Conflict-induced emigration of scientists from Ukraine to internal and international destinations

Michael Zaslavsky (University of Wisconsin-Madison, Madison, USA, Correspondence E-Mail: mzaslavsky@wisc.edu), Aliakbar Akbaritabar (Max Planck Institute for Demographic Research, Rostock, Germany).

Keywords: Ukraine, Scholars at risk, Bibliometric data, Conflict-induced emigration

Extended Abstract

Introduction. In today's knowledge economy, scientific ideas are produced and recombined to drive innovation, with high-skilled migration, thus largely being seen in a positive light. [1]. High-skilled migrants contribute to innovation in the host country and even increase natives' inventiveness [2]. They transfer ideas with their mobility [3]; hence, there is a global competition to attract scholars [4]. Because of their contribution to innovation and knowledge circulation [5], it is essential to study the migration of researchers. Yet scholarly migration is not always a tale of freedom, choice, and innovation. We document the problematic aspects of scholarly migration by investigating the case of Ukrainian and Ukraine-based scholars, some of whom have been directly affected by conflict since 2014.

In the face of war and conflict, the importance of studying the migration of researchers is further pronounced as they are a highly skilled subset of the population and have potential links, i.e., migration networks, and credentials that enable them to leave earlier [6–8] than the general population once significant conflict or war occurs[9]. Armed conflict negatively affects national science systems, and this negative effect goes beyond the national borders of the countries directly involved in the war by affecting the global science system as well [6, 10]. Knowing what share of a country's human capital has emigrated [11], what share of those remaining leave science for other professions [6], and what share of those who emigrate from the country return at a later time [12], enables speculating about the long-term effects of conflict on a country's research and development and science system which goes beyond the short-term destruction [10] given that these researchers are part of the human capital that could rebuild a country after the war is finished [13].

We contribute to the literature by highlighting a shortcoming in migration theories that consider high-skilled and academic mobility solely as economic migration [14]. This theoretical shortcoming persists in the most recent frameworks proposed in migration theories i.e., the aspirations/capabilities framework, which considers academic mobility solely as "free migration" [15]. The current view of seeing academic mobility as free migration, while being partially correct, completely ignores "researchers at risk," "scientists in exile," or "refugee academics" [16, 17]. For instance, despite the presumption that we know a lot about academics, we did not know how many scholars were in Ukraine or left after the war [7].

Data. With recent developments in the digitization and availability of data [18, 19], digital trace data, and especially bibliometric information (which is metadata of scientific publications) has been re-purposed to study actively publishing researchers [20–22]. Further, the literature on migration and development has shown that while the emigration of the general population

might have an inverse u-shape association with development [23, 24], meaning increases in development would decrease migration, for the case of scholars, the literature has found a u-shape association [22].

Building on the above mentioned literature, we focus on the case of the population of actively publishing researchers who, at one point in their career, have had affiliations to research institutes in Ukraine. We emphasize that our data does not only focus on academics, but also includes researchers in non-university research institutions and companies who publish scientific journal articles. We used two different data sources one licensed and proprietary provided by Elsevier, Scopus [25], and one publicly available, OpenAlex [26], to triangulate and address the coverage issues: for instance, the dominance of the English language in Scopus or the less clearly defined indexing philosophy of OpenAlex [27]. We investigate the outmigration of Ukrainian researchers from 2009 to 2022. These years were selected to cover at least five years before the start of Russian aggression in Ukraine in 2014 and the more recent full-scale war between these two countries in 2022. In our further extension of this work, we will use the period from 1996 to 2022. Please note that our data in Scopus covers 1996 until 2020, while the OpenAlex data ranges from 1950 to 2023. We use the overlapping period between these two databases to ensure that our migration rates are consistent across them (discussed below). Our data is innovative in its subnational granularity, which covers all GeoNames Admin 1 regions in Ukraine, which are roughly equivalent to oblast or province, and goes beyond solely looking at international migration, which is proved in the literature to be interlinked with internal migration in the case of general population [28–30] and researchers [31]. Hence, in addition to international outmigration, we also cover the internal emigration of scholars to other destinations inside Ukraine. To explore the association at the subnational level between the emigration of researchers and development, here we use the Subnational Human Development Index (SDHI) [32]. To identify migration events, we rely on our previously developed and tested method [20–22, 31] based on the mode affiliation of scholars, which considers the most occurring affiliation in a year. We emphasize that these affiliations also include the multiple affiliation-holder authors discussed in the literature [33, 34] and cover both affiliations in one publication or across multiple publications in a year to find the mode.

