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Homecoming After Brexit: Evidence on Academic Migration From Bibliometric Data

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ABSTRACT This study assesses the initial effects of the 2016 Brexit referendum on the mobility of academic scholars to and from the United Kingdom (UK). We leverage bibliometric data from millions of Scopus publications to infer changes in the countries of residence of published researchers by the changes in their institutional affiliations over time. We focus on a selected sample of active and internationally mobile researchers whose movements are traceable for every year between 2013 and 2019 and measure the changes in their migration patterns. Although we do not observe a brain drain following Brexit, we find evidence that scholars' mobility patterns changed after Brexit. Among the active researchers in our sample, their probability of leaving the UK increased by approximately 86% if their academic origin (country of first publication) was an EU country. For scholars with a UK academic origin, their post-Brexit probability of leaving the UK decreased by approximately 14%, and their probability of moving (back) to the UK increased by roughly 65%. Our analysis points to a compositional change in the academic origins of the researchers entering and leaving the UK as one of the first impacts of Brexit on the UK and EU academic workforce.

KEYWORDS High-skilled migration • Brexit • Bibliometric data • Migration of scholars

Introduction

On January 1, 2021, the free movement of people between the United Kingdom (UK) and the European Union (EU) ended. Regulations and requirements for professionals moving between the UK and the EU switched to a point-based visa system intended to favor the immigration of migrants deemed crucial for the UK economy. The UK's decision to leave the EU (referred to as Brexit) will likely have profound consequences for migration to and from the UK, including for researchers who still benefit from a special visa as part of the Global Talent program. Supporters of the Brexit camp argue that the UK's standing in the global competition for talent will improve because it will be able to increase its attractiveness to scholars from outside the EU. Critics point to the UK's lower level of attractiveness for top researchers, especially for EU nationals, who could face additional obstacles to working in the UK, including legal barriers for themselves, their families, and their collaborators, as well as the prospect of diminished access to EU resources.

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The Brexit process dates back to June 23, 2016, when the referendum on whether the UK should remain in the EU was held. The electorate's choice to leave, which was fueled by the idea that the UK should "take back control" of immigration (Gietel-Basten 2016:673), created an unprecedented situation of political discontinuity that led to widespread uncertainty about the status of immigrants in the UK. Changes in migration policy affect the decisions of researchers to migrate internationally (Arrieta et al. 2017; Scellato et al. 2015), which influence the scientific and technological development of the countries involved (Mahroum 2005; Moser et al. 2014). Brexit can be seen as a clear example of a shift in migration policy that could impede the international circulation of scholars, which is known to enhance research performance by facilitating knowledge recombination (Scellato et al. 2017; Sugimoto et al. 2017; Wible 2017) and to be fundamental to scientific discovery, especially in its most innovative forms (Fernández-Zubieta et al. 2016). Researchers and academic institutions were rattled by the outcome of the vote: in the weeks leading up to the referendum, leaders from 103 universities, including from all the top UK institutions, openly expressed their opposition to Brexit, stating that "Cutting ourselves out of the world's largest economic bloc would undermine our position as a global leader in science and innovation" (Goodfellow et al. 2016).

Although it is too early to assess the long-term consequences of Brexit on the migration of researchers, here we analyze large-scale bibliometric data to offer insights into the recent trends and compositional changes in the population of researchers moving to and from the UK. We use data from Scopus, a comprehensive bibliometric database that includes detailed metadata on more than 80 million scientific publications and is considered a source of highly precise individual-level data on published researchers and their affiliations (Aman 2018; Kawashima and Tomizawa 2015). Using these data, we can infer international migration patterns by examining changes in authors' institutional affiliations. In 2015, the precision of Scopus individual-level data on researchers (Scopus author ID) was estimated to be 99% (Kawashima and Tomizawa 2015); a precise author ID is a unique number that is associated only with the publications of a particular author. Previous studies on migration among researchers have used highly accurate data with low coverage (Bohannon 2017), bibliometric databases with high coverage and a focus on specific types of researchers (Chinchilla-Rodríguez, Bu et al. 2018), or ad hoc surveys that might include biases due to nonresponse (Scellato et al. 2015).

Given the trade-offs associated with using each of these data sources, we invested in further refining the quality of the Scopus data for use in migration research by enhancing the disambiguation of authors and tackling other data quality challenges (see the Data section), thus further improving the accuracy of inferences of migration events from bibliometric data. This approach enables us to strike a suitable balance between coverage levels, data quality, and timeliness in studying scholarly migration before and after Brexit.

Background and Conceptual Framework

High-Skilled Migration and Policy Change

The international circulation of scholars is essential to fostering scientific knowledge, especially in its most innovative forms (Agrawal et al. 2017; Fernández-Zubieta et al.

2016). For instance, nearly half of the world's most-cited physicists reside outside their country of birth (Hunter et al. 2009). The international migration and mobility of academics and researchers is a subfield of high-skilled migration that rightly commands attention from researchers and policymakers alike (Chinchilla-Rodríguez, Bu et al. 2018; Czaika 2018; Czaika and Parsons 2017; Sugimoto et al. 2016). For these reasons, it is of paramount importance that we understand the dynamics of the inflows and outflows of scholars across countries and the underlying determinants of the international mobility of researchers.

In the international migration literature, academic migration that is studied within the framework of the brain drain and brain gain relationships can be aptly framed using the concept of brain circulation (Saxenian 2005). The brain circulation concept assumes that high-skilled migration should be considered as a means of knowledge transfer through reciprocal migration flows and therefore represents a circular exchange rather than a one-way loss. Although many factors influence scholars' decisions to move (Azoulay et al. 2017), a key determinant is the policy environments in their country of residence and the destination country. More specifically, policy changes might substantially affect researchers' decisions to migrate internationally (Arrieta et al. 2017; Franzoni et al. 2014, 2015; Scellato et al. 2015), which can affect the scientific and technological development of the countries involved (Mahroum 2005; Moser et al. 2014).

Academic Migration and Social and Cultural Capital

Social capital consists of an individual's interpersonal ties (Granovetter 1973) and the institutionalized social networks they belong to (Bourdieu 1986), which provide opportunities to access economic, social, and professional resources. The relationship between social capital and migration is multifaceted. Evidence shows that the accumulation of social capital in one place has a pull effect for migrants (Putnam et al. 2001) and is associated with lower emigration (D'Ingiullo et al. 2023). The migration literature has also shown that social and interpersonal ties to the destination country, as well as migrant networks, increase the probability of migration by lowering the associated costs (Massey and España 1987). Social capital, in the form of resources, increases the propensity to migrate because it provides information and assistance for migration (Garip 2008).

Social capital in academia could influence scholars' decision to migrate in various ways. Given that interdisciplinary and international ties shape scholars' scientific and social capital and increase their productivity (Gonzalez-Brambila 2014; Melkers and Kiopa 2010), a possible relationship between social capital and international scholarly migration could emerge through practices at academic institutions. Alternatively, scholarly migration might help scientists and researchers advance their careers and build more scientific and social capital in a different country (Van Noorden 2012). Further, the nature of the social capital and collaboration networks could be a factor in international scholarly migration. Social capital accumulated in a specific context, such as the country of origin or the country of graduate studies, might lower the chances of moving abroad, whereas more international than local social capital might encourage international scholarly migration (Bauder 2020).

The concept of cultural capital was originally defined as a refined taste and appreciation of arts and culture, transmitted within the higher classes of society and institutionalized through academic qualifications (Bourdieu 1986). More recently, the social science literature started to distinguish between local and global, academic and nonacademic forms of cultural capital (Igarashi and Saito 2014; Prieur and Savage 2013).

