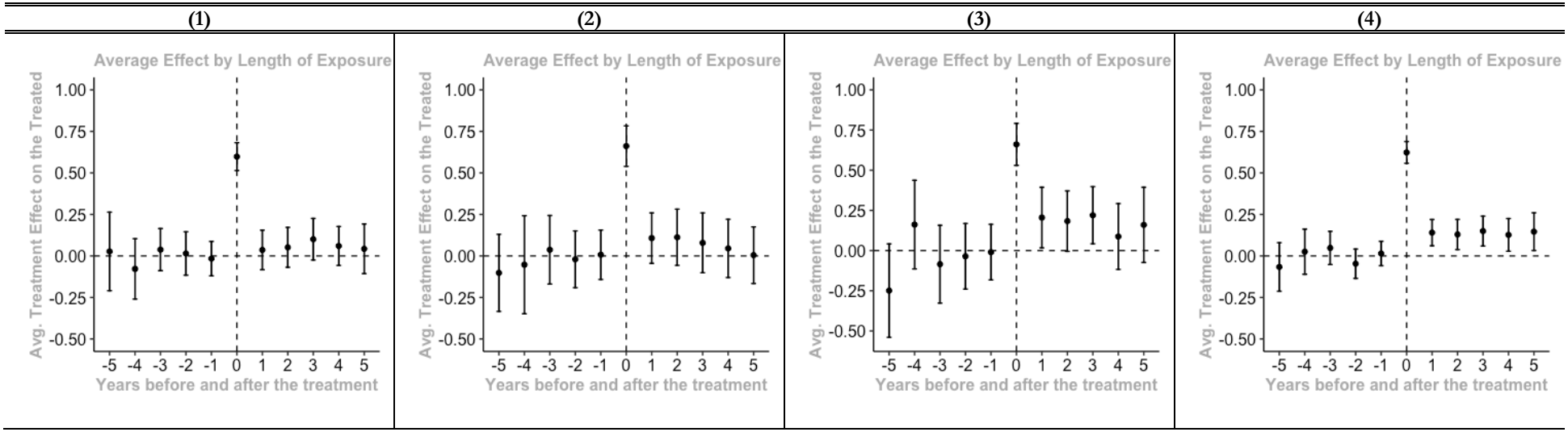
The Event Studies for the cumulative number of citations per publication (Figure 2) show a different pattern (Figure 1). When non-mobile researchers co-author with foreign-educated researchers, we find a significant increase in the cumulative number of citations per publication. In this case, the positive impact is long-lasting even after a co-authorship with only one foreign-educated researcher (Panel 1).

Figure 3 illustrates the dynamic effects of co-authoring with one or more foreign-educated researchers on a non-mobile researcher's publications in top journals. Results follow a pattern similar to the one reported for total publications. Although smaller, there is a positive impact in the year of co-authoring a paper, but not in the following years, unless the non-mobile researchers coauthor with several foreign-educated researchers. In other words, upon co-authoring with foreign-educated researchers, non-mobile researchers have a slight rise in the quality of their publications.

Figure 4 shows changes in the non-mobile researchers' publication language patterns resulting from co-authoring with foreign-educated researchers. Across the different panels, a positive and statistically significant increase in the share of English publications is observed. The only exception is Panel 3, where the treatment group sample size is small, leading to large standard errors and turning the point estimates statistically insignificant. Overall, non-mobile researchers who co-author with foreign-educated researchers become more inclined toward international publishing, as observed by the increase in the share of English publications.

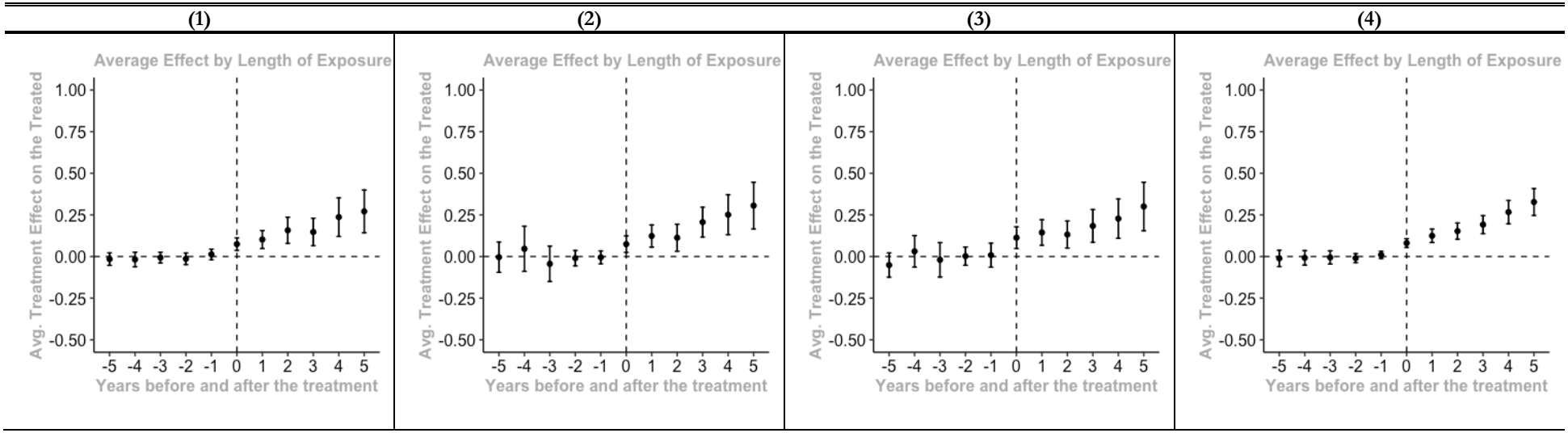
Our findings stay consistent when alternative estimators are applied (see Appendix 4) (Callaway & Sant'Anna, 2021; Sun & Abraham, 2020; Two-way Fixed Effects).

Figure 1 - Effects of co-authoring with foreign-educated researchers on non-mobile researchers' number of publications (in log)



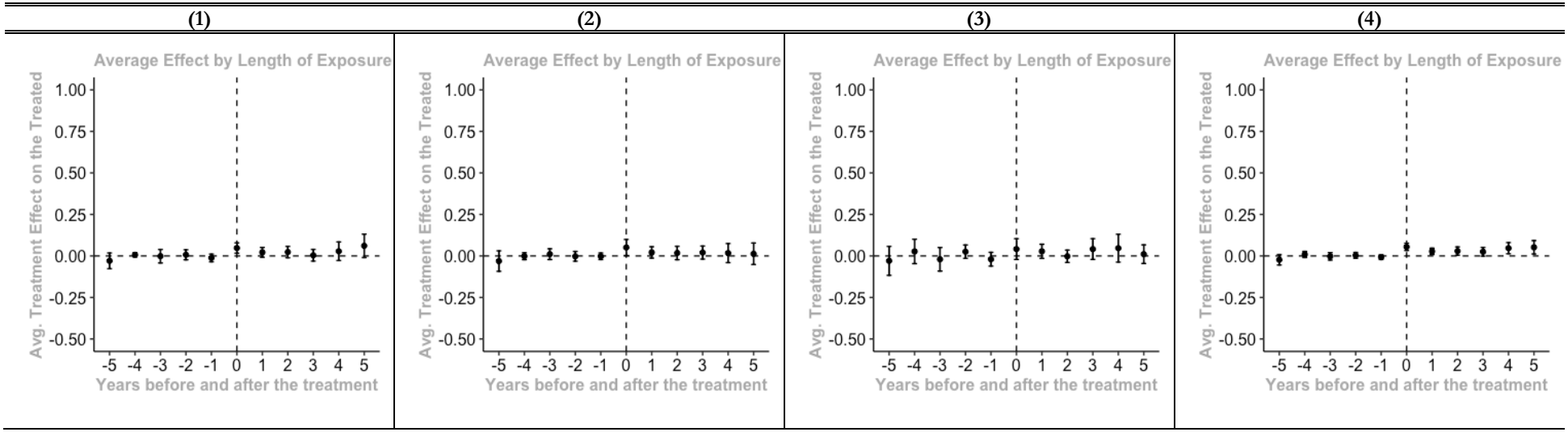
Notes: This figure exhibits the dynamic effects on non-mobile researchers' productivity after co-authoring with one (panel 1), two (panel 2), three (panel 3), and (any) foreign-educated researchers (panel 4). The panels show a pattern: the productivity of non-mobile researchers improves and displays long-lasting effects as they increase the stock of foreign-educated researchers. The bars indicate 95% confidence intervals. Standard errors are clustered at the individual level.