Preliminary Results. To investigate whether armed conflict in Ukraine is associated with a change in the rate of outmigration of Ukrainian researchers to internal and international destinations, we first provide a temporal view of the population of scholars over time in Figure 1. This view enables us to consider the potential expansion in the population of researchers. We use this population as the denominator in our analysis to standardize the calculated migration measures and put them into a population-level perspective. Figure 1 shows the population of scholars based on OpenAlex (left panel) and Scopus (right). While OpenAlex has much higher coverage, as documented in the literature [26, 27], it could be prone to indexing publications that are not strictly considered scientific journal publications such as not-yet-peer-reviewed preprints. This view is complemented by the stricter indexing philosophy of Scopus [25], which is shown on the right panel. Despite the differences in indexing philosophies of these two databases, the order of geographical regions shown on the two panels in this figure remains consistent across these two databases. This shows that in both of these databases, Northern Ukraine, defined based on the geographical regions proposed by the Subnational Human Development Database (SHD) [32] which includes the capital, Kyiv, is the largest region, followed by Eastern, Western, and Southern and Central regions.

We then add a spatial dimension to this temporal population view using the number of scholars leaving a region subtracted from those incoming and standardized by the population of the scholars in the region in the form of a net migration rate (NMR) [35] calculated as

in equation 1. Figure 2 maps these spatial and temporal patterns at the subnational region level and shows the regions most affected by conflict, which have a higher number of scholars leaving than receiving and depicted in red colors. Here, the figure shows that the eastern regions neighboring Russia, as well as Crimea, which was illegally annexed in 2014, have been affected the most in both internal (panels on the left) and international (panels on the right) net migration rates, indicating that regions such as Luhans'k, Kharkiv, and Donets'k have had more than 100 per 1000 scholars leave to both internal and international destinations (see Figure 4 for the NMR measures over time). Additionally, Figure 2 shows that researchers publishing in journals indexed by Scopus, which has a more strict indexing philosophy and are considered publications in higher impact journals [25], show earlier trends in outmigration than OpenAlex, which indexes a broader range of publications. For instance, while in the left panel of Figure 2 and the years 2009-2011, we already observe negative NMRs for internal emigration from eastern regions of Ukraine in Scopus, these trends appear in smaller magnitude, and later in OpenAlex which could also be driven by the larger size of the denominator and population of scholars in OpenAlex. Overall, the trends of emigration to international destinations shown on the right panel tend to be more negative. For instance, in the years 2021-2022 on the right panel and for OpenAlex, most regions in Ukraine show negative NMRs, indicating that more scientists leave than arrive to these regions, likely indicating academic flight prior to or after Russia's full-scale invasion on February 24th, 2022. Here we emphasize that while Figure 1 (and the following figures) are based on the geographical regions defined by the SHD database to enable us to use their human development index in our analysis, however, Figure 2 uses the GeoNames admin 1 regions which are roughly equivalent to provinces to enable a spatial comparison between regions over time.

Figure 3 adds speed to the presented population, spatial (in terms of regions), and temporal trends calculated as the time, in terms of years, that is required for the population of scholars emigrating to internal (on the left) or international (on the right) destinations to double. The calculated doubling times are interpreted in reverse, meaning a lower doubling time indicates a faster depletion of a region from its highly skilled and actively publishing researcher workforce. For internal migration, we see that Northern Ukraine, which also includes the city of Kyiv, has the fastest outmigration, followed by the Eastern region neighboring Russia, whose oblasts (provinces) have been embroiled in conflict since 2014. Relative to the "slowest" region, Northern Ukraine, has almost a three times higher speed in internal outmigration than Central Ukraine, which is the region with the lowest speed of outmigration (i.e., $((ln(2)/0.05)/(ln(2)/0.14) \approx 2.8)$). It is important to note that for international emigration Eastern Ukraine has the fastest doubling time in our observation period.