The cultural capital of high-skilled migrants consists of both the cultural capital in the country of origin and transnationally recognized cultural capital. The latter cultural capital provides an advantage in the transnational labor market and reduces the risks of downward mobility and certain migration barriers (Weiß 2005). A crucial requirement for high-skilled migration and, specifically, for academic migration is obtaining internationally recognized degrees and qualifications. Scholars and researchers who meet this requirement, whether they are mobile or not, are likely to have attended top schools enabling this recognition in the country of their academic origin. For scholars and researchers bestowed with high-level institutionalized academic qualifications in the labor market, cosmopolitanism and access to global communities could add to their cultural capital (Igarashi and Saito 2014).

Big Bibliometric Data and Academic Migration

Early studies using bibliometric data were based on a limited volume of data and focused more on citation counts as the measure of scientific impact, scientific progress (Martin and Irvine 1983), and institutional research performance (Moed et al. 1985). The assessment of scientific performance by using bibliometric data influenced not just scholars but also policymakers during the 1990s, especially under the New Public Management framework (Mingers and Leydesdorff 2015). In recent decades, the volume of data used for bibliometric analyses has expanded, and the data now extend beyond the country and the institutional levels, creating what could be called *big bibliometric data*. As the literature on measuring scientific performance using bibliometric data has continued to grow (Sugimoto and Larivière 2018), such data have paved a new way to study migration research (Alburez-Gutierrez et al. 2019).

Migration studies using bibliometric data rely on information on researchers' movements. Following the network-based approach to investigating high-skilled migration (Meyer 2001) and scientific migration (Ackers 2005), the use of bibliometric data to study researchers' migration and mobility started to receive attention (Laudel 2003). The feasibility of this method for examining scholars' migration and mobility patterns was demonstrated first for a select group of countries (Halevi and Moed 2013; Moed et al. 2013). More recently, the literature on scientific migration using bibliometric data has expanded with the publication of studies addressing co-affiliation and collaboration networks (Aref et al. 2018; Chinchilla-Rodríguez, Miao et al. 2018; Sugimoto et al. 2016), the identification of migration and mobility events (Robinson-García et al. 2019), and the mobility patterns of highly mobile researchers (Aref et al. 2019).

In addition, bibliometric data have been used to investigate certain demographic characteristics of researchers. For example, these data have been employed in prominent studies examining gender disparities and their influence on scientific performance

(Larivière et al. 2013), researchers' academic ages (Nane et al. 2017), and the impact of academic age on international mobility (Sugimoto et al. 2017).

The Case of the UK

The notion of brain circulation has long been a subject of scientific debate in the UK. Indeed, the term *brain drain* was coined in this very context. During the early 1960s, the Royal Society published a report on the increase in the emigration of scientists and engineers from the UK to the United States and Canada, and reactions to the report referred to this situation as a drain of scientists and a drain of talent (Oldfield et al. 1963). The drain of scientists and talent out of the UK was later labeled *brain drain* (Johnson 1965:299).

Concerns about brain drain lessened during the 1970s, as British policymakers started to view it as an inevitable part of globalization and as the United States became a less appealing destination for scientists because of its role in the Vietnam War (Godwin et al. 2009). However, fears that British science was declining reappeared in the 1980s. In the STEM fields, the UK's share of global publications and citations decreased by 10% and 15%, respectively, between 1973 and 1982; the sharpest declines, at more than 20%, occurred in biomedical research, physics, and engineering and technology (Irvine et al. 1985). In reaction to these concerns, the 1986 initiative Save British Science called on the government to take action and to support research because "opportunities are missed, scientists emigrate and whole areas of research are in jeopardy" ("Save British science" 1986, as cited in Noble 2016). Research from the early 1990s reported that Britain's scientific performance was growing in some areas, but the overall relative decline continued (Martin 1994).

Although the general impression of the performance of British science has been rather pessimistic since the early 1960s, the lack of scientific investment and the emigration of scientists should not be seen as the only underlying reasons for this trend. The gradual decrease in British scientific publications should also be considered in light of the global increase in English-language publications by nonnative authors, especially since the 1990s. Bibliometric data indicate that by 2018, the United Kingdom accounted for 3.82% of global publication output and ranked sixth globally for publication output (White 2019). The negative evaluation of the UK's scientific performance based on bibliometric data analyses and the impression that British science has been declining might be due to the increased ability of scientists worldwide to publish in English, which mitigated the bias in favor of native English speakers. Furthermore, from the late 1960s onward, the emigration of scientists from the UK to the United States and Canada has been offset by the immigration of scientists from developing countries (and Commonwealth countries) to the UK ("Gaps and drains" 1967; Godwin et al. 2009; Watanabe 1969).

These migration patterns were again disrupted when the UK withdrew from the EU as a result of the referendum held on June 23, 2016, and when Brexit became official on January 31, 2020. Despite long-standing fears that Britain has been losing researchers to other countries (Irvine et al. 1985; Martin 1994; Martin et al. 1987), the UK remains a world leader in scientific research. In 2019, the UK was the G20 country with the largest share of the top 10% of high-quality scientific publications

(Adams et al. 2019). Moreover, the UK was the highest-ranking EU member state in terms of the top 1% of highly cited scientific publications in 2016 (at 1.63%),[1] ranking third globally after Switzerland and the United States and exceeding the EU average (0.95%) by a considerable margin (Pereira et al. 2020: figure 6.1-8).

The UK received €7.86 billion in net research funding from the EU through the Horizon 2020 program, making it the member state with the second-largest share of funding received from the budget, after Germany (European Commission n.d.). The strong ties that British science and technology have established with the EU are among the reasons why some researchers have raised concerns about a potential loss of these relationships following Brexit (Golding 2017).

Data

Source of Raw Bibliometric Data

The main data we used in this study were obtained from Scopus through the institutional access provided by the German Competence Centre for Bibliometrics. The Scopus database contains detailed metadata on more than 80 million scientific publications. For each publication, the database includes the individual author IDs, the publication year, the affiliation countries linked to publications, and the All Science Journal Classification (ASJC) code for fields of each publication venue (e.g., journal, conference proceedings). To obtain the raw bibliometric data, we queried all Scopus data from a relational database using SQL. The query involved two steps: (1) obtaining IDs for all authors who have published at least once with a UK affiliation and (2) obtaining data on all publications during 1996–2019 from the list of author IDs produced in the previous step. Through this process, we obtained exhaustive data on 26,748,770 author–publication linkages (authorship record) involving more than 1,619,000 published researchers with ties to the UK and their 12,365,837 Scopus publications in 1996–2019. The raw data were then preprocessed for use in our analyses. The preprocessing steps mainly addressed the challenges of missing values for the country variable and author name ambiguity.

Data Preprocessing

We had to address two technical challenges associated with the raw bibliometric data before using them to analyze scholarly migration: (1) missing countries and (2) author name ambiguity. In the extract of the raw bibliometric data obtained through queries based on affiliation ties to the UK, the country variable was missing for a small number of records. We modified the neural network algorithm Miranda-González et al. (2020) developed to use it to predict the missing values. This neural network algorithm was trained and tested on a large sample of authorship records

[1] The figure refers to the percentage of the scientific publications produced in a country that are among the top 1% of most-cited publications worldwide.

for which the country variable was available. The trained neural network algorithm took the affiliation address as an input and predicted the country associated with the affiliation address with a high degree of accuracy. Section A of the online appendix provides statistics on our implementation of this method for handling missing values. For more technical details on the development of the neural network, refer to Miranda-González et al. (2020).