Figure 2 - Effects of co-authoring with foreign-educated on non-mobile researchers' cumulative number of citations per publication (in log)



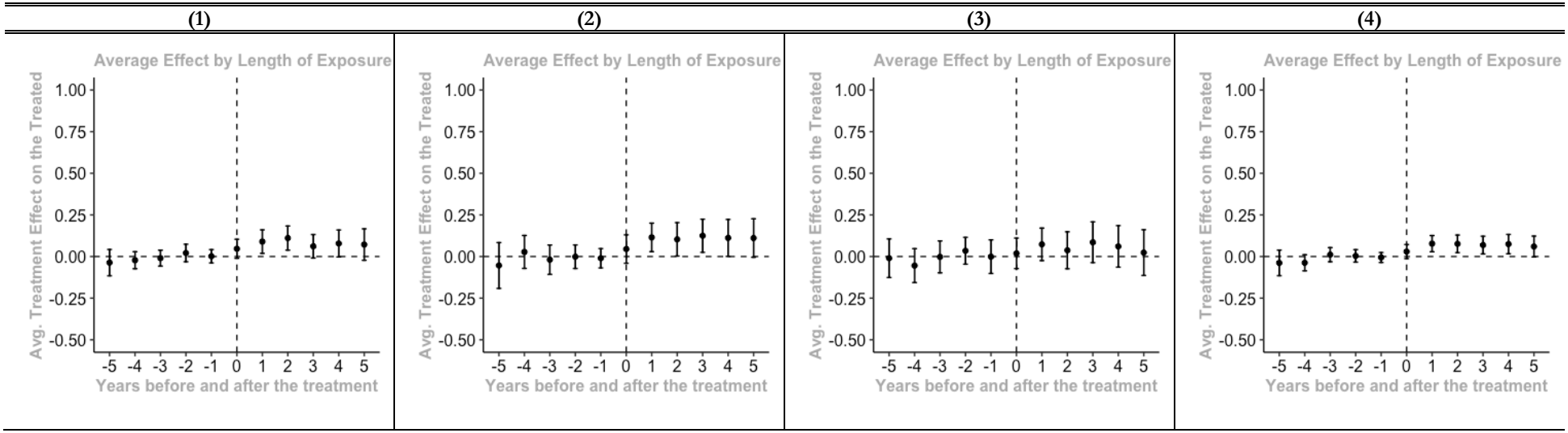
Notes: This figure exhibits the dynamic effects on non-mobile researchers' cumulative number of citations per publication after co-authoring with one (panel 1), two (panel 2), three (panel 3), and (any) foreign-educated researcher (panel 4). The panels illustrate a trend: Non-mobile researchers experience an increased number of citations, even after a single co-authorship with a foreign-educated researcher. Effects intensify as non-mobile researchers co-author with more foreign-educated researchers. The bars indicate 95% confidence intervals. Standard errors are clustered at the individual level.

Figure 3 - Effects of co-authoring with foreign-educated researchers on non-mobile researchers' number of publications in top journals (in log)



Notes: This figure exhibits the dynamic effects on non-mobile researchers' number of publications in top journals after co-authoring with one (panel 1), two (panel 2), three (panel 3), and (any) foreign-educated researcher (panel 4). The panels illustrate a modest and not statistically significant impact on publications in top journals even after increasing the number of foreign-educated researchers. The bars indicate 95% confidence intervals. Standard errors are clustered at the individual level.

Figure 4 - Effects of co-authoring with foreign-educated researchers on non-mobile researchers' share of English publications



Notes: This figure demonstrates the dynamic effects on non-mobile researchers' share of English publications after co-authoring with one (panel 1), two (panel 2), three (panel 3), and (any) foreign-educated researcher (panel 4). The panels indicate a consistent pattern: A noticeable increase in the share of English publications after co-authoring with foreign-educated researchers. The only exception is panel 3, where, despite positive point estimates, the results are not statistically insignificant. The bars indicate 95% confidence intervals. Standard errors are clustered at the individual level.

6.3 Exploring field heterogeneity

In this section, we ask whether the patterns we have reported above change by macro field. To examine possible heterogeneous effects, we group researchers into two macro-scientific fields: Science, Technology, Engineering, and Mathematics (STEM) and Social Sciences and Humanities (SSH).

Table 4 illustrates the effects on non-mobile researchers' performance in the scenario where they have co-authored with at least one foreign-educated researcher. Panel A details these effects for researchers in STEM fields, while Panel B focuses on researchers in the SSH fields.

Table 4 presents two patterns. First, non-mobile researchers from both macro fields exhibit increased performance indicators following collaborative efforts with foreign-educated researchers. However, the magnitude of these effects varies between macro fields. The positive impact on the number of publications is similar to that of SSH and STEM researchers. However, the effect on the other indicators (mainly related to visibility) seems to be larger in STEM than in SSH. Notably, the impact on citations and publication language patterns is large. The cumulative number of citations per publication of STEM non-mobile researchers increases by almost 26% (column 2), the number of publications in top journals increases by 6% (column 3), and the share of English publications increases by 9 percentage points (column 4). In comparison, SSH counterparts experience a 13% increase in citations (column 6), a 2% increase in the number of publications in top journals (column 7), and almost a 3 percentage point increase in the share of English publications, although statistically insignificant (column 8). These results show that STEM non-mobile researchers benefit more in citations and reach a wider audience than SSH researchers.

Table 4 – Aggregate results: Non-mobile researchers' performance by macro field (STEM and SSH)

	Panel A - STEM				Panel B - SSH			
	Number of publications (in log)	Cumulative Number of citations per publications (in log)	Number of publications in top journals (in log)	Share of English publications	Number of publications (in log)	Cumulative Number of citations per publications (in log)	Number of publications in top journals (in log)	Share of English publications
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Co-authoring with foreign-educated researchers	0.22***	0.2563***	0.0609***	0.0913***	0.2287***	0.1295***	0.0218*	0.035
	(0.0359)	(0.0259)	(0.0115)	(0.0228)	(0.0312)	(0.0203)	(0.0089)	(0.0202)
Observations	7,851	7,851	7,851	7,851	9,015	9,015	9,015	9,015
N non-mobile researchers	766	766	766	766	890	890	890	890

Notes: This table presents point estimates across various performance indicators for non-mobile researchers in STEM and SSH fields. Columns 1 to 4 detail the performance indicators of STEM non-mobile researchers, while Columns 5 to 8 are dedicated to those in SSH fields. In general, STEM non-mobile researchers benefit more from co-authoring with foreign-educated researchers than SSH non-mobile researchers regarding citations, publications in top journals, and the share of English publications. However, there is one exception: SSH and STEM non-mobile researchers experience a similar increase in the number of publications. The levels of statistical significance are: * $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$. Standard errors in parentheses are clustered at the individual level.

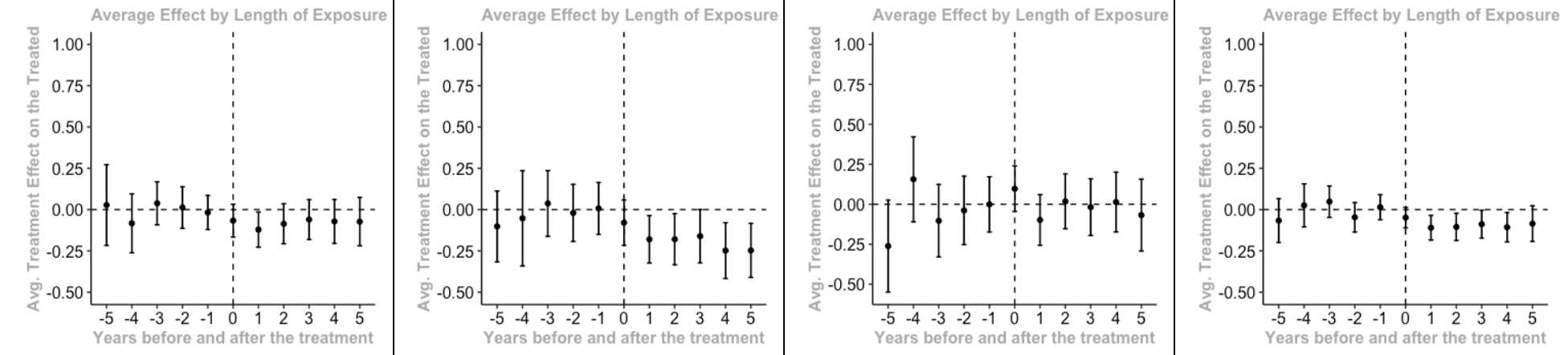
7 Digging into the results

In subsection 6.2, we show that non-mobile researchers publish more, including in top journals, only if they collaborate with several foreign-educated researchers. This suggests that the higher number of publications (including in top journals) results from co-authoring publications with foreign-educated researchers rather than an increase in productivity sustained independently from those collaborations. To test for this, we remove all publications co-authored with foreign-educated researchers.

