Cross-border Visits and Scientific Collaboration*

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August 2024

Abstract

We examine the effect of cross-border visits on scientific collaboration by leveraging the implementation of the US Visa Waiver Program (VWP) across 41 countries, 1988-2023. The VWP facilitates easier travel for international researchers to the US for attending conferences, visiting US research institutions, and networking potential collaborators. The results from individual and country-level staggered difference-in-differences estimation show that even short-term visits significantly increased scientific collaboration between researchers in VWP-designated countries and those in the US. The effect varies across academic fields. We observe more pronounced effects in fields such as nursing, veterinary science, health professions, economics, and management, compared to smaller effects in chemistry, physics, biochemistry, and mathematics. Fields previously dominated by solo authors also exhibited a greater effect. Further, the impact on conference proceedings was both more immediate and larger than on journal publications. A series of Falsification analyses shows that the number of publications solely by a single author, authors from the same country, and non-US authors did not change. This supports that the VWP and an eased short-term visits to the US indeed drive the results. Our findings underscore the important role of short-term face-to-face interactions between researchers from different countries and provide implications for hosting in-person seminars and conferences, visa and immigration policies, research and development (R&D) strategies, and the future of work.

Keywords: short-term visits, visa waiver program, scientific collaboration, knowledge recombination, science of science, future or work

JEL Codes: J61, O31, F22

*We thank the support from the Institute of Management Research at Seoul National University and the Lloyd Greif Center for Entrepreneurial Studies at the USC Marshall School of Business. We also appreciate the seminar participants at the 2022 Institutions and Innovation Conference, KAEA Applied Micro Seminar, CCC Entrepreneurship Junior Faculty Brownbag, and KAIST Business School. The authors are listed in alphabetical order.

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1 Introduction

Innovation serves as a cornerstone of economic growth, with new ideas often emerging from the creative recombination of existing knowledge pools. It is therefore essential to facilitate the mixing and integration of disparate sets of knowledge to catalyze breakthroughs and developments. The ability to innovate by recombining knowledge is especially critical in todays globalized world, where the pace of technological change is accelerating and the demands for novel solutions are increasing across all sectors of the economy.

The challenge in promoting knowledge recombination lies in the inherent localization of knowledge, particularly non-codifiable knowledge which is often tacit and deeply embedded within individual scientists. The barriers stemming from geographical, cultural, and institutional distances then segregate knowledge within specific locales and impedes its free dissemination. As a result, it is difficult to achieve the most productive and innovative combinations of ideas and expertise.

In response to these challenges, researchers have examined the cross-border mobility of workers. Studies, in particular, highlighted the role of high-skilled immigrants and noted a trend towards increasing migration patterns of skilled workers towards innovation hubs like the United States (Kerr et al., 2016). This mobility is important as it allows individuals to place themselves in environments that maximize their potential for impact and contribution to the creation of new knowledge. Furthermore, the likelihood of such moves tend to increases among the most distinguished researchers (Azoulay et al., 2017).

Despite the extensive documentation of long-term and permanent migration effects, the specific impact of short-term, temporary visits remains underexplored, especially on forming and accelerating scientific collaboration among researchers in the hosting and visiting countries. Short-term visits–ranging from one day visit to an extended stay up to six months–are much less costly and does not require long-term commitment; and are distinct from longer-term migration for pursuing degrees, working, and obtaining permanent residency or citizenship. Still, scientists can engage with meaningful academic activities during their short-term, temporary

visits. Therefore, short-term visits could represent a crucial mechanism by which transient but intense interactions occur, possibly leading to sustained and enhanced scientific collaborations.

This study fills the gap on short-term visits by leveraging the US Visa Waiver Program (VWP), which was implemented across 41 countries from 1988 through 2023. The VWP substantially eases the process of entering the United States by waiving the lengthy and often prohibitive visa application process, which can vary from a month to over a year. By enabling easier access for up to 90 days, the program facilitates participation in academic conferences, seminars at research institutions, and scientific exhibitions, thereby increasing opportunities for non-US scientists to establish and cultivate collaborations with US counterparts.

We find from the staggered difference-in-differences estimation that even short-term visits significantly increased scientific collaboration between researchers in VWP-designated countries and those in the US. Importantly, the effect varies across academic fields. We observe more pronounced effects in fields such as nursing, veterinary science, health professions, economics, and management, compared to smaller effects in chemistry, physics, biochemistry, and mathematics. Fields previously dominated by solo authors also exhibited a greater effect. Further, the impact on conference proceedings was both more immediate and larger than on journal publications.