Scopus provides author IDs to identify the publications of each researcher. These author IDs appear to be sufficiently reliable for analyzing the migration of researchers (Aman 2018), given previous research showing that 98.3% of author IDs precisely identify one researcher[2] (Paturi and Loktev 2020). Despite the high degree of precision of the Scopus author IDs, we consider Scopus to be an imperfect source of digital trace data for studying the migration of researchers. The lack of precision in the Scopus author IDs implies that, on average, 1.7% of author IDs might involve publications from multiple individuals who share the same name. To address this problem systematically, we applied a conservative author disambiguation process (D'Angelo and van Eck 2020; Miranda-González et al. 2020) to the author profiles that were more likely to be affected by the precision flaws of the Scopus author IDs. The author disambiguation algorithm we implemented was based on recent developments in the use of unsupervised learning for disambiguating bibliometric data (D'Angelo and van Eck 2020). This algorithm was designed using a conservative approach: it assumes that every two authorship records are from distinct individuals unless sufficient evidence demonstrates the similarity of the two records. We considered the author profiles that exceeded either of these thresholds suspicious and treated them with the disambiguation algorithm. These author IDs were associated with a suspiciously high number of countries or publications, with those thresholds being more than 6 and more than 292, respectively. We chose the 292 threshold to imply that a given author ID had an average of more than one publication per month across 24 years and four months. These thresholds were chosen by trial and error. The aim of this screening of outliers was to reduce the risk that the lack of precision in 1.7% of author profiles, which might have represented more than one individual researcher, would lead to the overestimation of migration. For further details on data preprocessing, see the online appendix (section A).

A Focus on Active Researchers

Migration is well-known to be a selective process. However, partly because of a lack of data, the measurement of high-skilled migration has typically been based on broad categories, such as educational attainment or economic sectors. Unobservable characteristics that might be related to the potential for breakthroughs are more difficult to measure. The results of our analyses using the disambiguated Scopus data show that although migrant researchers were outnumbered by those who remained

[2] According to the latest accuracy evaluation in August 2020, the precision of the Scopus author profiles is 98.3%, and the completeness is 90.6% (Paturi and Loktev 2020). In this context, precision is the percentage of author profiles that contain the publications of only one individual. Completeness is the ratio of individual researchers whose publications are all in one author profile.

affiliated with UK institutions only, the scientific impact of migrants was substantially larger. For example, our data indicate that migrant scholars received, on average, 90% more citations per year. In this study, we focus on the migration of upper-tier researchers who were consistently active in producing scientific publications over the study period (hereafter, *active researchers*). By concentrating on migrant and active researchers in our empirical analysis (i.e., the top end of the distribution), we aimed to identify those groups who are typically the targets of immigration policies intended to attract top talent.

Methods

Detecting Migration Events

We build on previous research on bibliometric data to define academic migration. Throughout this article, we use the country of academic origin to refer to the country of first publication. The academic origin is not considered a proxy for a scholar's nationality but as the country most likely to have invested in the individual's pre- or postdoctoral period of academic development that led them to become a published researcher, regardless of their nationality (Aref et al. 2019; Robinson-García et al. 2016; Robinson-García et al. 2019; Subbotin and Aref 2021; Zhao et al. 2021, 2022). For each year and scholar, we assessed the mode country of affiliation, given that some researchers were affiliated with multiple countries in a given year. We used a calendar year as the time unit, per the definition of long-term international migration as a change of the country of usual residence for at least one year (International Organization for Migration 2019:125), which is also the definition the Office for National Statistics (ONS) uses in the UK (ONS 2020). We defined migration across countries as a change in this mode country. For example, a scientist who published with an affiliation(s) mostly from Germany in 2016 and then published with an affiliation(s) mostly from the UK in 2017 was considered by our algorithm to have moved from Germany to the UK in 2016. To be precise, we calculated the year of the move using the rounded midpoint between the last year when the researcher had Germany as a mode country of affiliation and the first year when the researcher had the UK as the mode country of affiliation. Because of the time it takes to conduct and publish research, the publication years did not necessarily match the years of move. However, according to our method, when a continuously active researcher has at least one publication every year, the move year becomes the last year of the common usage of the old affiliation. For a researcher with less frequent publications, the potential gap between the actual move year and the move year that our algorithm estimated could be larger.

Inferring the migration events retrospectively from publications posed a challenge of the right-censoring of the data. Because not every researcher necessarily publishes every year, the number of movers at the end of our period was inevitably underestimated, which cannot be corrected until more recent data become available. For the last few years of our dataset, we were able to identify only the most immediate migration events. We thus assume that the number of migration events we detected is an underestimate. Therefore, we used the partial information we had for 2020 to

detect migration events but did not include 2020 in the analysis, given that those estimates would be unreliable. Furthermore, to prevent the right-censoring from biasing our results, we restricted our sample to the researchers for whom locational signals from affiliation countries are available for every year of the analysis—a group we refer to as *active researchers*. Although we identified 946,991 published researchers with ties to the UK in 1996–2019, only approximately 11% of them (102,058) were classified as active, irrespective of whether they were internationally mobile. We used the dataset that included all researchers in the descriptive and visual analyses only, applying additional caution in our statistical analyses and interpretations because of the right-censoring issue.

Therefore, our sample for the statistical analysis consisted of researchers who were either continuously active (had at least one publication for each year of the analysis period) or published with such a frequency that with the above-mentioned inference of migration events, their location information could be identified for the seven consecutive years between 2013 and 2019. Restricting our sample to active researchers enabled us to observe the migration patterns of researchers (with respect to the UK) who would be considered the potential target of policies to attract talent owing to their productivity, as measured by their publications.

Focusing on a selected group of people (i.e., active researchers) also enabled us to create a panel dataset and observe how the migration patterns of a large group of researchers with relatively high levels of scientific productivity and ties to the UK changed in the years before and after the Brexit referendum. Our use of strongly balanced panel data also avoided the problem of attrition.

Inferring Gender

The most likely gender of each active researcher included in the dataset was inferred from the first names of the researcher using the *genderizeR* package in R (Wais 2006). Studies of big bibliometric data analysis typically rely on various gender estimation algorithms (Krapf et al. 2016). However, because these algorithms were initially developed for marketing rather than for research, they are more accurately applied to certain populations than to others. Generally, the gender inference algorithms work better for Anglo-Saxon and European names, for which the training sample is large. In contrast, because Asian and African names are underrepresented in the training data, the predicted gender is less accurate for these names. Moreover, for unisex names, the probability of the inferred gender being reported is low, indicating that the result is unreliable. Therefore, for our analysis of gender, we used three categories: female name, male name, and unknown. The last category contained all the authorship records for which gender could not be estimated or the gender estimation lacked accuracy. The accuracy of the gender estimation was based on the probability reported by the *genderize* function from the *genderizeR* package. We used two probability thresholds to infer the most likely gender of researchers: 75% and 90%. We considered the gender inference accurate enough if the reported probability of being male or female for a given name was at least 75%. If the gender estimation failed to meet this criterion, the predicted gender was tagged as unknown. For robustness checks, we created a separate gender variable that used the same logic but had a

minimum threshold of 90%. The distribution of estimated gender is presented in Table A1 in the online appendix.

Statistical Modeling

To quantify changes in brain circulation patterns in the UK after the Brexit referendum, we narrowed our focus to the sample of active researchers in our statistical analysis. The sample of active researchers formed strongly balanced panel data for 2013–2019. We applied a random-effects logistic regression model to the panel data of the 45,316 internationally mobile researchers who were classified as active between 2013 and 2019. The dependent variable is binary, taking the value of 1 to represent a year with an out- or in-migration event and 0 otherwise for each active researcher and for each year between 2013 and 2019. Our main explanatory variables are (1) *Brexit*, represented by a binary variable equal to 1 after 2016 and 0 before 2016; and (2) *academic origin*, defined as the country of the author's primary institutional affiliation when they published their first article, going as far back as 1996 (see the Detecting Migration Events section).