Figure 5 demonstrates that, excluding publications co-authored with foreign-educated researchers, the treated non-mobile researchers publish slightly less than the control group. This finding suggests that the treated non-mobile researchers do not publish more independently from the foreign-educated researchers. It seems that as non-mobile researchers frequently co-author with foreign-educated peers, the time invested in this co-authorship is large, leaving no extra room for publications without them.

Figure 5 - Effects of co-authoring with foreign-educated researchers on non-mobile researchers' number of publications without foreign-educated researchers (in log)

(1)	(2)	(3)	(4)



Notes: This figure exhibits the dynamic effects on non-mobile researchers' productivity (without publications with foreign-educated researchers) after co-authoring with one (panel 1), two (panel 2), three (panel 3), and (any) foreign-educated researchers (panel 4). The panels show a pattern: non-mobile productivity is not sustained when foreign-educated researchers are not involved. The bars indicate 95% confidence intervals. Standard errors are clustered at the individual level.

8 External validity

Our results show a positive reinforcement in the performance of non-mobile researchers when collaborating with foreign-educated ones. However, part of these results might be driven by different characteristics of Colombia, such as the quality of the scientific infrastructure in the country or funding availability. To test the external validity of our results, we perform the same analysis with a similar dataset of Brazilian scientists. The difference between the two datasets is that while we have information on Colombian researchers who updated their CVs in different years, we only have information about Brazilian researchers who updated their CVs in 2020.

In Appendix 5, we include similar tables and figures presented above for the Brazilian data. Our results are consistent throughout. We first observe an increase in all outcome indicators when non-mobile researchers collaborate with foreign-educated researchers (see Table 7). Investigating the Event Study Figures (see Figures 10-13), we also notice a positive reinforcement in the number of publications, the number of publications in top journals, and the share of English publications, as non-mobile researchers collaborate with more foreign-educated researchers. Similarly, we find that non-mobile researchers experience an increase in visibility even after collaborating with one foreign-educated researcher. Finally, similar results are also found when differentiating researchers by macrofield: overall, STEM non-mobile researchers experience a higher visibility in terms of citations, publications in top journals, and share of English publications than SSH non-mobile ones (see Table 7).

9 Discussion and conclusion

In this paper, we tackle a significant yet underexplored question in the literature: do foreign-educated researchers influence the performance of their non-mobile colleagues who remain in their sending countries through direct collaboration? To explore this question, we construct a unique and extensive panel dataset, combining CV, publication, and Ph.D. scholarship list data from active Colombian researchers in different fields between 1990 and 2021. We implement a nearest-neighborhood matching to create comparable groups. We also use a Difference-in-Differences with multiple time period estimator to estimate the impact over the years. Furthermore, we explore heterogeneity across researchers in the STEM and SSH fields.

Our initial findings demonstrate a positive and statistically significant association between co-authoring with foreign-educated researchers and an increase in the scientific performance of non-

mobile researchers. Notably, non-mobile researchers who co-author with foreign-educated peers experience increased performance outputs: a 22% rise in their publications, a 19% increase in citations, a 4% growth in the number of publications in top journals, and a 6 percentage points boost in the share of English publications. Disaggregating these results by macro-fields, we observe different dynamics. Non-mobile researchers in SSH and STEM fields have similar productivity benefits. Conversely, STEM researchers exhibit higher gains in citations, frequency of publications in top journals, and share of English publications.

The Event Study results show distinct patterns. First, we find a positive reinforcement of the effect on publications when non-mobile researchers co-author with more foreign-educated researchers. These results align with Yadav et al. (2023), whose findings show that a single co-authorship with a star scientist only increases peers' productivity in the first year. As peers expand collaborations with other star scientists, there has been a gain in productivity over the years.

Further exploring the Event Study on scientific productivity, we find no effect on independent production (without the foreign-educated researchers). This result suggests that non-mobile and foreign-educated researchers have complementary assets, which leads them to collaborate. There might also be opportunity costs: it might be more expensive for non-mobiles to produce independently than maintain the collaboration with foreign-educated researchers.

Regarding citations, we find a long-lasting impact even after one co-authorship with a foreign-educated researcher. These findings can be interpreted through various lenses. First, non-mobile researchers might benefit from simply associating with foreign-educated researchers, often perceived as more productive (Gibson & McKenzie, 2014; Scellato et al., 2015). These collaborations potentially increase non-mobile researchers' reputations, contributing to the perception of their work as high-quality. Second, co-authoring with foreign-educated researchers provides non-mobile researchers opportunities to acquire new skills and knowledge, positively reinforcing these latter researchers' performance (Fry & Furman, 2023; Yang et al., 2022). Last, the increase in the number of citations can be attributed to network effects (Uddin et al., 2013). Foreign-educated researchers often have more extensive and diverse networks (Petersen, 2018; Scellato et al., 2015). By co-authoring with foreign-educated researchers, non-mobile researchers' citations may also be impacted by reinforcing network effects. A possible concern might be that the additional citations are those linked to joint publications with foreign-educated researchers.

The Event Study results on publications in top journals indicate a small effect, even after a non-mobile researcher collaborates with more foreign-educated researchers. Nevertheless, this small effect does not necessarily indicate that non-mobile researchers are not learning from foreign-educated researchers and becoming more productive researchers. Instead, it might be attributed to the nature of publishing in top journals, where acceptance rates are relatively low (Haensly et al., 2008; Sugimoto et al., 2013).

From the Event Study graphs, we also show that treated non-mobile researchers increase their share of English as they start collaborating with foreign-educated researchers. This shift suggests that foreign-educated researchers are essential for non-mobile ones to reach a broader and more global audience.

Overall, this study underlines the role of foreign-educated researchers in helping non-mobile researchers increase their scientific performance. Notably, our findings suggest that collaborating with foreign-educated researchers significantly improves the positioning of non-mobile researchers in the scientific community while also increasing the share of publications in English.

Our work makes several contributions to the existing literature. Along with other authors (Franzoni et al., 2018; Fry & Furman, 2023; Fry, 2023; Müller et al., 2023; Yang et al., 2022), our study diverges from the traditional ones on researchers' mobility with a focus on how mobility experiences directly impact foreign-educated researchers. Instead, we look at the implications of mobility experiences at large, especially for researchers who have never moved abroad. What differentiates our work from the authors investigating the extended effects of a mobility experience is that we consider an analysis at the micro-level, focusing on individuals as units of analysis rather than considering the meso-level, such as a department. Second, we expand the research scope to include researchers from a broad range of scientific fields instead of narrowing it to one field.

This paper opens opportunities for future research. Our findings indicate that co-authoring with foreign-educated researchers increases the performance of non-mobile researchers. However, the mechanisms behind this improvement remain to be further explored. Previous studies have identified potential mechanisms. For instance, according to Ito et al. (2024), foreign-educated researchers offer access to networks of foreign researchers. Future research is needed to determine whether the benefits of co-authoring with foreign-educated researchers also arise from knowledge transfer and access to

skills, as stated in the literature on teams in science (Ductor, 2015; Hart, 2000). A promising research avenue also involves expanding this study to include researchers from other middle-income countries, such as Mexico and South Africa. These countries have centralized CV systems similar to Colombia's CVLAC (González-Sauri & Rossello, 2023; Müller et al., 2023), providing an opportunity to validate our findings in the context of middle-income countries with different sizes and levels of socio-economic development. A final opportunity involves differentiating foreign-educated researchers into diaspora (i.e., those researchers who have remained abroad) and returnees (i.e., those who have returned to their country of origin). We have attempted to isolate the impact of returnees and diaspora researchers; however, given the small sample size, we could not detect any differential effect.