Further, in Figure 4, we provide a temporal perspective using the most widely used measures of migration, such as in- and out-migration rates which are calculated based on the population of scholars in a region and year, to compare them with the net migration rate, and migration effectiveness index which are proposed as suitable measures for the effect of migration on redistributing the population and to enable comparative views on migration at internal and international levels (see a discussion in [35]). Please find formulas for these measures in equations 1, 2, 3, 4, and 5. Figure 4 further confirms our description above that while outmigration rates had an unprecedented increase after the 2014 conflict, the outflow of scholars has been going to both internal and international destinations. The Eastern and Southern regions in Ukraine have witnessed the highest international emigration rates since the latter half of the 2010s.

To investigate the association between the subnational human development index [32] and internal and international outmigration rates while controlling for the size of the population

of regions, we ran some initial negative binomial regression models. We hypothesize that 1) the outmigration of scholars from the regions closest to Russia should accelerate after the 2014 conflict and peak at the 2022 war. 2) We further expect to see this outmigration increase for both internal and international destinations. 3) Additionally, we expect that regions with higher subnational human development index, due to being more developed, perhaps being larger urban areas, have witnessed a higher rate of outmigration and more so to international destinations.

Table 1 shows that for internal outmigration, the size of the general population of a region (not the population of scholars, which is already considered in the standardized rates) is positively and significantly associated with the outmigration of scholars, which is consistent once we add fixed effects for geographical regions in the full model (see the last column on the right). This means that larger regions, in terms of population, might have more research-oriented institutions, academic centers, and universities, and have higher outmigration rates among scholars. Additionally, the models presented in this table show that the subnational human development index might not be significantly associated with the "internal" outmigration rates. We find this result intuitive, in light of the results for "international" outmigration rates presented below, as in the face of war and conflict, all regions in a country, whether they are more developed or not, are negatively affected, and those with a possibility of outmigration, while going to internal destinations as we showed in our descriptive results, would go more to international destinations which are shown in results in Table 2. Here in the baseline model we see that regions with higher subnational human development index have a significant association with higher outmigration rates. Once the size of the general population of a region is considered (see the model in the second column), while the coefficient for subnational human development is reduced, it remains high and significant. Once we consider the subnational regions and include fixed effects for them to allocate a varying intercept for regions and account for their different starting point, i.e., intercept, in the outmigration rate, we see that Northern and Eastern regions have a positive and significant coefficient for outmigration rate which is also the case of regions with the larger general population, but the subnational human development is not significant anymore which again is intuitive in light of the conflict conditions affecting all regions. Finally, in Table 3, we show the preliminary results for a difference-in-difference two-way fixed effects model. We considered the Eastern region of Ukraine as the "treated" region, as it was the site of armed conflict in Ukraine after Russia began a proxy war there in 2014. The interaction between it and the post-2014 turned out to be significant, both for internal and international out-migration. In our extension of this modeling strategy, we plan to select regions that are comparable in terms of the size of researchers and the general population but have not been exposed to the conflict in a difference-in-difference framework to further test our current results.

To conclude, our results allowed us to provide a population, spatial, and temporal perspective on the unprecedented conflict-induced outmigration of scholars from Ukraine to internal and international destinations. We further investigated these trends with negative binomial statistical models and a preliminary version of a difference-in-difference model. In our models, we used the subnational human development index [32] and, while controlling for the population of regions, we tested its association with the out-migration rate of scientists. In our next steps, we will further extend these analyses to confirm the robustness of our results. Our results, although preliminary, have certain implications for using digital trace data to study conflict-induced outmigration of researchers and specifically to shed light on the case of Ukrainian scientists and the negative consequences of ongoing conflict on the science system of Ukraine.