The panel data we compiled consist of 45,316 internationally mobile, active researchers with at least one UK-affiliated publication throughout their career, for whom location (of residence) information is available via Scopus-indexed publication references or inferences of migration events during 2013–2019. Our strongly balanced panel data with annual observations for each active researcher in the sample, which were derived from the information from multiple publications, provided us with a robust resource for our statistical analyses. In addition, the random-effects model allowed us to explore the potential effects of the time-invariant variables (e.g., academic origin) and control variables (e.g., scientific field and gender). Therefore, we selected the individual-specific random-effects model as the main model for our analysis. For robustness, we also apply and present the results of its replication using simple logistic regression.

We consider the following two models for the emigration and immigration of active researchers, respectively:

$$MovesOut_{i,t} = \ln\left(\frac{P}{1-P}\right)_{i,t} = \alpha + \beta_1 Brexit_t + \beta_2 Origin_{i,t} + \beta_3\left(Brexit \times Origin\right)_{i,t} + \sum_{(k=9)}^{K}\beta_k \mathbf{X}_{i,t} + \omega_i + \tau_t$$

$$MovesIn_{i,t} = \ln\left(\frac{P}{1-P}\right)_{i,t} = \alpha + \beta_1 Brexit_t + \beta_2 Origin_{i,t} + \beta_3\left(Brexit \times Origin\right)_{i,t} + \sum_{(k=9)}^{K}\beta_k \mathbf{X}_{i,t} + \omega_i + \tau_t.$$

In these random-effects logistic regression equations, the dependent variables *MovesOut* and *MovesIn* are binary variables equal to 1 when in a given year *t* the researcher *i* leaves the UK or moves to the UK, respectively. We consider scientific immigration and scientific emigration as two different models, acknowledging that

moving into and out of a country might follow different patterns, as is also observed in the descriptive graphs. The main explanatory variables are denoted by the interaction term *Brexit* × *Origin*, and the control variables are represented by **X**. The variable *Brexit* is a binary variable that equals 1 for 2016–2019 and 0 otherwise. The control variables include academic age and dummy variables for having higher-than-average publication and citation counts, scientific field, and gender.

Similar to the approach used to define academic origin, academic age is measured on the basis of the first publication. The year of first publication is considered to be the academic birth year of a researcher, and the researcher's academic age is calculated dynamically for subsequent years. The scientific field dummy variable is based on the ASJC field codes tagged by Scopus and consists of four general categories: life sciences,[3] social sciences,[4] physical sciences,[5] and health sciences.[6]

The publication and citation count variables were calculated over the entire dataset (starting with 1996) available for each researcher in the active researchers sample. The gender variable was created using the method explained earlier (see the Inferring Gender section).

Results

Descriptive Analysis

To understand the changing characteristics of brain circulation in the UK, we first consider descriptive statistics. We visually explore the dynamic flows of researchers moving to and from the UK, by academic origin, before Brexit (Figure 1) and after Brexit (Figure 2). The online appendix also illustrates the trends in outgoing and incoming researchers by academic origin in the UK (Figure A1).

The results of our descriptive analysis of longitudinal Scopus bibliometric data suggest that if the post-Brexit trends we observe continue, Brexit might trigger a change in the composition of the British scientific workforce. Although we used a comprehensive source of data on published researchers, conducting an empirical analysis with these data was a challenge because of the lack of observations in the years the authors did not publish. For the visualizations using the dataset with no restrictions (to active researchers), we consider a sharp decline only as a potential decline in the pattern that should be reassessed in future work. We expect the slope of the trend to change upward in the coming years when more recent data become available that enable us to fill the data gaps for the most recent years. Therefore, under these circumstances, observing an increasing trend in such visualizations with

[3] Life sciences include Agricultural and Biological Sciences; Biochemistry; Genetics and Molecular Biology; Immunology and Microbiology; Neuroscience; and Pharmacology, Toxicology and Pharmaceutics.

[4] Social sciences include Arts and Humanities, Business, Management and Accounting, Decision Sciences, Economics, Econometrics and Finance, Psychology, and Social Sciences.

[5] Physical sciences include Chemical Engineering, Chemistry, Computer Science, Earth and Planetary Sciences, Energy, Engineering, Environmental Science, Materials Science, Mathematics, and Physics and Astronomy.

[6] Health sciences include Medicine, Nursing, Veterinary, Dentistry, and Health Professions.

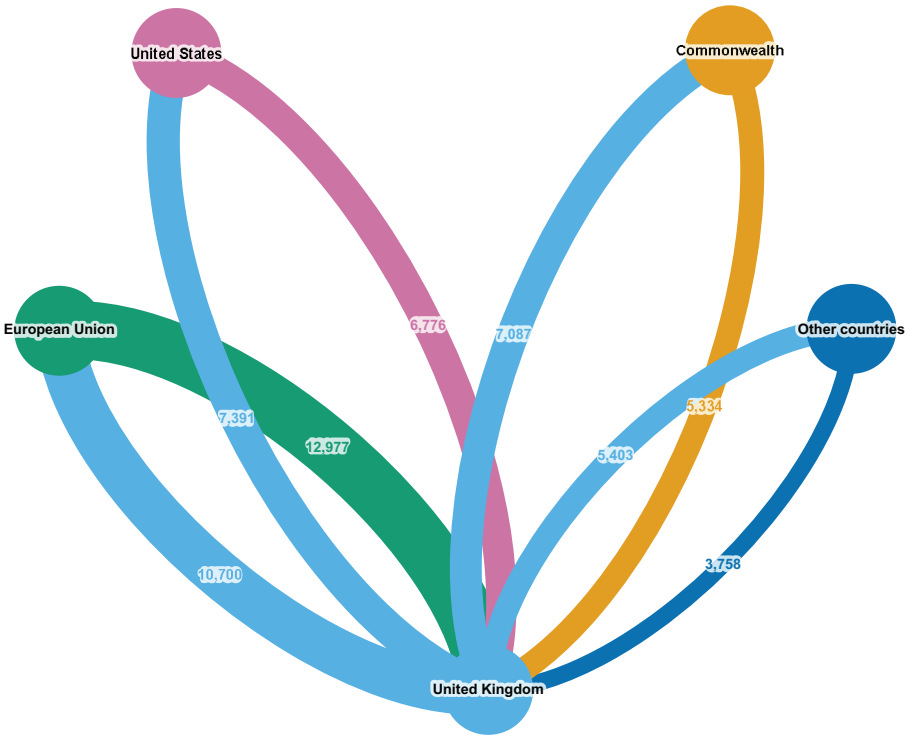

Fig. 1 Migration flows and the overall patterns of scholarly migration in the three years before the Brexit referendum. The EU had the largest flows to and from the UK, followed by the United States, the Commonwealth countries, and all other countries. The colored bands represent the migration flows in 2013–2015, with colors based on the origin node.

the minimum estimates for the most recent years, instead of a sharp decline, would be striking.