Our findings carry significant policy implications, especially for middle-income countries with scientific systems akin to those in Colombia, such as Peru and Chile. Those countries can increase the overall productivity of their scientific system by sponsoring scientific mobility programs for their locals to go abroad. In return, those who benefit from those programs can carry novel scientific and technological knowledge back to their countries of origin and co-author with researchers who never moved. Also, those foreign-educated researchers who remain abroad can provide access to infrastructure and a network of international colleagues. However, this policy implication alone is not a complete solution. Countries should foster collaborations among their researchers, but improving their local training and scientific infrastructure is also important for non-mobile researchers to establish effective collaboration and assimilate the knowledge carried by foreign-educated researchers.

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Appendix 1 – Dataset and sample construction

We construct our database, including researchers' profiles and their publications, by combining three primary data sources: CvLAC, the lists of PhD fellowship beneficiaries from the three main national funding agencies (Colfuturo, Colciencia, and Fulbright in Colombia), and OpenAlex.

As the first step, starting from CvLAC, we extracted the names of all the Colombian researchers who uploaded their CVs to the national dataset between 1990 and 2021, identifying 28,729 individuals. To ensure the coverage of the whole Colombian population of researchers and also retrieve those who did not register in CvLAC (maybe because they were abroad), we complemented the original list of names with the names appearing in the lists of the PhD holders from the main national funding agencies, adding another 3,917 individuals. As the next step, we matched our list of names with OpenAlex's publication data. In matching with OpenAlex's publication data, we faced the challenge of having multiple identifiers for a single researcher. To overcome this issue, we employed several author name disambiguation strategies, such as Author name fuzzy match, ORCID match, Title fuzzy match, Bibliographic info match, and DOI match. Using the information of the publications self-declared and uploaded to CvLAC in the latter two matching strategies helped us attribute unequivocal publications to researchers. In OpenAlex, we matched 68% of our initial sample. In other words, we identified 19,661 researchers with at least one publication from OpenAlex.

Considering the affiliations retrieved in CvLAC's CVs and OpenAlex publication affiliations, we identified 10,666 researchers who have completed a master's or Ph.D. in Colombia and have not spent more than 11 consecutive months abroad. However, some of these non-mobile researchers are not active in publishing. We set a 3-publication threshold to restrict our final sample of active researchers. Doing that, we ended up with 6,609 non-mobile researchers.

We reconstructed the complete co-authorship network to distinguish among non-mobile researchers, those who collaborated with foreign-educated researchers, and those who restricted their collaborations to locals. Following previous studies, we consider foreign-educated researchers as those who pursued their PhD abroad (Kahn & MacGarvie, 2012, 2016; Liang et al., 2022; Turpin et al., 2008).

The final step in constructing our sample involves removing non-mobile researchers who collaborated with a foreign-educated researcher in their first year of entry into the dataset. This adjustment is necessary when applying a Difference-in-Differences approach since it requires observing pre-treatment trends to assume that treated non-mobile researchers would have behaved similarly to the control group in the absence of treatment in the post-treatment period (Angrist, 2008).

We ended up with a final sample of 3,833 individuals, of whom 2,532 co-authored with at least one foreign researcher.

Appendix 2 – Extra analysis on publications in top journals and publications in Spanish

Table 5 presents extra analysis conducted in our study. To construct the 'number of publications in top journals indicator,' we precisely match ISSNs from the publications in our dataset with data from the SciMago Journal Rank. However, the ISSNs of some journals have changed over the years, leading to a lack of match. To overcome this limitation, we employ a fuzzy matching technique for further validation. Notably, the result in Column 1 is almost identical to the one in Column 3 of Table 3, indicating consistency in our results. Column 2 displays the aggregate effect on the share of Spanish publications. This result illustrates that non-mobile researchers in the treatment group tend to publish more in English while decreasing their output in Spanish.

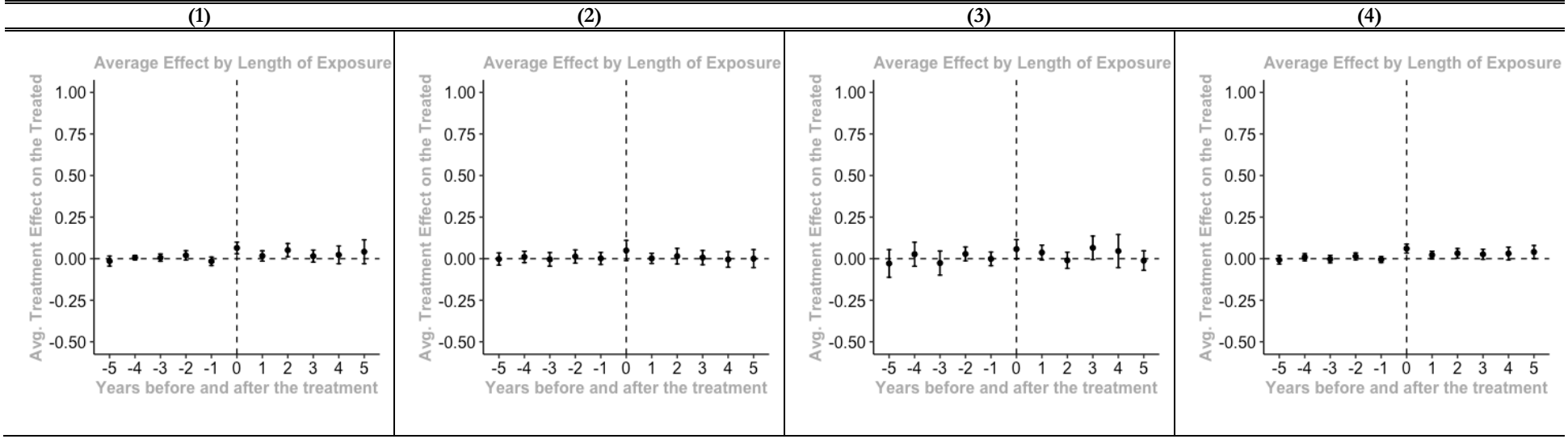
Table 5 – Additional aggregate results: Non-mobile researchers' performance

	Number of publications in top journals (in log)/Fuzzy matching	Share of Spanish publications
	(1)	(2)
Co-authoring with foreign-educated researchers	0.0354***	-0.0778***
	(0.0073)	(0.0172)
Observations	16,866	16,866
N non-mobile researchers	1,656	1,656
Individual Fixed Effects	YES	YES

Notes: This table provides point estimates for additional performance indicators. In column 1, the data shows a 3.5% increase in top publications among non-mobile researchers following co-authorship with foreign-educated researchers. Colum 2 shows that non-mobile researchers have a decrease of 8 percentage points in the share of Spanish publications after co-authoring with foreign-educated researchers. The levels of statistical significance are: * $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$. Standard errors in parentheses are clustered at the individual level.