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Figures and Tables

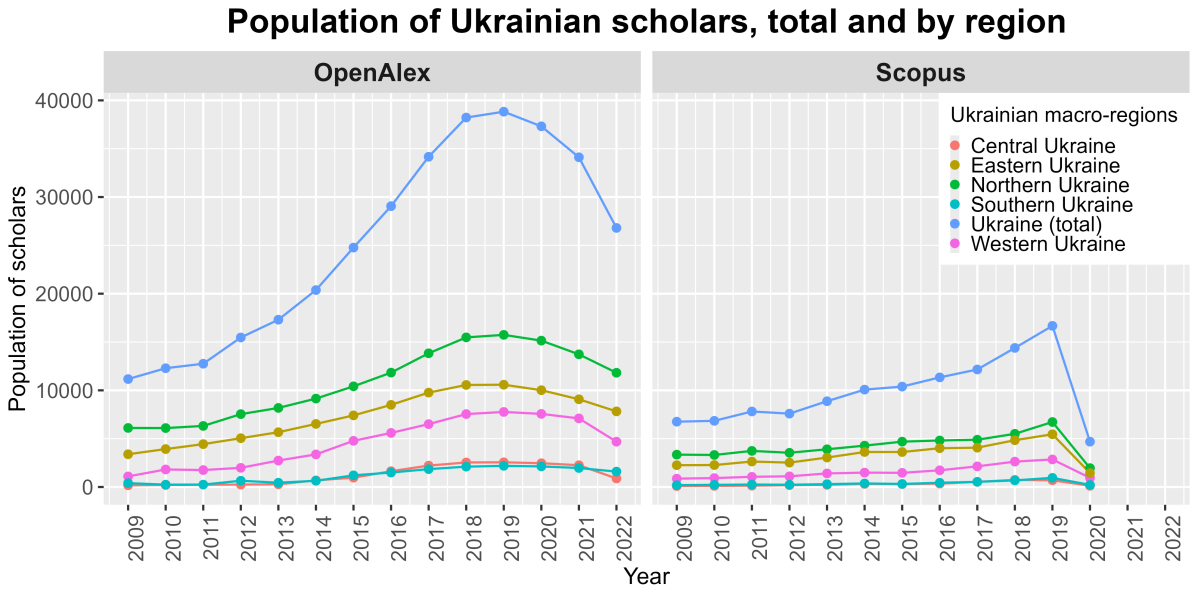

Figure 1: Population of actively publishing researchers who have had an affiliation with an institution in Ukraine based on OpenAlex (left) and Scopus (right) bibliometric databases and grouped by geographical regions defined by Global Data Lab macro-regions [32].