Despite this challenge, the results of the descriptive analysis in Figure 3 point to a potential change in researchers' patterns of movement out of and to the UK by academic origin. Indeed, the figure shows a slight but steady increasing trend in leaving the UK for researchers with an EU country of academic origin up to 2018. The decreasing trend between 2018 and 2019 is probably due to the right-censoring in the data. To avoid overestimating immobility during the years without any publications, we focused on a subset of the active migrant researchers: the same subset we used in the statistical analysis (N=45,316). We categorized the academic origins into four groups: EU countries, the United States, the UK, and other. The migration trends in leaving and entering the UK among the active researchers in each academic origin category are shown in Figure 4. Following the Brexit referendum, the share of active researchers with an EU country of academic origin who left the UK increased, whereas the share of active researchers with a UK academic origin who left the UK decreased. Figure A1 (online appendix) displays a similar picture of the number of active researchers leaving and entering the UK by academic origin. The compositional changes after the Brexit referendum are clear among active researchers moving to (leaving) the UK, given that the share of those with an EU academic origin

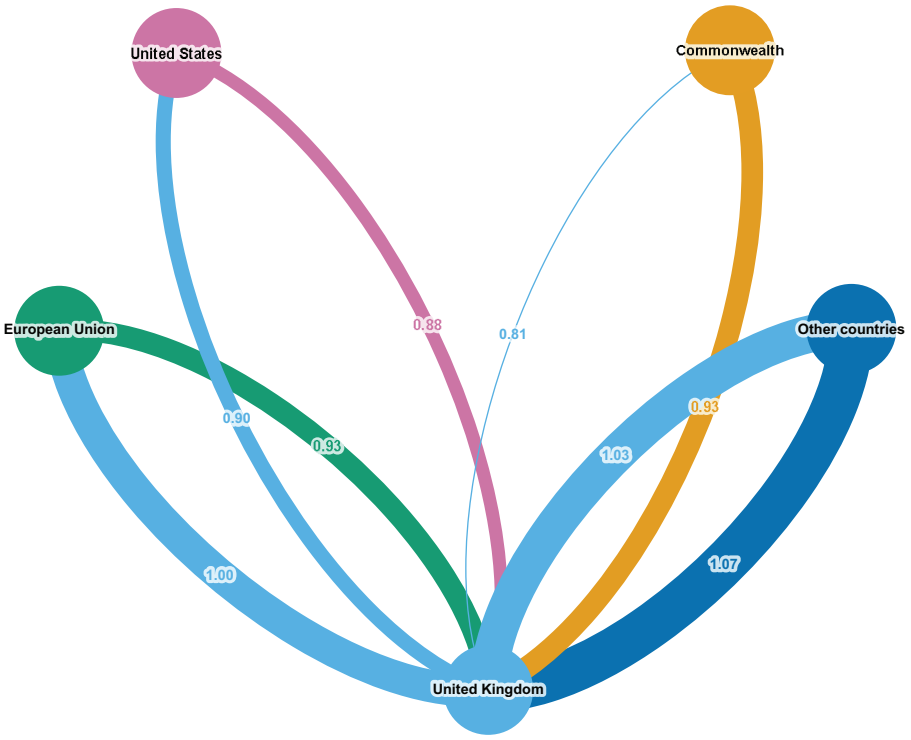

Fig. 2 In the three years after the Brexit referendum, the flows decreased, except for those from the UK to the EU (which remained the same) and those between the UK and other countries (which increased in both directions). The bands represent the changes in migration flows in 2016–2018 relative to 2013–2015. For example, the weight of the green band from the EU to the UK is 0.93, indicating that the total flow from the EU to the UK in the three years after the Brexit referendum was equal to 0.93 of the corresponding flow during the three years before the Brexit referendum. The colors of the bands are based on the origin node.

decreased (increased) but the share of those with a UK academic origin increased (decreased).

Statistical Analysis

The results of the random-effects logistic regressions assessing the out-migration and in-migration patterns of active researchers between 2013 and 2019 are presented in Table 1. For comparison, Table 2 shows the results of estimating the parameters of the logistic model without random effects. These results are shown as robustness checks considering moving out of the UK (leaving) and moving to the UK (entering), respectively. The results of the empirical analysis corroborate the implications of the initial descriptive analysis and confirm the statistical significance of the changes in migration patterns. Table 1 shows that the odds of moving to the UK after Brexit were 44% higher for active researchers with a UK academic origin than for the baseline group of active researchers with an academic origin other than the UK, an EU country, or the United States. Without the interaction with the Brexit variable, the odds of

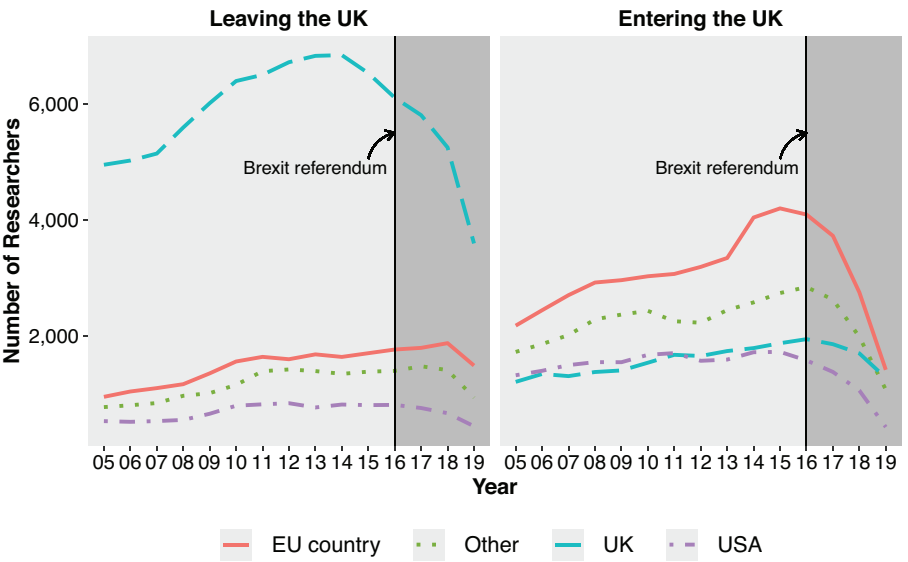

Fig. 3 Numbers of all researchers in our dataset leaving and entering the UK by country of academic origin. Instead of starting in the year 2013, we report the numbers for the longer period of 2005–2019. The figure shows the patterns of the annual total number of researchers leaving the UK on the left side, and the patterns of the annual total number of researchers moving to the UK on the right side. The year of the Brexit referendum (2016) is marked with a black vertical line. In both graphs, the sharp decline observed in the later years should be interpreted as a result of right-censoring. The slope is expected to partially flatten with the introduction of more recent publication data and related improvements for the inference of migration events. However, we observe a slightly increasing trend for all researchers leaving the UK whose academic origin was an EU country after the year of Brexit and despite the right-censoring, except for 2019, for which we see the impact of right-censoring in the data for all groups.

moving to the UK were 64% lower for active researchers with a UK academic origin than for the baseline group. Furthermore, after Brexit, the odds of leaving the UK were 36% higher for active researchers with an EU academic origin than for a researcher with an academic origin other than the EU, the UK, or the United States. Without the condition of Brexit, this trend would be reversed, with the odds of leaving the UK 21% lower, for an active researcher with an EU academic origin than for an active researcher from the baseline group. Figure A2 (online appendix) shows the changing patterns of the odds of moving out of and to the UK.