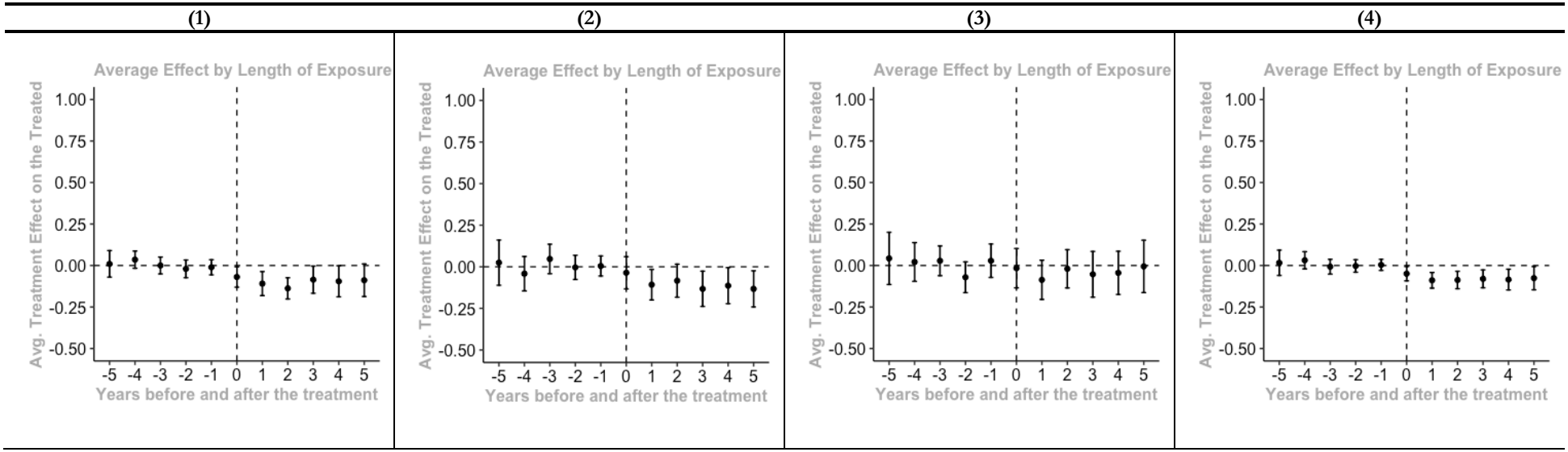
Figures 6 and 7 illustrate the effect on non-mobile researchers' number of publications in top journals and share of Spanish publications, respectively. In Figure 6, employing the 'the number of publications in top journals' outcome variable – constructed with fuzzy matching – leads to results closely aligned to those in Figure 3. Figure 7 shows a discernible pattern: as non-mobile researchers co-author with foreign-educated researchers, there is a decrease in Spanish publications and an increase in English Publications (see Figure 4).

Figure 6 - Effects of co-authoring with foreign-educated researchers on non-mobile researchers' number of pub in top journals (in log)/fuzzy matching



Notes: This figure exhibits the dynamic effects on non-mobile researchers' number of publications in top journals after co-authoring with one (panel 1), two (panel 2), three (panel 3), and (any) foreign-educated researcher (panel 4). The panels illustrate a modest impact on publications in top journals even after increasing the number of foreign-educated researchers. The bars indicate 95% confidence intervals. Standard errors are clustered at the individual level.

Figure 7 - Effects of co-authoring with foreign-educated researchers on non-mobile researchers' share of Spanish publications

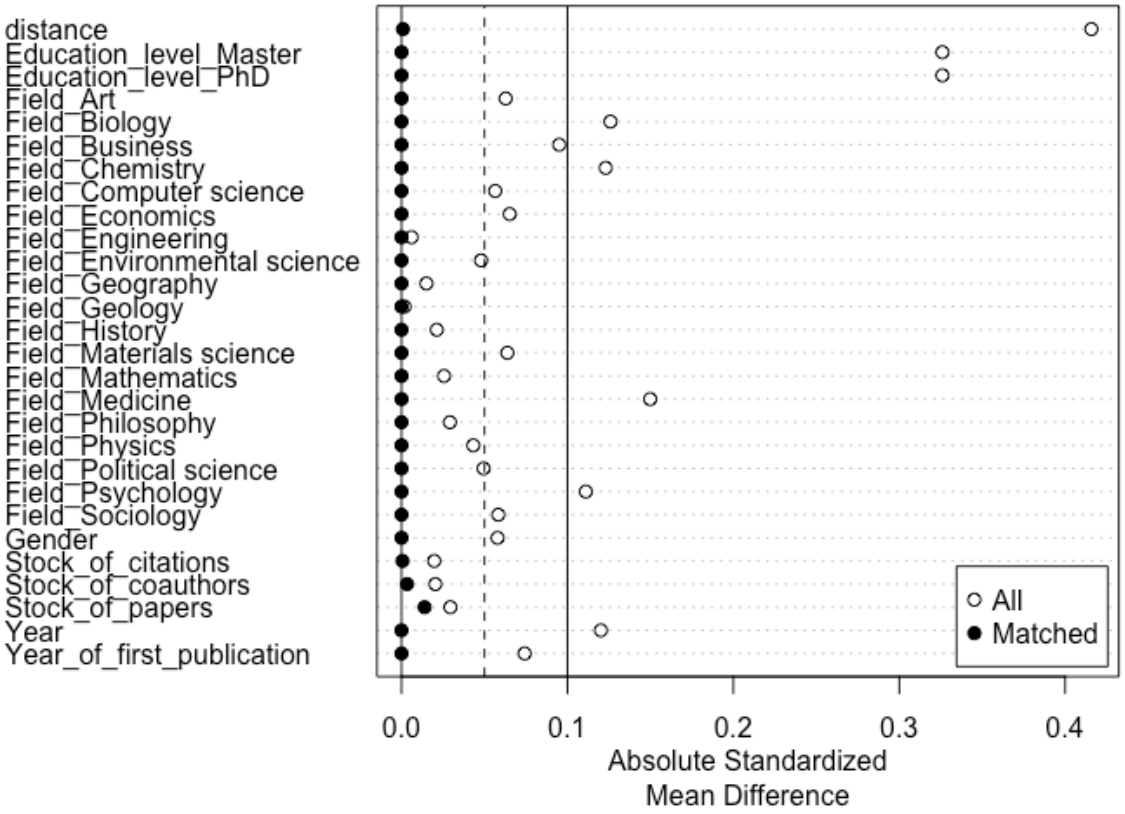


Notes: This figure demonstrates the dynamic effects on non-mobile researchers' share of Spanish publications after co-authoring with one (panel 1), two (panel 2), three (panel 3), and (any) foreign-educated researchers (panel 4). The panels indicate a decrease in the share of Spanish publications after co-authoring with foreign-educated researchers. The only exception is panel 3, where, despite negative point estimates, the results are not statistically insignificant. The bars indicate 95% confidence intervals. Standard errors are clustered at the individual level.

Appendix 3 - Covariate balance plot

Figure 8 visually represents the Standardized Mean Difference columns from Table 1. The white dots in the figure represent the Standardized Mean Difference between baseline covariates from treatment and control groups before the matching. On the other hand, the black dots represent the mean differences after the matching. Notably, the figure shows that nearly all covariates' Absolute Standardized Mean Differences are near zero following the matching. This indicates that treatment and control groups are well-matched based on the covariates.

Figure 8– Covariate balance plot



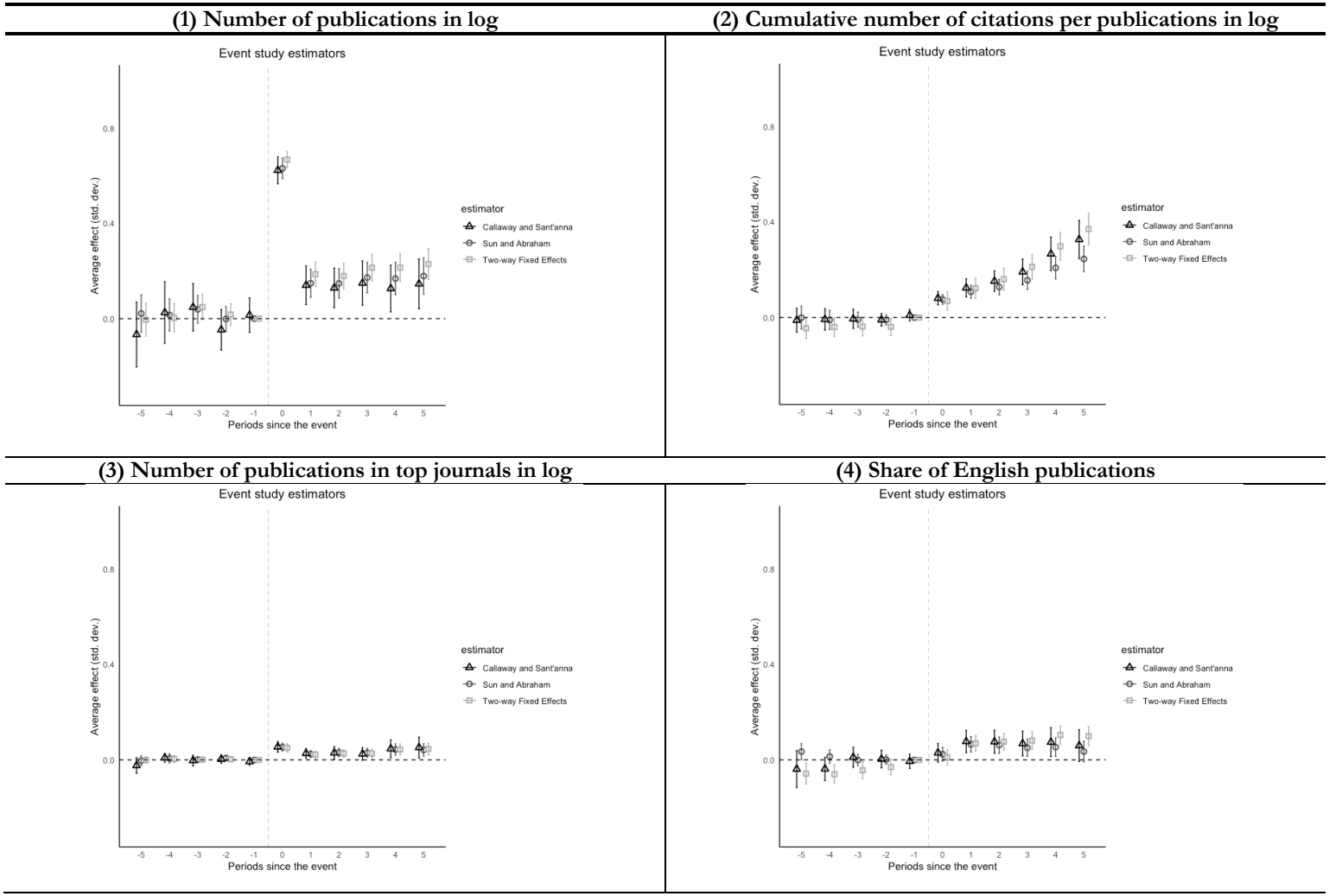
Notes: This figure demonstrates graphically the balance of covariates before and after the matching. Before the matching, the white dots are highly spread, indicating that the covariates between the treatment and control groups are not balanced. After the matching, the black dots are close to zero, showing that the covariates are well-balanced between the groups.