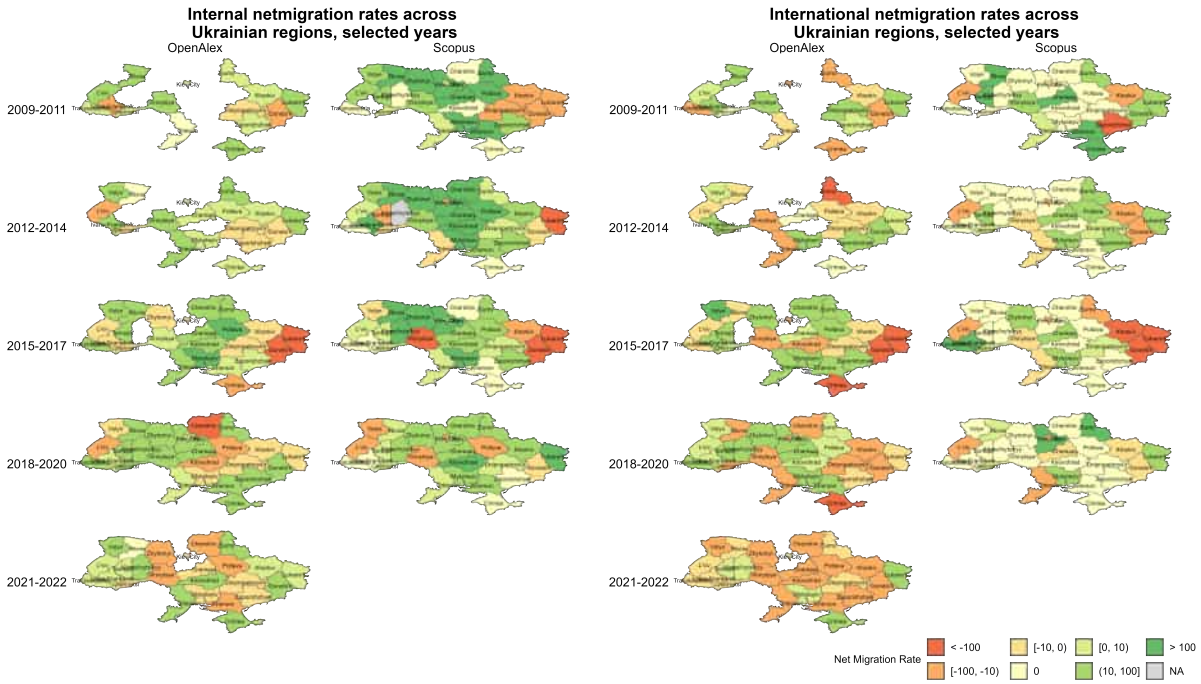

Figure 2: Net migration rates based on OpenAlex (left panels in two columns) and Scopus (right panels in two columns) for internal (two columns on the left) and international (two columns on the right) per 1,000 scholars calculated based on the equation 1. Colors that tend toward red indicate regions that are sending more emigrant researchers than receiving immigrants, while colors that tend toward green indicate regions that are receiving more immigrants than sending emigrants. Please note that some regions, especially in the earlier years, do not have data and are not included on the map.

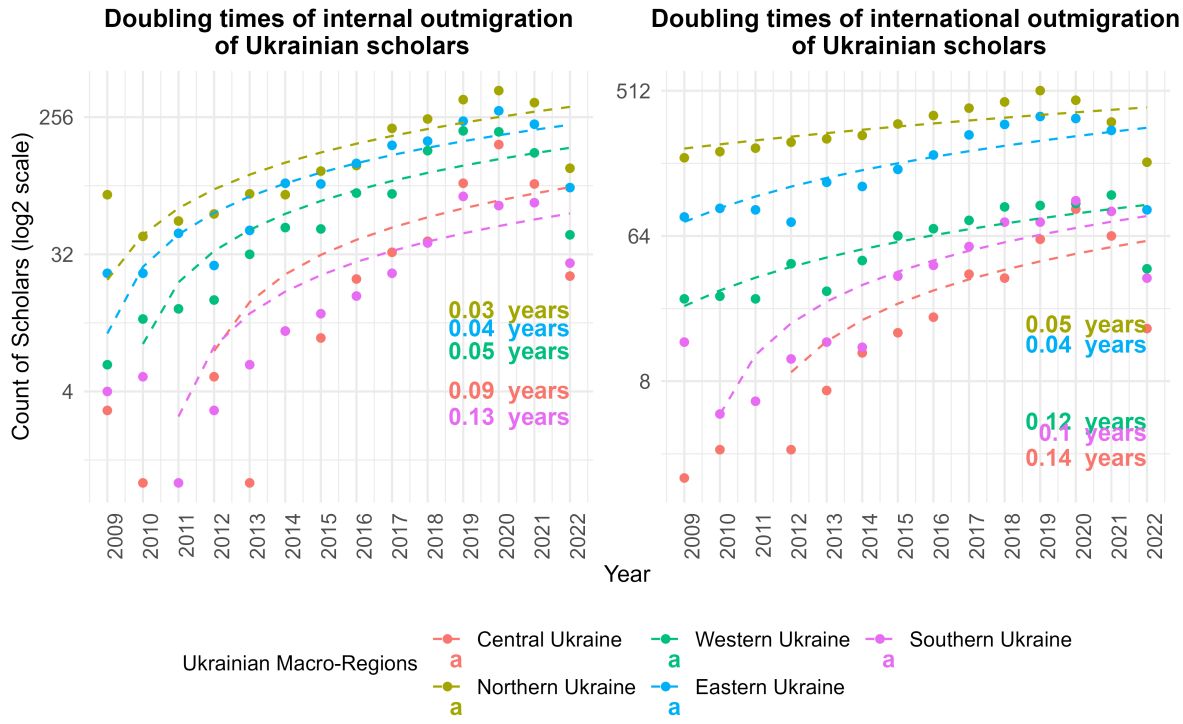

Figure 3: Doubling times calculated in terms of years for internal (left) and international (right) outmigration of researchers divided over GDL macro geographical regions based on equation 5.