Figure 5 and Table 3 show the probabilities of leaving and entering the UK, calculated using the results of the random-effects logistic regression, for the active researchers by academic origin, before and after Brexit, respectively. Figure 5 illustrates that among the active researchers, the probability of leaving the UK after Brexit declined only for those with a UK academic origin. For active researchers, the probability of leaving the UK fell from 5.25% to 4.54%, representing a 14% decrease. All the active researchers except for those with a UK academic origin became increasingly likely to leave the UK after Brexit. The change in the probability of leaving was largest for the active researchers with an EU academic origin, rising from nearly 2.96% to 5.51%—an increase of approximately 86%. Thus, our results support the argument that active researchers with an EU academic origin,

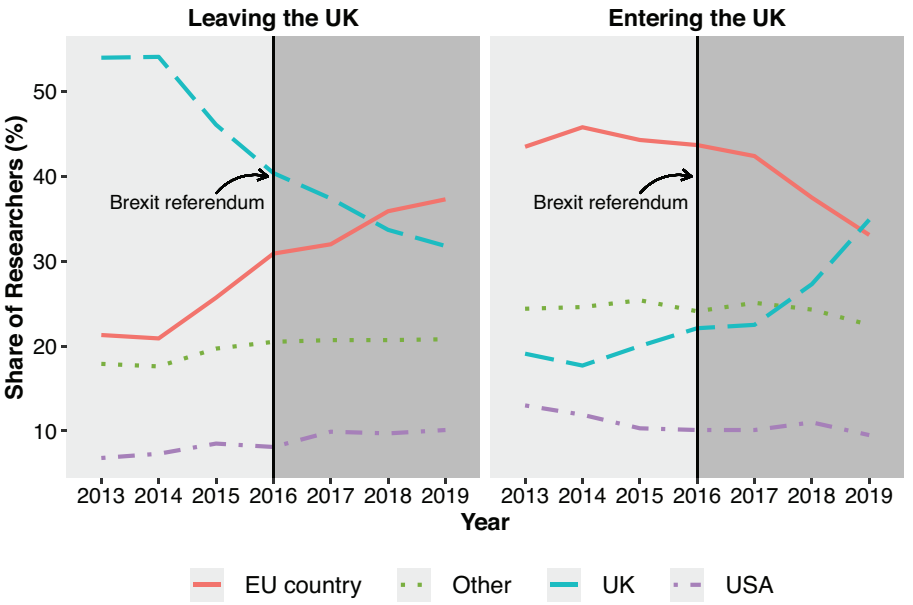

Fig. 4 Shares of active researchers leaving (emigration) and entering (immigration) the UK by country of academic origin from 2013 to 2019 (N=45,316). The shares reflect the percentages of the four academic origin groups among all active researchers leaving and entering the UK in a given year. The year of the Brexit referendum (2016) is marked with a black vertical line. Building on the descriptive analysis in Figure 3, we observe that the changing patterns of active researchers by academic origin are more prominent when we focus on their shares among all active researchers leaving or entering the UK instead of on the sheer numbers. The changes after the Brexit referendum were more remarkable for active researchers entering the UK. In 2015, among all active researchers entering the UK, the share of researchers with an EU country of academic origin was above 40%, whereas the share of researchers with a UK academic origin was roughly 20%. By 2019, the share of researchers with an EU country of academic origin had decreased by approximately 10 percentage points, and the share of researchers with a UK academic origin had increased by more than 10 percentage points—accelerating an increasing trend right before Brexit that brought both categories to roughly the same level of above 30%.

who constituted a sizable share of the academic population in the UK, were significantly more likely to leave the UK after the Brexit referendum than they were before the vote. Although the probability of entering the UK before and after Brexit did not change significantly for active researchers with a U.S. or EU academic origin, the probability increased significantly for active researchers with a UK or other academic origin. For active researchers with a UK academic origin, the probability of moving to the UK increased from 1.97% to 3.24% after Brexit, representing a change of approximately 65%. Active researchers with another academic origin (a non-EU country other than the UK and the United States) experienced a statistically significant increase (by 15%) in the probability of moving to the UK after Brexit, from 5.15% to 5.92%. However, active researchers with a U.S. or EU academic origin had decreased odds of entering the UK (see Table 1), although the marginal probability displayed stable patterns with no statistically significant changes. This apparent divergence is likely because the other academic origin group was the baseline group used for the odds ratio calculations.

Table 1 Results of the random-effects logistic regression models for leaving and entering the UK

	Leaving the UK		Entering the UK	
	Logit Coef.	Odds Ratio	Logit Coef.	Odds Ratio
Post-Brexit	0.356**	1.428**	0.152**	1.164**
	(0.0399)	(0.0570)	(0.0361)	(0.0420)
EU Origin	–0.231**	0.794**	0.168**	1.183**
	(0.0387)	(0.0307)	(0.0279)	(0.0331)
UK Origin	0.378**	1.459**	–1.013**	0.363**
	(0.0330)	(0.0482)	(0.0358)	(0.0130)
U.S. Origin	0.0122	1.012	0.173**	1.189**
	(0.0534)	(0.0540)	(0.0401)	(0.0477)
Post-Brexit × EU Origin	0.304**	1.356**	–0.098*	0.906*
	(0.0517)	(0.0701)	(0.0450)	(0.0408)
Post-Brexit × UK Origin	–0.513**	0.599**	0.367**	1.443**
	(0.0474)	(0.0284)	(0.0508)	(0.0732)
Post-Brexit × U.S. Origin	0.112	1.118	–0.122†	0.885†
	(0.0716)	(0.0800)	(0.0638)	(0.0564)
Academic Age	–0.108**	0.898**	–0.119**	0.888**
	(0.0014)	(0.0013)	(0.0015)	(0.0013)
Above-Average Publications	–0.245**	0.783**	–0.185**	0.831**
	(0.0186)	(0.0145)	(0.0177)	(0.0147)
Above-Average Citations	0.043*	1.043*	0.007	1.007
	(0.0198)	(0.0206)	(0.0193)	(0.0194)
Social Sciences	0.154**	1.167**	0.247**	1.281**
	(0.0330)	(0.0385)	(0.0292)	(0.0374)
Health Sciences	–0.0298	0.9710	–0.0184	0.9820
	(0.0285)	(0.0277)	(0.0279)	(0.0274)
Physical Sciences	–0.118**	0.888**	–0.087**	0.917**
	(0.0218)	(0.0194)	(0.0206)	(0.0189)
Life Sciences	–0.058*	0.943*	–0.091**	0.913**
	(0.0247)	(0.0233)	(0.0238)	(0.0218)
Male (75% probability)	0.008	1.008	0.144**	1.155**
	(0.0277)	(0.0279)	(0.0277)	(0.0320)
Female (75% probability)	–0.074*	0.929*	0.117**	1.124**
	(0.0306)	(0.0285)	(0.0300)	(0.0337)
Constant	–1.897**	0.150**	–1.597**	0.202**
	(0.0672)	(0.0101)	(0.0383)	(0.0079)
Number of Observations	317,212	317,212	317,212	317,212
Number of Researchers	45,316	45,316	45,316	45,316

Notes: For both models, the first column shows the logit coefficients, and the second column shows the odds ratios. Robust standard errors are shown in parentheses.

†$p < .10$; *$p < .05$; **$p < .01$

Discussion

Bibliometric data allow us to study the migration patterns of researchers and scholars as high-skilled migrants with respect to academic origin, academic age, and inferred gender. They further allow us to analyze how policies might directly or indirectly affect the migration decisions of researchers and scholars, providing insights into

Table 2 Comparison of the odds ratio values in random-effects (RE) logit models and simple logit models for robustness, including the addition of year and destination country fixed-effects (FE) controls in the second and third columns, for active researchers leaving and entering the UK