Appendix 4: Different Difference-in-Differences Estimators

We rely on several Difference-in-Differences estimators to investigate the consistency of our point estimates, given that these estimators have different assumptions and methods (Callaway & Sant'Anna, 2021; Sun & Abraham, 2020; Two-way Fixed Effects). For example, the Two-way Fixed Effect estimator assumes a strong assumption of homogenous treatment effects (Callaway, 2020), and the Sun & Abraham (2021) estimator relies on the Ordinary Least Squares regressions with many interaction terms for its estimation. Given these differences, relying on a range of estimators is important to show robustness in the results (Freedman et al., 2023).

Figure 9 presents the event study graphs on all four performance indicators in the scenario where non-mobile researchers have co-authored with (any number of) foreign-educated researchers. Across all four graphs, the parallel trends assumption holds: regardless of the estimator employed, the point estimates are consistently around zero, showing no divergent trends in pre-treatment years. Different estimators provide similar point estimates in all four graphs during the treatment year and subsequent periods, reinforcing our findings' robustness.

Figure 9 – Effects of co-authoring with foreign-educated researchers on the performance of non-mobile researchers over time



Notes: This figure presents the Event Study plots on performance indicators following co-authoring with (any) number of foreign-educated researchers, employing multiple Difference-in-Differences estimators (Callaway & Sant'Anna, 2021; Sun & Abraham, 2020; Two-way Fixed Effects). Panel 1, on the number of publications (in log), indicates a notable peak in the number of publications in the year of the treatment. Although the point estimates decrease in the following years, they remain stable, positive, and statistically significant. Panel 2 shows that treated researchers steadily increase the cumulative number of citations per publication following the treatment. Panel 3 illustrates that co-authoring with foreign-educated researchers has a slight yet positive and stable impact on the number of publications in top journals over the years. Panel 4 demonstrates a stable yet upward shift in the share of English publications. It indicates that non-mobile researchers who co-authored with foreign-educated researchers shifted the language of their publications towards English more than those in the control group. In the four panels, we use different estimators to indicate that the estimations are robust and to test for parallel trends during pre-treatment periods. The bars indicate 95% confidence intervals. Standard errors are clustered at the individual level.

Appendix 5 – Analysis using the dataset on Brazilian researchers

The Brazilian data has a similar structure and data sources to the Colombian data. In the case of Brazil, we rely on Lattes, which is the benchmark for all academic CV repositories in Latin America, and scholarship lists from the Coordination for the Improvement of Higher Educational Personnel (CAPES) and the National Council for Scientific and Technological Development (CNPq). We also rely on OpenAlex to gather bibliometric information.

After assembling the dataset and identifying the different types of researchers, we have a final sample of 43,073 Brazilian non-mobile researchers. It is important to mention that, in the Brazilian case, we include only researchers who have a PhD, as it is a prerequisite in the country to continue as researchers in academia.

We then perform a similar matching to the Colombian case with some adaptation. In the case of the Brazilian sample, we do not include gender and education level for some reasons. First, we do not have information on the gender of the researchers available. Although we attempted to fix this issue using an R package to identify the gender through the names, we could not assign a gender to many non-mobile researchers. Second, as we focus on Brazilian non-mobile researchers with a PhD, it was unnecessary to include the education level differentiating researchers with only a Master's or a PhD, as we did for the Colombian sample. Finally, given that we do not include these two covariates for the Brazilian match, we add an extra covariate: the stock of English publications.

With the matching, we filter our final sample to 13,100 Brazilian researchers (6,550 in each group). Similar to the Colombian case, matched researchers have similar covariates, and the different indicators show a good balance (see Table 6).

Table 6 – Assessing the covariates balance before and after the matching for the Brazilian sample

	Panel A - Unmatched (1)					Panel B - Matched (2)					
	Means Treated	Means Control	Std. Mean Diff.	Var. Ratio	eCDF Mean	Means Treated	Means Control	Std. Mean Diff.	Var. Ratio	eCDF Mean	Std. Pair Dist.
Distance	0.3083	0.1528	0.938	1.6846	0.2742	0.1926	0.1926	0.0001	1.0001	0.0001	0.0004
Year of First Publication	2004.4083	2006.3222	-0.2863	1.0372	0.0598	2008.2545	2008.2545	0	1	0	0
Stock of co-authors	15.4026	10.8934	0.1362	3.2838	0.0169	5.7826	5.4834	0.009	1.0025	0.0014	0.0631
Stock of publications	6.5367	5.899	0.0727	1.2866	0.0045	3.0882	3.1423	-0.0062	0.9629	0.0004	0.0527
Stock of citations	7.1142	4.8393	0.0767	1.4909	0.0056	1.1956	1.1832	0.0004	0.685	0.0005	0.0581
Stock of Eng. publications	2.2673	1.3166	0.2336	1.5081	0.0113	0.525	0.529	-0.001	0.9844	0.0002	0.1136
Current year	2010.1483	2012.917	-0.4573	1.0737	0.0865	2011.4276	2011.4276	0	1	0	0
Field: Art	0.0206	0.1327	-0.7877	.	0.112	0.0687	0.0687	0	.	0	0
Field: Biology	0.1909	0.0521	0.3532	.	0.1388	0.0776	0.0776	0	.	0	0
Field: Business	0.0269	0.0212	0.0352	.	0.0057	0.0171	0.0171	0	.	0	0
Field: Chemistry	0.1074	0.0331	0.2401	.	0.0743	0.0476	0.0476	0	.	0	0
Field: Computer science	0.0505	0.0441	0.0295	.	0.0065	0.045	0.045	0	.	0	0
Field: Economics	0.006	0.0068	-0.0105	.	0.0008	0.0029	0.0029	0	.	0	0
Field: Engineering	0.0018	0.0021	-0.006	.	0.0003	0.0003	0.0003	0	.	0	0
Field: Environmental science	0.0345	0.0179	0.0909	.	0.0166	0.0162	0.0162	0	.	0	0
Field: Geography	0.0505	0.0555	-0.0226	.	0.005	0.0582	0.0582	0	.	0	0
Field: Geology	0.0126	0.0048	0.0702	.	0.0078	0.0021	0.0021	0	.	0	0
Field: History	0.0001	0.0002	-0.0142	.	0.0001	0	0	0	.	0	0
Field: Materials science	0.0474	0.0215	0.1217	.	0.0259	0.0237	0.0237	0	.	0	0
Field: Mathematics	0.0124	0.0222	-0.089	.	0.0098	0.0125	0.0125	0	.	0	0
Field: Medicine	0.228	0.0871	0.3357	.	0.1408	0.1192	0.1192	0	.	0	0
Field: Philosophy	0.0069	0.0413	-0.4175	.	0.0344	0.0202	0.0202	0	.	0	0
Field: Physics	0.0099	0.0155	-0.057	.	0.0056	0.0076	0.0076	0	.	0	0
Field: Political science	0.0686	0.1711	-0.4053	.	0.1025	0.1918	0.1918	0	.	0	0
Field: Psychology	0.0524	0.0772	-0.1111	.	0.0248	0.0798	0.0798	0	.	0	0
Field: Sociology	0.0725	0.1936	-0.4669	.	0.1211	0.2095	0.2095	0	.	0	0
Number of units	30510	12563				6550	6550				