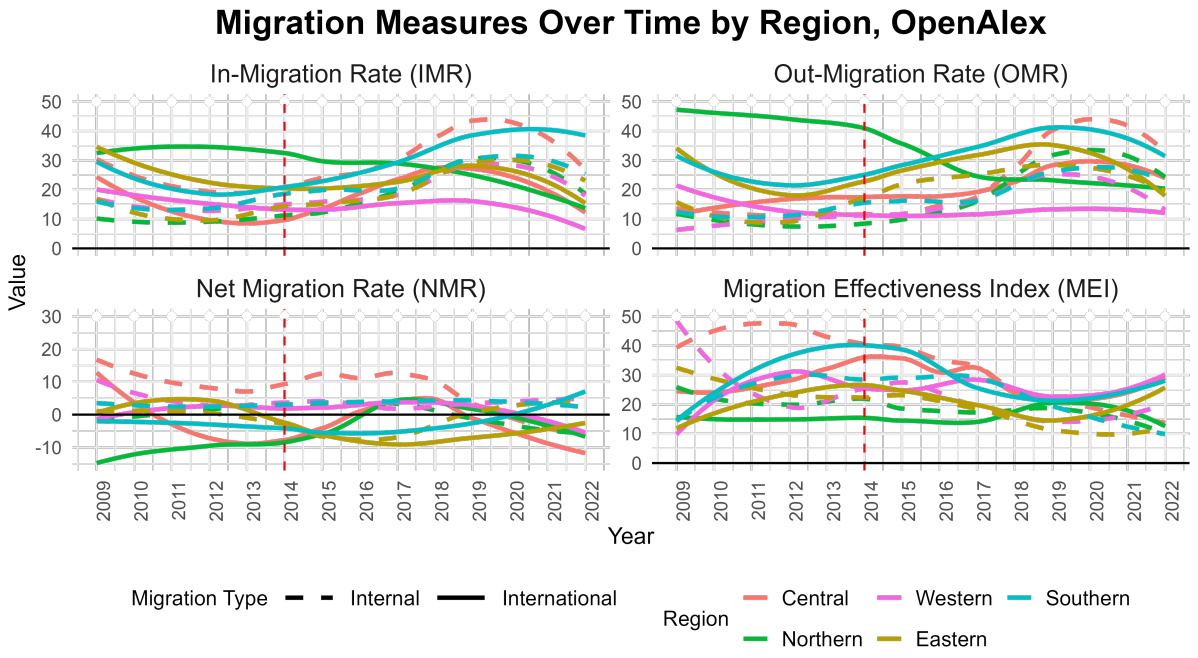

Figure 4: In-migration (top left), Out-migration (top-right), Net Migration (bottom left) rates and Migration Effectiveness Index (bottom right) for macro geographical regions (based on GDL's definition) calculated based on equations 2, 3, 1, and 4, respectively.

Table 1: Negative Binomial Regression Results for Internal Out-Migration

	Dependent variable:			
	Internal Out-Migration			
	Baseline	+ log population	+ regional FE	+ post-2014 dummy
	(1)	(2)	(3)	(4)
Subnational HDI (SDHI)	6.80 (8.61)	−2.52 (4.93)	−5.70 (4.45)	−5.84 (5.14)
Log Population (GDL)		0.78*** (0.06)	0.97*** (0.10)	0.98*** (0.18)
Central Ukraine			1.15*** (0.20)	1.16*** (0.30)
Northern Ukraine			0.69*** (0.18)	0.69*** (0.21)
Eastern Ukraine			0.28 (0.18)	0.28 (0.18)
Southern Ukraine			0.92*** (0.22)	0.93*** (0.33)
Post-2014				−0.01 (0.21)
Constant	−2.13 (6.58)	−1.63 (3.75)	−1.41 (3.50)	−1.36 (3.60)
Observations	69	69	69	69
Log Likelihood	−282.39	−238.73	−220.57	−220.57
θ	1.19*** (0.20)	4.64*** (1.05)	11.55*** (3.58)	11.57*** (3.59)
Akaike Inf. Crit.	568.79	483.46	455.14	457.14

Note: *p<0.1; **p<0.05; ***p<0.01

Note: 'Western Ukraine' is the reference category for GDL Area.