	Leaving the UK						Entering the UK					
	RE Model	Logit	RE Model	Logit	RE Model	Logit	RE Model	Logit	RE Model	Logit	RE Model	Logit
Brexit	1.428**	1.428**	1.720**	1.720**	1.759**	1.759**	1.164**	1.164**	1.341**	1.341**	1.279**	1.279**
	(0.0570)	(0.0571)	(0.0854)	(0.0856)	(0.0881)	(0.0881)	(0.0420)	(0.0420)	(0.0652)	(0.0652)	(0.0628)	(0.0628)
EU Origin	0.794**	0.794**	0.792**	0.792**	0.780**	0.780**	1.183**	1.183**	1.183**	1.183**	1.082**	1.082**
	(0.0307)	(0.0307)	(0.0307)	(0.0307)	(0.0306)	(0.0306)	(0.0331)	(0.0331)	(0.0331)	(0.0331)	(0.0322)	(0.0322)
UK Origin	1.459**	1.459**	1.460**	1.460**	1.274**	1.274**	0.363**	0.363**	0.363**	0.363**	0.426**	0.426**
	(0.0482)	(0.0476)	(0.0483)	(0.0477)	(0.0422)	(0.0422)	(0.0130)	(0.0130)	(0.0130)	(0.0130)	(0.0157)	(0.0157)
U.S. Origin	1.012	1.012	1.015	1.015	1.047	1.047	1.189**	1.189**	1.192**	1.192**	1.069	1.069
	(0.0540)	(0.0540)	(0.0543)	(0.0542)	(0.0558)	(0.0558)	(0.0477)	(0.0477)	(0.0478)	(0.0478)	(0.0449)	(0.0449)
Brexit × EU Origin	1.356**	1.356**	1.356**	1.356**	1.358**	1.358**	0.906*	0.906*	0.906*	0.906*	0.907*	0.907*
	(0.0701)	(0.0701)	(0.0701)	(0.0701)	(0.0707)	(0.0707)	(0.0408)	(0.0408)	(0.0409)	(0.0409)	(0.0416)	(0.0416)
Brexit × UK Origin	0.599**	0.599**	0.599**	0.599**	0.596**	0.596**	1.443**	1.443**	1.442**	1.442**	1.449**	1.449**
	(0.0284)	(0.0283)	(0.0284)	(0.0283)	(0.0284)	(0.0284)	(0.0732)	(0.0732)	(0.0733)	(0.0733)	(0.0746)	(0.0746)
Brexit × U.S. Origin	1.118	1.118	1.118	1.118	1.119	1.119	0.885†	0.885†	0.885†	0.885†	0.886†	0.886†
	(0.0800)	(0.0800)	(0.0801)	(0.0801)	(0.0808)	(0.0808)	(0.0564)	(0.0564)	(0.0565)	(0.0565)	(0.0573)	(0.0573)
Constant	0.150**	0.150**	0.140**	0.140**	0.169†	0.169†	0.202**	0.202**	0.156**	0.156**	0.401*	0.401*
	(0.0101)	(0.0063)	(0.0100)	(0.0064)	(0.1540)	(0.1540)	(0.0078)	(0.0078)	(0.0067)	(0.0067)	(0.1650)	(0.1650)
Number of Observations	317,212	317,212	317,212	317,212	316,967	316,967	317,212	317,212	317,212	317,212	316,687	316,687
Number of Researchers	45,316		45,316		45,281		45,316		45,316		45,241	
ICC	1.39e–06		1.39e–06		2.47e–07		2.00e–07		1.99e–07		6.56e–07	
Sigma	0.0021		0.0021		0.0009		0.0008		0.0008		0.0015	
χ^2	6,612		6,502		6,577		9,787		9,787		9,888	
Psuedo-R^2		.0485		.0492		.0677		.0763		.0785		
Controls	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Year FE	No	No	Yes	Yes	Yes	Yes	No	No	Yes	Yes	Yes	Yes
Destination FE	No	No	No	No	Yes	Yes	No	No	No	No	Yes	Yes

Notes: Controls refer to the control variables used in the random-effects model shown in Table 1, which are included in all regressions shown in the table. These variables are academic age, above-average publications, above-average citations, dummy variables for field of work (social, health, life, and physical sciences), and inferred gender with 75% probability. ICC refers to the intraclass correlation. Robust standard errors are shown in parentheses.

†$p < .10$; *$p < .05$; **$p < .01$

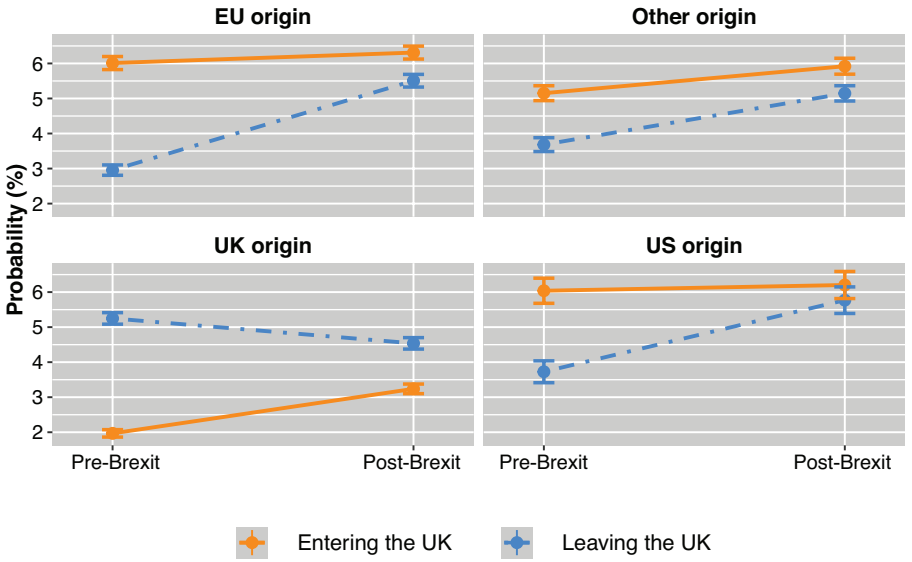

Fig. 5 Marginal probabilities of entering (immigration) and leaving (emigration) the UK before and after Brexit, with 95% confidence intervals, for active researchers ($N = 45{,}316$) by country of academic origin. The probability of leaving the UK increased after Brexit for all academic origin groups except for the UK group. The probability of leaving the UK decreased by roughly 14% after Brexit for active researchers with a UK academic origin, falling from 5.3% to 4.5%. The largest change was observed for active researchers with an EU country of academic origin, whose probability of leaving the UK increased by 86%, from almost 3.0% before Brexit to 5.5% after Brexit. Regarding the probability of entering the UK, active researchers with an EU or a U.S. academic origin show no statistically significant change. The "other" academic origin group experienced a small but statistically significant increase in the probability of entering the UK after Brexit. The most striking change was in the probability of moving (back) to the UK among active researchers with a UK academic origin, which increased by 65%, from nearly 2.0% before Brexit to 3.2% after Brexit.

migration studies and public policy. Our aim in this study was to estimate the immediate effects of the 2016 Brexit referendum on the mobility of top talent in British academia by using bibliometric data to follow scholars' migration patterns. We focus on migrant and active researchers as a sample of top talent that countries wish to attract for their continuous scientific productivity, access to academic networks in multiple countries, and potential willingness to move.