A series of falsification analyses further support that the VWP and an eased short-term visits to the US indeed drive the results. If an eased visit to the United States is the primary channel driving the results, we do not expect to see any effects on the number of publications solely by (1) a single author, (2) authors from the same country, (3) and non-US authors. We do not reject the null hypotheses that the estimates on the three "placebo" outcomes are statistically distinguishable from zero.

This study contributes to the literature in three ways. First, it extends our understanding of visa policies for high-skilled workers beyond traditional long-term programs, such as the H-1B visa and permanent residency, to include short-term visits that do not involve seeking employment (Bloom et al., 2019; Hunt and Gauthier-Loiselle, 2010; Kerr and Lincoln, 2010; Peri

et al., 2015). We highlight the importance of short-term visits on the dynamics of scientific collaboration and establish one of the first causal estimates.

Second, our study engages with the literature on ethnic/geographic diversity and knowledge production and extends our understanding in that an eased short-term visits could help achieve the full potential of researchers of diverse backgrounds in creating knowledge and advancing science (AlShebli et al., 2018; Choudhury and Kim, 2019). This is an important step forward in that short-term, temporary visits have not been traditionally considered a meaningful and powerful way to facilitate knowledge transfer and recombination.

Third, by examining how the VWP affects collaboration networks and knowledge spillovers, this study adds to the understanding of how interpersonal and intercultural interactions can lead to greater scientific productivity and innovation (Azoulay et al., 2010, 2019; Chai and Freeman, 2019; Moser et al., 2014; Iaria et al., 2018; Wuchty et al., 2007). Our examination highlights the broader implications for knowledge dissemination and co-creation resulting from facilitated exchanges of knowledge via an eased temporary visits across borders. We offer a deeper understanding of how policies like the VWP can act as catalysts for enhancing global scientific collaboration, thereby contributing to the broader advancement in science and innovation and economic development.

2 Research Design

2.1 Setting: US Visa Waiver Program and short-term visits

To causally identify the effect of short-term visits on scientific collaboration, it is important to find a variation that eases such visits that is exogenous–i.e., not correlated with our outcome of interest, which in this case is collaboration between researchers from different countries. We leverage the staggered introduction of the US Visa Waiver Program (VWP) to 41 countries over the past four decades. This program grants visa waivers for short-term visitors to the United States, significantly simplifying the process of entering the country for purposes such as

academic conferences, seminars, and collaborative meetings.

Prior to the VWP, obtaining a US visa (B-1 for tourism or B-2 for business) could be a lengthy and unpredictable process. Applicants were required to compile extensive documentation, attend in-person interviews, and wait for their passports to be stamped with a visaprocedures that could delay travel plans by several months or even years. The introduction of the VWP eliminated these requirements, substantially streamlining the process for short-term travels to the United States.

The US VWP provides an ideal empirical setting for analyzing the impact of eased travel restrictions on international scientific collaboration for several reasons. First, the VWP was introduced to 41 different countries at various times over the last four decades, as outlined in Table 1. This staggered rollout is beneficial for our analysis because the timing of a country's inclusion in the program is unlikely to be systematically correlated with potential confounding factors such as macroeconomic conditions or the general advancement of science in that country. Hence, the designation of VWP status is arguably exogenous to each country's academic activities, particularly the local researchers' propensity to collaborate with US counterparts.

Second, a primary criterion for inclusion in the VWP is a low visitor visa refusal rate, specifically below 3%. This requirement serves as "a significant barrier to entry into the VWP (Kolker and Platzer, 2020, p. 4)". For instance, the US Embassy in Croatia highlighted this on February 16, 2021, by tweeting, "The final refusal rate for Croatian tourist/business visa applicants fell to 2.69% last year, an essential step forward in joining the U.S. Visa Waiver Program." Croatia was subsequently admitted to the VWP on December 1, 2021. The stringent refusal rate criterion ensures that only countries with reliable and low-risk travel profiles are included, minimizing concerns about the selection bias in our analysis.

Third, the VWP has demonstrably increased the volume of visitors from participating countries, underlining its impact on facilitating short-term travels. Figure 1 illustrates a discontinuous rise in the number of visitors to the United States from VWP-designated countries (indicated by a solid red line), compared to their non-VWP counterparts from the same conti-

nents (shown with a dashed blue line). This sharp increase is indicative of the VWP's role in enhancing cross-border mobility, which is hypothesized to foster greater international collaboration.

By analyzing the effects of the VWP using this empirical setting, we aim to provide insights into how short-term mobility facilitated by visa waivers influences the scope and scale of scientific collaborations across borders. This approach not only helps isolate the specific contributions of short-term visits but also contributes to broader discussions on the policies that support international academic and professional exchanges.