Table 2: Negative Binomial Regression Results for International Out-Migration

	Dependent variable:			
	International Out-Migration			
	Baseline	+ log population	+ regional FE	+ post-2014 dummy
	(1)	(2)	(3)	(4)
Subnational HDI (SDHI)	**28.02***** (9.12)	**19.32***** (5.99)	4.52 (4.77)	3.42 (5.48)
Log Population (GDL)		0.78*** (0.07)	0.38*** (0.08)	0.44*** (0.16)
Central Ukraine			0.11 (0.21)	0.19 (0.30)
Northern Ukraine			1.82*** (0.19)	1.78*** (0.21)
Eastern Ukraine			0.79*** (0.19)	0.79*** (0.19)
Southern Ukraine			0.40* (0.22)	0.50 (0.32)
Post-2014				−0.09 (0.21)
Constant	−17.82** (6.97)	−17.81*** (4.58)	−4.03 (3.74)	−3.61 (3.87)
Observations	69	69	69	69
Log Likelihood	−318.82	−281.58	−249.74	−249.66
θ	1.04*** (0.16)	2.77*** (0.50)	8.83*** (2.10)	8.85*** (2.11)
Akaike Inf. Crit.	641.63	569.15	513.47	515.31

Note: *p<0.1; **p<0.05; ***p<0.01

Note: 'Western Ukraine' is the reference category for GDL Area.

Table 3: Difference-in-Differences Results for Out-Migration

	Dependent variable:	
	Internal Migration	International Migration
	(1)	(2)
Post-2014	-0.579^{***} (0.203)	-0.463^{**} (0.215)
Eastern Ukraine	-0.393^{*} (0.230)	0.195 (0.227)
Central Ukraine	0.896^{***} (0.314)	0.584^{*} (0.332)
Northern Ukraine	0.681^{***} (0.184)	1.609^{***} (0.197)
Southern Ukraine	0.497 (0.370)	0.922^{**} (0.373)
Year	0.092^{***} (0.028)	-0.016 (0.028)
Subnational HDI (SHDI)	5.210 (5.814)	-0.662 (6.122)
Log Population (GDL)	0.804^{***} (0.196)	0.671^{***} (0.189)
Post-2014 $\times$ Eastern Ukraine	0.779^{***} (0.221)	0.887^{***} (0.222)
Constant	-192.887^{***} (58.365)	29.221 (59.085)
Observations	69	69
Log Likelihood	-208.335	-242.966
θ	22.242^{***} (8.462)	12.631^{***} (3.440)
Akaike Inf. Crit.	436.669	505.933

Note: *p<0.1; **p<0.05; ***p<0.01

Note: The reference category for regions is Western Ukraine.

Formulas for migration measures

We calculated the Net Migration Rate (NMR) as in equation 1 that accounts for the incoming and outgoing population of scholars over the total number of scholars in a region in a given year. Similarly, In-Migration Rate (IMR), Out-Migration Rate (OMR), Migration Effectiveness Index (MEI), and Doubling Time (DT) are calculated based on equations 2, 3, 4, and 5, respectively.

$$NMR_{i,t,k} = 1000 \times \frac{I_{i,t,k} - O_{i,t,k}}{N_{i,t}} \tag{1}$$

$$IMR_{i,t,k} = 1000 \times \frac{I_{i,t,k}}{N_{i,t}} \tag{2}$$

$$OMR_{i,t,k} = 1000 \times \frac{O_{i,t,k}}{N_{i,t}} \tag{3}$$

$$MEI_t = 100 \times \frac{\sum_i |I_{i,t,k} - O_{i,t,k}|}{\sum_i (I_{i,t,k} + O_{i,t,k})} \tag{4}$$

$$DT_t = \frac{ln(2)}{R_t} \tag{5}$$

where i is the subnational region. t is the year. Subscript k shows the type of data, i.e., internal or international. $I_{i,t}$ is the inflow of scholars entering a region and $O_{i,t}$ is the outflow of scholars exiting that region. $N_{i,t}$ is the total number of scholars in the region in a given year. R_t is the exponential growth rate per unit time.

Acknowledgments

We are thankful to Tom Theile for support in downloading the raw bibliometric data, to Dmytro Chumachenko for the initial discussions about this study's idea, and to Nataliia Levchuk, Nataliia Kaliuzhna, and Liudmyla Petrenko for their helpful comments on an earlier draft.