Notes: This table displays the covariates used for matching and averages for the treatment and control groups before (Panel A) and after (Panel B) the matching. This table also provides statistics to indicate the quality of covariates balance (i.e., standardized mean difference, variance ratios, and empirical cumulative distribution function (eCDF)). For standardized mean difference and eCDF mean, an absolute value close to 0 indicates a good balance, while for variance rations, values close to a range between 0.5 and 2 are recommended. After the matching, the three statistics are close to the recommended values.

Table 7 reports the ATTs for the Brazilian sample. Similar to the results from Table 3, we also observe an increase in the performance indicators of treated Brazilian non-mobile researchers. On average, they experience an increase of 30% in the number of publications, 22% in citations, 8% in publications in top journals, and a 13 percentage point rise in the share of English publications.

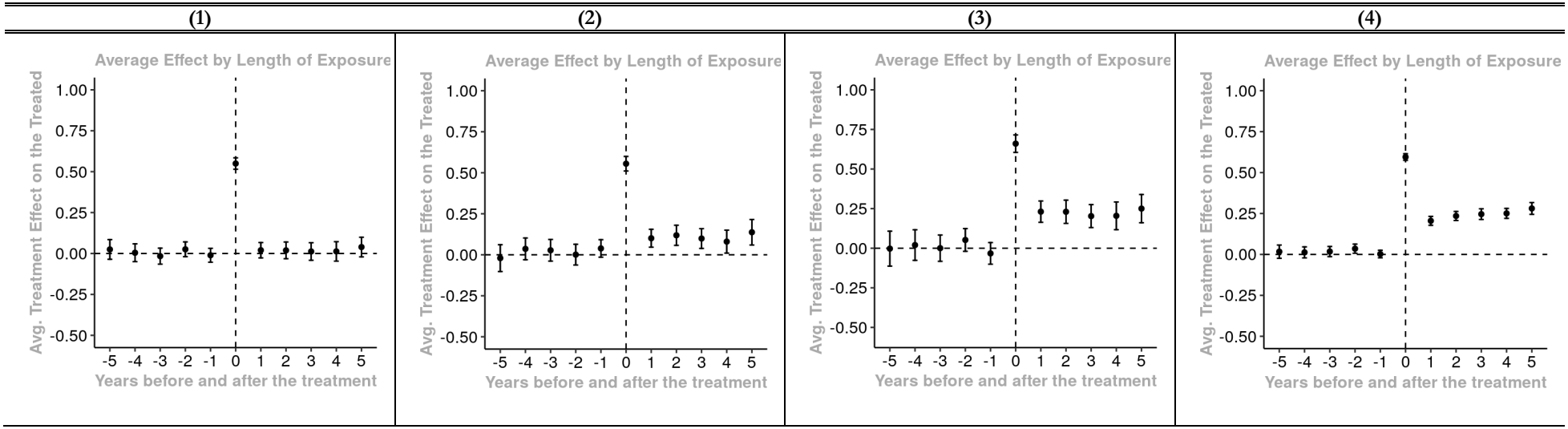
Table 7 – Aggregate results: Brazilian non-mobile researchers' performance

	Number of publications (in log)	Cumulative Number of citations per publication (in log)	Number of publications in top journals (in log)	Share of English publications
	(1)	(2)	(3)	(4)
Co-authoring with foreign-educated researchers	0.3022***	0.2234***	0.0791***	0.1347***
	(0.0075)	(0.0057)	(0.0031)	(0.0049)
Observations	163,385	163,385	163,385	163,385
N non-mobile researchers	13,100	13,100	13,100	13,100

Notes: This table provides point estimates for various performance indicators. In Column 1, the data show a 30% increase in publications among non-mobile researchers following co-authorship with foreign-educated researchers. Similarly, Column 2 presents a 22% rise in citation counts per publication. Column 3 shows that non-mobile researchers have a slight yet positive increase of 8% in the number of publications in top journals. Column 4 indicates a positive shift of 13% in the share of English publications. The levels of statistical significance are: * $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$. Standard errors in parentheses are clustered at the individual level.

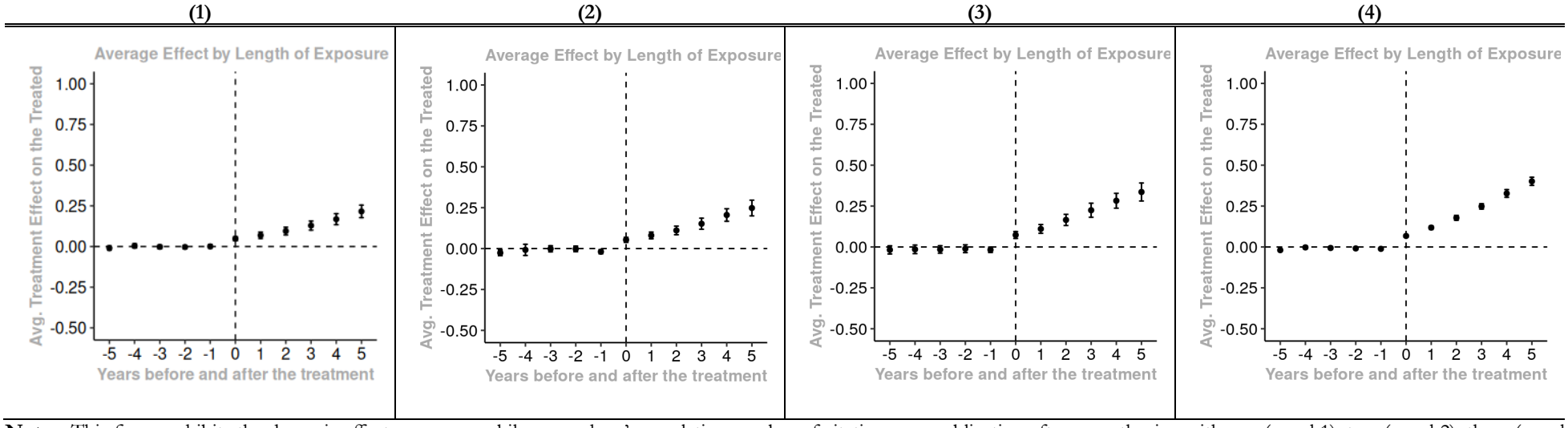
Figures 10 to 13 show the Event Study results of the different outcome variables. We also observe two patterns, as indicated in Figures 1 to 4 (for the Colombian case). First, as non-mobile researchers collaborate with different foreign-educated researchers, there is an increase in the point estimates. Second, similar to the Colombian case, even after collaboration with one foreign-educated researcher, there is a long-lasting effect in citations.