2.2 Data and sample

For our empirical analysis, we utilize data from Scopus, accessed via the Elsevier Developer Portal and its API. Scopus is renowned for providing the most comprehensive overview of global research output. The database boasts over 78 million records, encompassing 23,452 peer-reviewed journals and 120,000 conference proceedings. It also includes detailed information on 16 million authors and 70,000 institutions, making it an invaluable resource for examining academic and scientific trends and collaborations.

Our sample is constructed from all publications and conference proceedings indexed from the years 1980 through 2010. Data collection efforts to include publications from years beyond 2010 are currently in progress. This extension is constrained by a weekly query limit set by the Elsevier API. Despite these sample limitations, the current sample adequately covers the majority of countries included in the VWP. Of the 41 countries in the program, only five are not represented in our dataset due to their later designation dates: Taiwan (designated in 2012), Chile (2014), Poland (2019), Croatia (2021), and Israel (2023). The absence of these countries from the initial sample is noted, but given their recent inclusion, their impact on the overall analysis of historical trends is likely minimal. However, as data collection continues and these countries' records become available, they will provide valuable insights into the more recent dynamics of the VWP's influence on scientific collaboration.

2.3 Empirical Strategy

To estimate the impact of the US Visa Waiver Program (VWP) on scientific collaboration, we employ staggered difference-in-differences (DD) models. The treatment in these models corresponds to the introduction of the VWP to each participating country. For the purposes of our analysis, the treatment group consists of countriesand by extension their researchersthat were included in the VWP during our sample period, referred to as switchers. Conversely, the control group includes countries and their researchers that were either never included in the VWP (never treated) or were included after the sample period ended (not yet treated). Our estimation is done at two distinct levels: country-year and individual(non-US researcher)-year.

Country-year level analysis

The first method involves a country-year level analysis utilizing a Two-Way Fixed Effects (TWFE) model, which can be formulated as follows in Equation 1:

$$Y_{ct} = \beta_1 \cdot VWP_{ct} + \beta_2 \cdot Post_{ct} + \beta_3 \cdot VWP_{ct} \cdot Post_{ct} + \alpha_c + \delta_t + \epsilon_{ct} \tag{1}$$

where VWP_{ct} is a binary indicator that denotes whether country c has been designated into the VWP at time t, and $Post_{ct}$ is an indicator for the periods following the VWP designation for each country c. α_c and δ_t represent country and year fixed effects, respectively, which control for unobservable heterogeneity at the country and year levels.

A notable concern with the TWFE model arises from potential treatment effect heterogeneityspecifically, the risk of making improper comparisons between 'not yet treated' units in the treatment group and 'already treated' units serving as controls. Such comparisons could introduce bias into the estimates Baker et al. (2022). To mitigate this issue, we adopt recently developed estimators that specifically address this problem: the estimator proposed by Sun and Abraham (2021) (SA21), Callaway and SantAnna (2021) (CS21), and De Chaisemartin and dHaultfoeuille (2020). Our preferred estimator is CS21 with not-yet-treated units (including

those never treated) as the control group. We provide the estimates from alternative estimators and model specifications in the appendix.

Another concern is dealing with non-negative count variables that include zero values. Methods such as log transformation (with the addition of an arbitrarily small number) and the inverse-hyperbolic sine (IHS) transformation are prone to biases, especially when there are many zero values. The main issue is that these methods produce estimates that reflect a non-trivial recombination of both extensive (i.e., changes from zero to a positive value) and intensive (i.e., changes between positive values) margins. In the robustness checks, we provide estimates using quasi-Poisson maximum likelihood estimation and assign different weighting parameters, x, as suggested by Chen and Roth (2024).

Individual(non-US Researcher)-year level analysis

Second, we estimate a staggered difference-in-differences model at a more granular individual-year level. We create a panel data for each non-US researcher by year and estimate their probability of collaborating with US researchers:

$$Y_{ict} = \beta_1 \cdot VWP_{ct} + \beta_2 \cdot Post_{ct} + \beta_3 \cdot VWP_{ct} \cdot Post_{ct} + \alpha_i + \delta_t + \epsilon_{ict} \tag{2}$$

where i stands for an individual non-US researcher who published at least one paper during the sample period. The results from this individual-year level analysis are largely consistent with those from the country-year level analysis. Detailed results are reported in the online appendix and available upon request.

3 Results

3.1 Cross-border collaboration

We first establish the first stage and check whether the VWP meaningfully increased the number of short-term visitors from VWP-designated countries to the United States around the VWP introduction. This was indeed the case, as shown in Figure 1, demonstrating the VWP was a meaningful policy that significantly changed the temporary visitations to the United States. The number of short-term visitors to the United States, averaged across VWP countries and across non-VWP countries in the same continent for each VWP country for a relative time from VWP introduction, shows disproportionate increase for the VWP countries, post-VWP.

Our main research question explores whether and how these visits foster scientific collaboration between researchers in the VWP countries and the United States. The results from the staggered difference-in-differences estimation at the country-year level indicate that the number of publications or conference proceedings jointly produced by US and non-US researchers in the VWP-designated countries increased substantially after the introduction of the VWP. Figures 2a and 2b consistently demonstrate the parallel trend up until the introduction of the VWP and the gradual yet substantial increase in scientific collaboration thereafter. Table 2 presents the simple DID estimates comparing pre- and post-VWP years. Four columns detail estimates from different approaches–TWFE estimation, CS21 with two different control group specifications, and SA21. Our preferred estimation approach (CS21 with the never-treated group as a control) is shown in column 2. The number of scientific collaborations, measured by co-publications of papers or conference proceedings, increased by 31% ($e^{0.315} - 1$) after the VWP.

3.2 Heterogeneous effects

The aggregated effects from the entire sample, as reported in Section 3.1, are informative but do not account for heterogeneous effects. In this section, we aim to delve deeper into how

these effects vary across different segments of the data. Specifically, we explore the effects by academic fields, the key characteristics that define these fields, and the types of work.

3.2.1 Variation by academic fields

We explore the heterogeneous effects across academic fields. Figure 3 illustrates the estimation results categorized by academic fields. Notably, the effect is more pronounced in fields such as nursing, veterinary sciences, health professions, economics, and management. In contrast, the effects are comparatively smaller in fields such as chemistry, physics, medicine, biochemistry, and mathematics.

3.2.2 Variation by the intensity of single-author works

We then consider the key characteristics that define each academic field, specifically the propensity to collaborate prior to the introduction of the VWP. The results show in Figure 4 reveals a pronounced effect in fields historically characterized by a substantial prevalence of solo authorship. This finding suggests that scientific collaborations in certain domains were impeded by the significant costs associated with short-term visits to colleagues or their research facilities in different countries. The VWP then alleviates such restrictions. In other words, the historical scarcity of global collaboration in these fields cannot be solely attributed to an intrinsic preference for solo work. Instead, it underscores the considerable influence of administrative and regulatory barriers on international travel and the facilitation of face-to-face interactions.

3.2.3 Variation by work type

The time from the onset of collaboration to journal publication can span several years. Meanwhile, the outcomes of the work are often made public through conference proceedings. We, therefore, examine the dynamic patterns of effects separately for journal publications and conference proceedings. This variation in publication timelines also serves as a validity check. If the Visa Waiver Program (VWP) indeed drove the increase in scientific collaborations, we would

expect to see that the effects materialize faster for conference proceedings than for journal articles. Figure 5 illustrates our findings: the effects manifest more rapidly and with greater magnitude in conference proceedings compared to journal publications.

4 Falsification Analyses

We conduct a series of falsification analyses. If the main effect on scientific collaboration is driven by eased travel to the United States, we would not expect to observe effects on the number of publications by single authors, authors from the same country, or authors in non-US countries.

Single-author publications An independently working author should not be affected by the VWP and the associated ease of short-term visits. Figure 6a shows no discernible effect on single-author publications.

Collaboration by same-country researchers Likewise, collaboration among researchers from the same country is not influenced by the impact of short-term visits. We find no effect, as demonstrated in Figure 6b.

Collaboration among non-US researchers Furthermore, the VWP and the ease of visits should not affect collaborations among non-US researchers. Even if they belong to different countries, the eased visit to the United States is unrelated to their collaboration. Figure 6c confirms that there is no effect.

The findings from these analyses also speak to potential substitution or crowding-out effects. These results suggest that the observed increase in collaborations is not due to the substitution or displacement of single-authored works or joint works by authors from non-US countries. While further analysis is necessary to definitively conclude, the current results suggest that the

observed increase in collaborations has not come at the expense of existing modes of scholarly work.

5 Discussion and Conclusion

This study highlights the role of short-term cross-border visits and their extensive impact on scientific collaboration facilitated by such interactions. The findings from the staggered introduction of the US VWP underscore the critical importance of face-to-face interactions, albeit temporary, between researchers from different countries of residence. These interactions have significant implications for academic seminars and conferences, visa and immigration policies, R&D, innovation, and the future of work.