Figure 10 - Effects of co-authoring with foreign-educated researchers on non-mobile researchers' number of publications (in log), Brazil



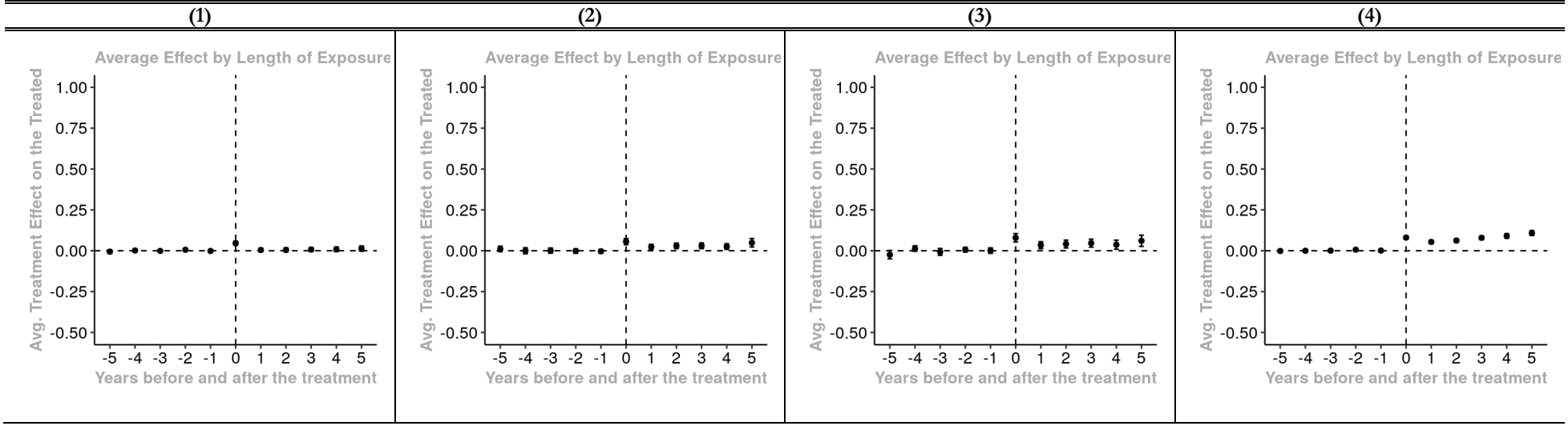
Notes: This figure exhibits the dynamic effects on non-mobile researchers' productivity after co-authoring with one (panel 1), two (panel 2), three (panel 3), and (any) foreign-educated researchers (panel 4). The panels show a pattern: the productivity of non-mobile researchers improves and displays long-lasting as they increase the stock of foreign-educated researchers. In the Brazilian case, co-authoring with two mobile researchers lead to a sustained effect over the years. The bars indicate 95% confidence intervals. Standard errors are clustered at the individual level.

Figure 11 - Effects of co-authoring with mobile on non-mobile researchers' cumulative number of citations per publication (in log), Brazil



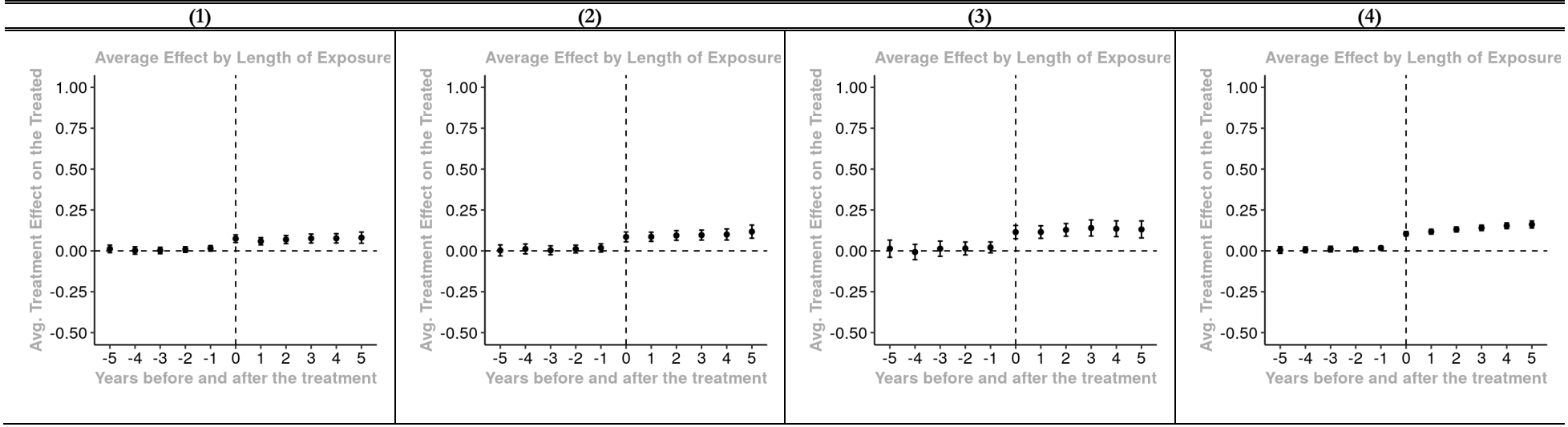
Notes: This figure exhibits the dynamic effects on non-mobile researchers' cumulative number of citations per publication after co-authoring with one (panel 1), two (panel 2), three (panel 3), and (any) foreign-educated researcher (panel 4). The panels illustrate a trend: non-mobile researchers experience increased visibility, even after a single co-authorship with a foreign-educated researcher. Effects intensify as non-mobile researchers co-author with more mobile researchers. The bars indicate 95% confidence intervals. Standard errors are clustered at the individual level.

Figure 12 - Effects of co-authoring with foreign-educated researchers on non-mobile researchers' number of publications in top journals (in log), Brazil



Notes: This figure exhibits the dynamic effects on non-mobile researchers' number of publications in top journals after co-authoring with one (panel 1), two (panel 2), three (panel 3), and (any) foreign-educated researcher (panel 4). After increasing the number of mobile researchers, the panels illustrate a positive but modest impact on publications in top journals. The bars indicate 95% confidence intervals. Standard errors are clustered at the individual level.

Figure 13 - Effects of co-authoring with foreign-educated on non-mobile researchers' share of English publications, Brazil



Notes: This figure demonstrates the dynamic effects on non-mobile researchers' share of English publications after co-authoring with one (panel 1), two (panel 2), three (panel 3), and (any) foreign-educated researcher (panel 4). The panels indicate a consistent pattern: A noticeable increase in the share of English publications after co-authoring with mobile researchers. In the Brazilian case, there is already a shift towards English publications after a non-mobile researcher co-author with one mobile researcher (panel 1). The bars indicate 95% confidence intervals. Standard errors are clustered at the individual level.

Finally, we also find that treated Brazilian STEM non-mobile researchers experience larger effects than their SSH counterparts (see Table 8). For example, the effect on citations has a 37% increase in magnitude for STEM researchers (column 2) compared to a rise of 11% for SSH researchers (column 6). STEM non-mobile researchers also experience a positive shift of 21% in the share of English publications (column 4). In comparison, SSH counterparts observe an increase in their share of English publications by 6% (column 8). Co-authoring with mobile researchers also has a larger impact on publishing in top journals for STEM non-mobile researchers than SSH researchers (columns 3 and 7). These results show that STEM non-mobile researchers benefit more in reaching a wider audience than SSH researchers.

Table 8 – Aggregate results: Non-mobile researchers' performance by macro field (STEM and SSH), Brazil

	Panel A - STEM				Panel B - SSH			
	Number of publications (in log)	Cumulative Number of citations per publications (in log)	Number of publications in top journals (in log)	Share of English publications	Number of publications (in log)	Cumulative Number of citations per publications (in log)	Number of publications in top journals (in log)	Share of English publications
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Co-authoring with mobile researchers	0.2781***	0.3695***	0.1608***	0.2105***	0.3171***	0.1148***	0.0226***	0.0606***
	(0.0128)	(0.0091)	(0.0064)	(0.0099)	(0.0103)	(0.005)	(0.0018)	(0.0046)
Observations	61,600	61,600	61,600	61,600	101,785	101,785	101,785	101,785
N non-mobile researchers	4,610	4,610	4,610	4,610	8,490	8,490	8,490	8,490

Notes: This table presents point estimates across various performance indicators for non-mobile researchers in STEM and SSH fields. Columns 1 to 4 detail the performance indicators of STEM non-mobile researchers, while Columns 5 to 8 are dedicated to those in SSH fields. In general, STEM non-mobile researchers benefit more from co-authoring with foreign-educated researchers than SSH non-mobile researchers regarding visibility, publications in top journals, and the share of English publications. However, there is one exception: SSH and STEM non-mobile researchers experience a similar increase in the number of publications. The levels of statistical significance are: $^{*}\ p < 0.05$, $^{**}\ p < 0.01$, $^{***}\ p < 0.001$. Standard errors in parentheses are clustered at the individual level.