Moving forward, we are focusing on individual-level data to understand the mechanisms through which the VWP influences scientific collaboration. This individual-level analysis will investigate how the effects vary according to personal characteristics, such as gender, years of experience, and publication productivity. Furthermore, we will examine the impact of team characteristics, including ethnic diversity and team size, and investigate whether the VWP has fostered new collaboration networks or strengthened existing ones.

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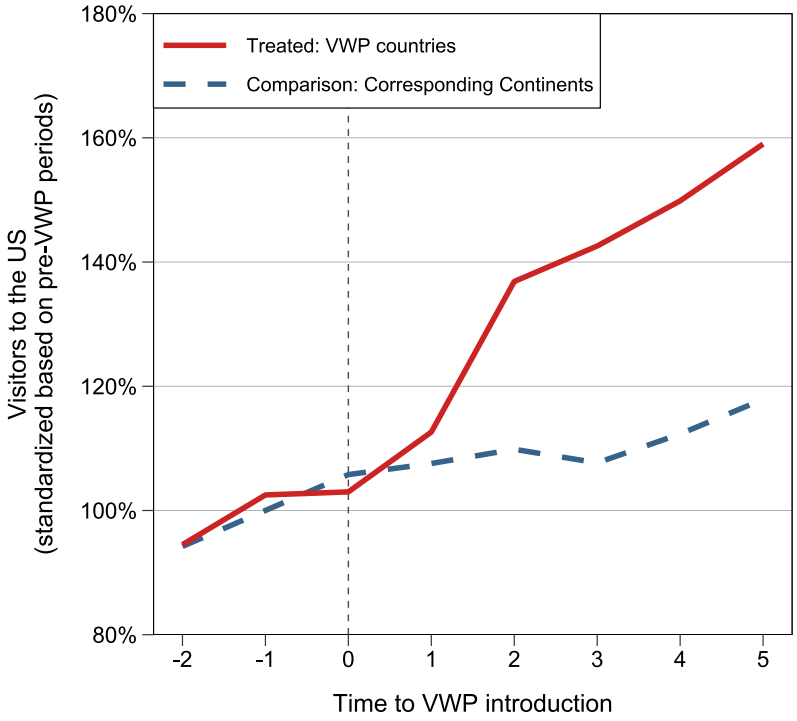
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Figure 1: Visa-Waiver and Short-Term Visitors to the United States

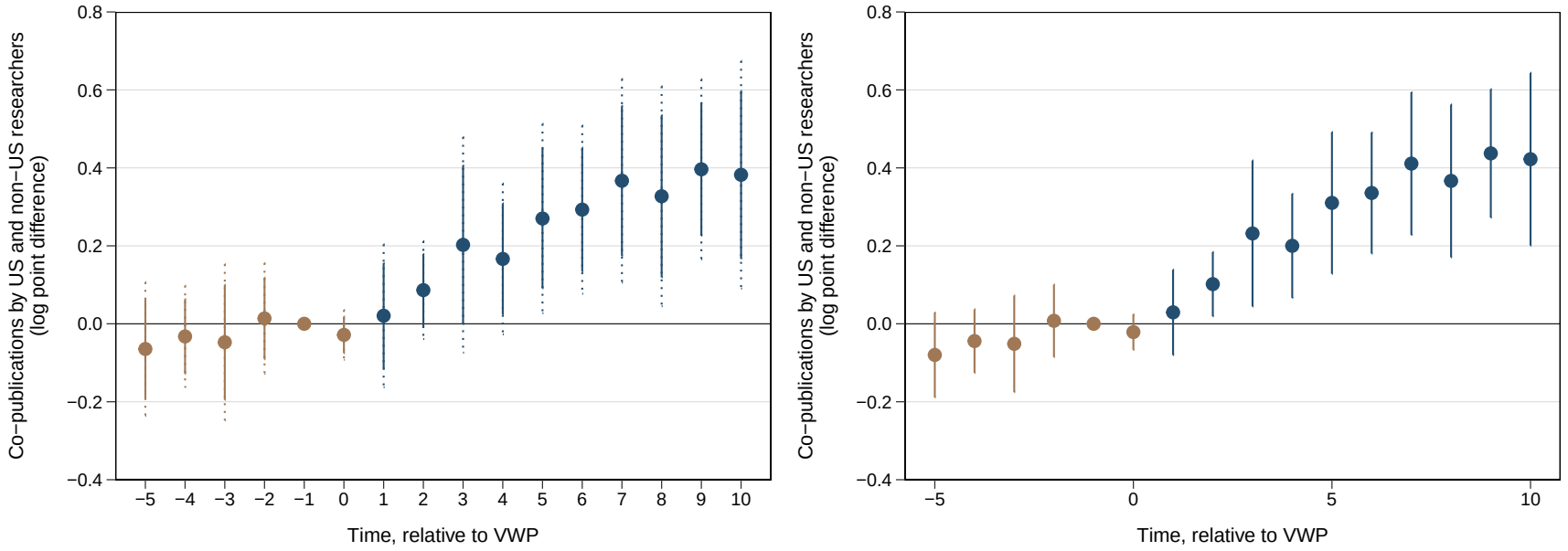


Notes. Visitor visas include nonimmigrant visas for a temporary stay in the US: B-1 (business) and B-2 (tourism).The total number of short-term visitors to the US from the countries that received the VWP on and after 1999 (data is only available from 1999; a solid red line) and the total number of short-term visitors from continents each country belongs to (a dashed blue line) around the year of VWP introduction. The numbers are standardized based on the pre-VWP year average. This figure is an excerpt from Kang and Eklund (2024), Figure 3(a).

Figure 2: Effects of VWP on scientific collaboration by US and non-US researchers

(a) Callaway and Sant'Anna (2021) estimator

(b) Sun & Abraham (2021) estimator



Notes. The points represent the estimates from the staggered difference-in-differences method (Callaway and SantAnna, 2021). T=0 is the year of VWP introduction. The estimates for pre-treatment periods are colored brown, while the red points represent the estimates for the post-treatment periods. *Panel (a)*: Analytical 95% confidence intervals are reported in solid vertical lines. Bootstrap 95% confidence intervals (10,000 iterations), clustered at the firm level, are provided in dotted vertical lines.

Figure 3: Effects of VWP on scientific collaboration by academic fields

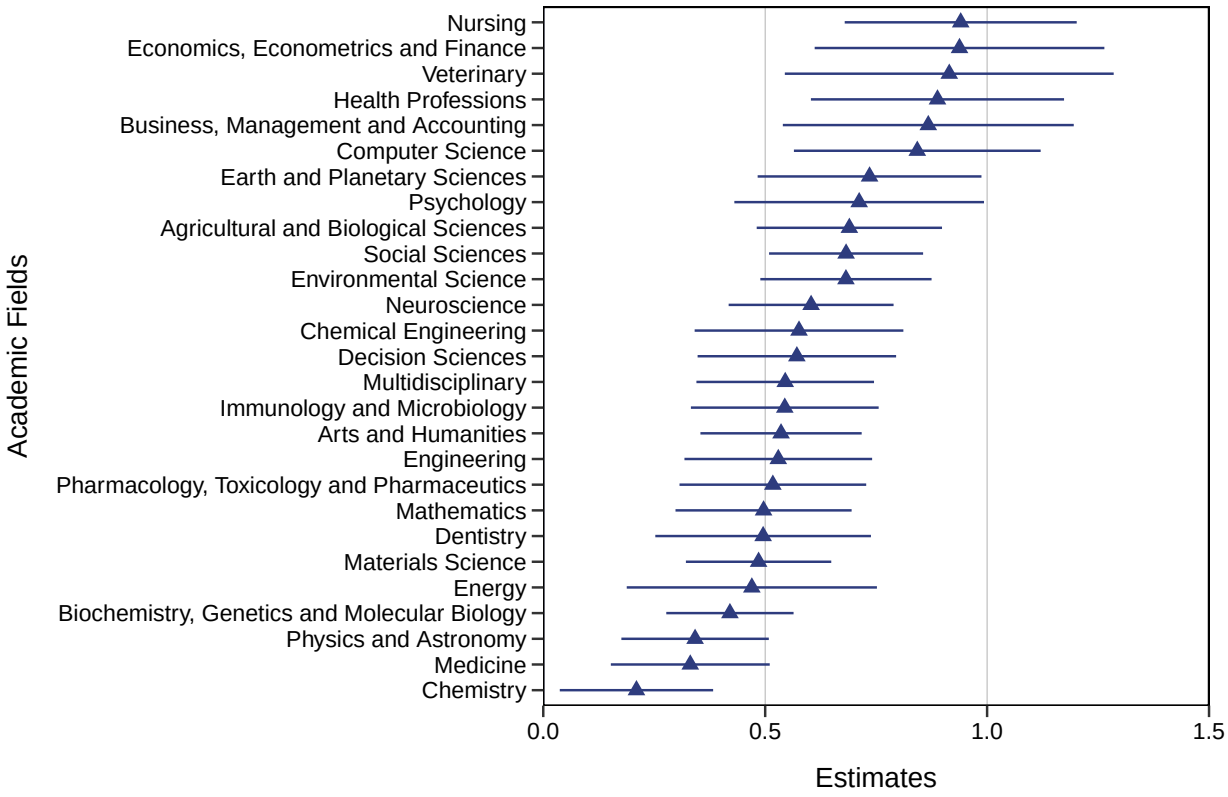


Figure 4: Effects of VWP on scientific collaboration by the solo-author intensity

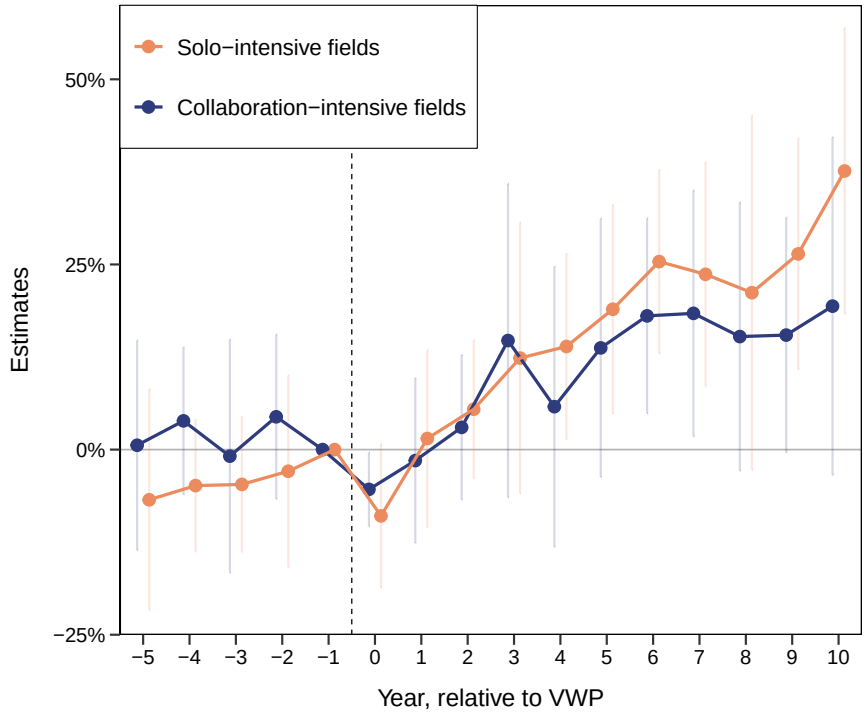


Figure 5: Effects of VWP on scientific collaboration by work type

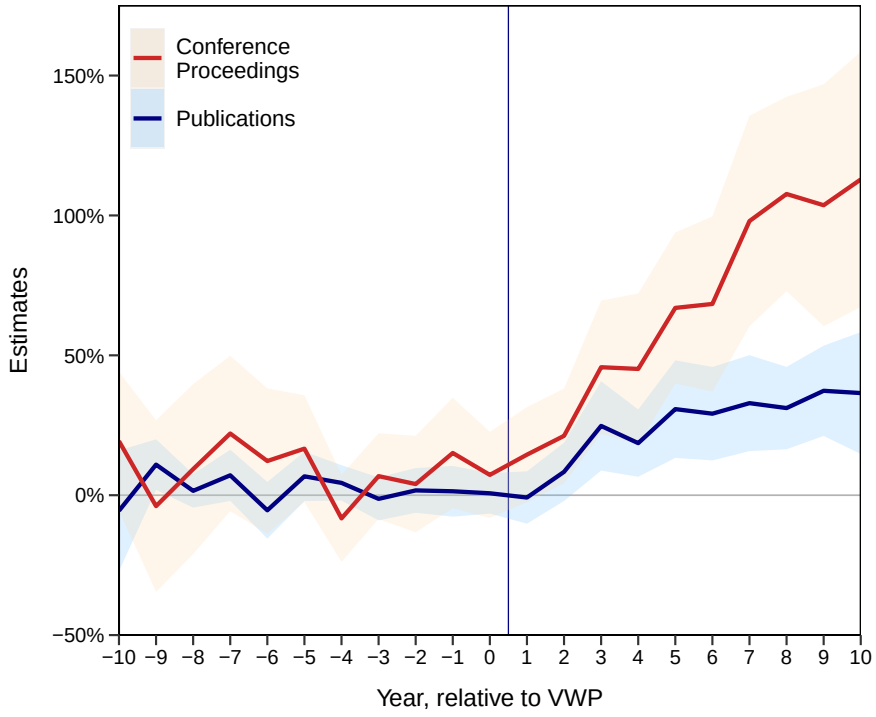


Figure 6: Effects of VWP on scientific collaboration: Falsification analyses

(a) Single-author publications

(b) Co-publications by same-country researchers

(c) Co-publications by non-US researchers

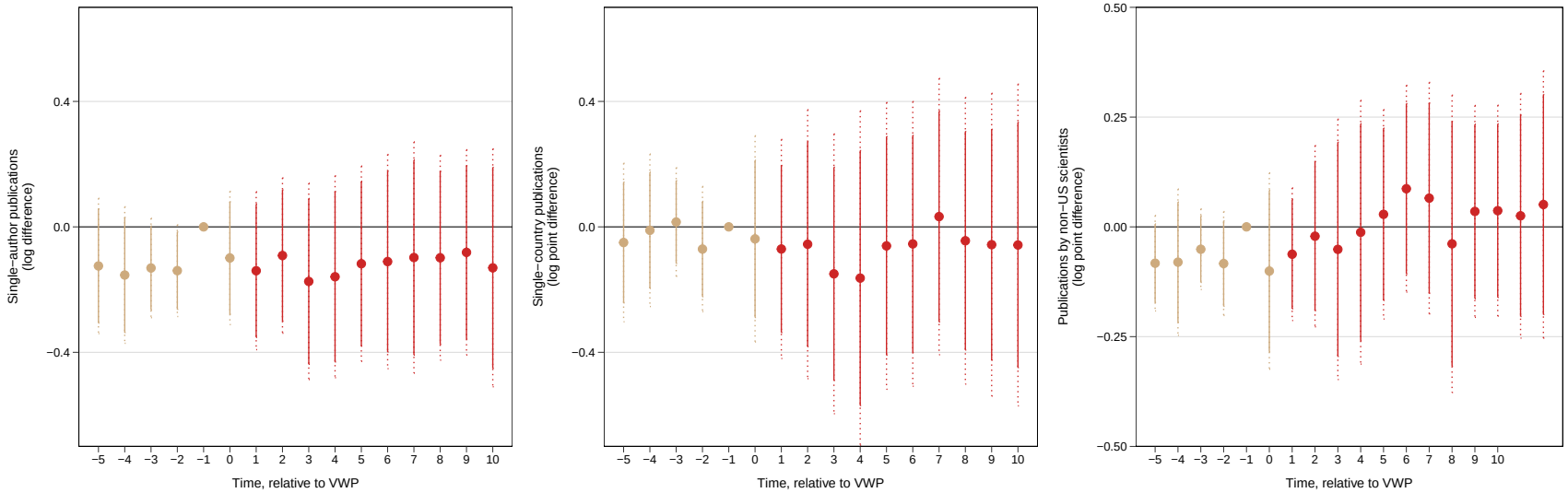


Table 1: The Introduction of the U.S. Visa Waiver Program, 19882023

Year	Country	Year	Country
1988	United Kingdom	1993	Brunei
	Japan	1995	Ireland
1989	France	1996	Argentina (-2002)
	Switzerland	1996	Slovenia
	(West) Germany	1997	Uruguay (-2003)
	Sweden	1999	Portugal
	Italy		Singapore
	Netherlands	2008	Czech Republic
1991	Andorra		Estonia
	Austria		Hungary
	Belgium		Latvia
	Denmark		Lithuania
	Finland		Malta
	Iceland		Slovakia
	Liechtenstein		South Korea
	Luxembourg	2010	Greece
	Monaco	2012	Taiwan
	New Zealand	2014	Chile
	Norway	2019	Poland
	San Marino	2021	Croatia
	Spain	2023	Israel

Source. U.S. Department of Homeland Security.

Table 2: Effects of VWP on scientific collaboration by US and non-US researchers

Dependent Variable:	*Co-publication by US and non-US researchers (log transformed)*			
Model:	TWFE	CS21 (Never treated)	CS21 (Not yet treated)	SA21
	(1)	(2)	(3)	(4)
Variables				
Treat×Post	0.321***	0.315***	0.283***	0.315***
	(0.070)	(0.085)	(0.085)	(0.081)
	[p<0.01]			[p<0.01]
Fixed-effects				
Year	Yes	Yes	Yes	Yes
Country	Yes	Yes	Yes	Yes
Fit statistics				
Observations	6,872	7,470	7,470	7,470
R^2	0.936	–	–	0.937

Notes. Column (1) presents results from the two-way fixed effects (TWFE) model. Columns (2) and (3) use the Callaway and Sant'Anna (2021) estimator (CS21). Column (4) employs the Sun and Abraham (2021) estimator (SA21). Signif. Codes: ***: 0.01, **: 0.05, *: 0.1.