Our analysis did not reveal a pattern of brain drain for the period after the referendum and before Britain's withdrawal from the EU became official. This finding suggests that the migration policies that the UK implemented after Brexit in 2020 likely bear more importance for the migration decisions of internationally mobile researchers than the uncertainty of the intermediary period between 2016 and 2019. This hypothesis for researchers, based on the results of bibliometric data analysis, seems to align with the long-term international migration estimates for the general population in the UK. According to estimates published by the ONS (2021), the EU migration patterns with respect to the UK changed drastically in 2020. From 2018 to 2020, these estimates showed an increasing trend of emigration and a decreasing

Table 3 Marginal probabilities of leaving and entering the UK pre- and post-Brexit, with standard errors and 95% confidence intervals

	Marginal Probability	SE	95% CI	
Leaving the UK				
Pre-Brexit × Other origin	0.0368	0.0010	0.0349	0.0388
Pre-Brexit × EU origin	0.0296	0.0008	0.0281	0.0310
Pre-Brexit × UK origin	0.0525	0.0008	0.0509	0.0541
Pre-Brexit × U.S. origin	0.0373	0.0016	0.0341	0.0404
Post-Brexit × Other origin	0.0515	0.0011	0.0493	0.0536
Post-Brexit × EU origin	0.0551	0.0009	0.0533	0.0569
Post-Brexit × UK origin	0.0454	0.0008	0.0437	0.0470
Post-Brexit × U.S. origin	0.0577	0.0019	0.0539	0.0615
Entering the UK				
Pre-Brexit × Other origin	0.0515	0.0011	0.0494	0.0536
Pre-Brexit × EU origin	0.0601	0.0010	0.0583	0.0620
Pre-Brexit × UK origin	0.0197	0.0005	0.0186	0.0207
Pre-Brexit × U.S. origin	0.0604	0.0018	0.0568	0.0640
Post-Brexit × Other origin	0.0592	0.0012	0.0569	0.0615
Post-Brexit × EU origin	0.0631	0.0009	0.0613	0.0650
Post-Brexit × UK origin	0.0324	0.0007	0.0310	0.0338
Post-Brexit × U.S. origin	0.0620	0.0020	0.0582	0.0659

trend of immigration for EU nationals. In 2020, as a result of the global pandemic, immigration and emigration estimates fell by almost 50% for every group other than EU nationals. Coupled with the fall in immigration estimates for all groups, this decline created a sizable negative net migration for EU nationals in the UK. Although we did not observe a pattern of brain drain for the study period, our results uncovered a significant pattern of compositional change in the academic origins of active researchers entering and leaving the UK. The compositional change appears to have started before the Brexit referendum but sharpened after 2016, drastically altering the shares of active researchers leaving and entering the UK with respect to UK and EU academic origins within a few years. The early trend of compositional change might be related to the public discussions about Brexit that preceded the 2016 referendum. In these discussions, even the Remain campaign considered the issue of within-EU immigration, including for highly qualified migrants, as one of the main issues to negotiate with the EU (Cameron 2015). Our descriptive analysis demonstrates that this trend started before 2016 (Figures 4 and A1), and our statistical analysis shows that this trend significantly increased for the highlighted cases after 2016 (Table 3 and Figure 5). Unless future academic migration policies address this trend of compositional change, it could make British academia more insular.

The descriptive analyses showed the post-Brexit changes in the migration behavior of internationally mobile researchers by academic origin. Without restricting our dataset to active researchers, we observed a slight increase in the trend toward leaving the UK among researchers whose academic origin was an EU country, despite the bias in the data. When we narrowed our focus to active researchers to obtain a more accurate picture, we observed that after the Brexit referendum, the share of active

researchers with an EU academic origin who left the UK increased continuously, surpassing the share of active researchers with a UK academic origin who left the UK. We also observed the reverse trend for active researchers entering the UK: the share of incoming active researchers with a UK origin surpassed the share of incoming active researchers with an EU origin and increased continuously after the Brexit referendum. The visualizations suggest that the trend of compositional change by academic origin for leaving rather than entering the UK started in 2015 and continued after the Brexit referendum.

The reasons for this shift require further exploration. However, anti-immigrant and anti-foreigner sentiments did not start with the Brexit referendum in 2016. They first became the focus of public discussions following the success of Brexit supporters in the 2014 EU Parliament elections.

Statistical analysis confirmed the significance of the changing migration patterns that emerged from this simple visualization. The marginal probabilities for leaving and entering the UK before and after the Brexit referendum by academic origin (Table 3 and Figure 5), calculated via random-effects logistic regressions, support the implications of the compositional changes outlined in the descriptive analyses. We found that for active researchers with a UK academic origin, the probability of moving (back) to the UK increased by approximately 65% following Brexit, rising from nearly 2.0% before Brexit to 3.2% after Brexit. In contrast, the probability of leaving the UK among this group declined by roughly 14% following Brexit, from nearly 5.3% before Brexit to 4.5% after Brexit. Active researchers with a UK academic origin constituted the only group of active researchers in this categorization by academic origin for whom the probability of leaving the UK decreased after Brexit. For the remaining three groups in our analysis, the probability of leaving the UK increased after Brexit. Regarding the probability of leaving the UK after Brexit, the most striking result was observed for active researchers with an EU academic origin, who represented a large fraction of the foreign-trained scholars in the UK. For an active researcher with an EU academic origin, the probability of leaving the UK rose by approximately 86%, from nearly 3.0% before Brexit to 5.5% after Brexit. For active researchers with an EU or a U.S. academic origin, we did not observe a statistically significant change in the probability of moving to the UK when comparing the periods before and after Brexit. However, active researchers with an academic origin other than the UK, the EU, or the United States experienced a small but statistically significant increase in the probability of moving to the UK after Brexit.

The concept of brain circulation (Saxenian 2005) offers one possible interpretation of the increased probability of moving to the UK among active researchers with an academic origin other than the UK, the EU, or the United States. The worldwide pool of internationally mobile active researchers is limited. Considering that the UK hosts many internationally reputed academic institutions, one might assume that an increased probability of an outflow of active researchers from a certain academic origin might be offset by an increased probability of an inflow of researchers from different academic origins. The Brexit referendum decision did not introduce any direct changes in terms of the migration bureaucracy or recognition of degrees for the researchers with a non-EU academic origin. If they happen to be nationals of countries other than the UK, EU, and the United States, they might face higher migration barriers. However, they would not be affected by Brexit and would not have a reason

to reconsider the UK as an option as a result of Brexit. Conversely, their social capital in the international academic context and transnationally recognized degrees would lower migration barriers. Another possible explanation for the increased probability of moving to the UK among active researchers with other academic origin could be the potential for academic upward mobility. Complementing the assumption of brain circulation and the need to fill the positions previously held by researchers who left the UK after the Brexit referendum, researchers in the group of *other* academic origin would be more likely to consider this situation to be an opportunity to move to institutions with greater resources and international outreach. Similarly, researchers with a UK academic origin might perceive this situation as an opportunity to move back into their previous social and academic networks. Further, researchers with a UK academic origin might utilize the social capital they accumulated in the UK at the start of their careers to seize the newly available positions.

In our study, we refrained from making causal assumptions. Instead, we provided evidence for scholarly migration patterns associated with the Brexit referendum. Because bibliometric data are not real-time data, we could only retrospectively observe scholarly migration patterns. Bearing in mind that Brexit became official in January 2021 and that the available bibliometric data for 2020 were incomplete at the time of our statistical analysis (which therefore ended in 2019), we considered the observed patterns as a reaction to the Brexit referendum. Further research is needed when the relevant data become available to observe the Brexit effect after 2021 and to enable causal claims.

Although it is too early to assess the full scope of the impact of Brexit on the migration of active scholars, our evidence on active researchers indicates that the anticipation of the erection of legal barriers between the UK and the EU has already influenced migration flows. Top researchers cannot be attracted only by offers of visas and funding. Many of them have families that need long-term prospects along many dimensions, and the scientists themselves are key drivers in attracting other successful researchers (Waldinger 2016). Thus, over the longer term, the disruption of Brexit could reduce the circulation of scholars between the EU and the UK, potentially negatively impacting not only the UK but also the EU and the international science system. Explicit changes in science collaboration policies between the UK and the EU are needed to counteract this trend. The early signs are not completely encouraging. On the positive side, the UK has signed a cooperation agreement for Horizon Europe, including for the European Research Council, in which the UK has been highly successful. On the negative side, the UK will not participate in the Erasmus+ collaboration, the flagship program of scientific exchange between university students in Europe. Instead, the UK has focused on developing its own Turing Scheme, which will not offer placements for teaching and college staff. Developing and funding new programs that favor visiting periods abroad for productive international scholars, including for their families, should become a priority to help compensate for the barriers to the circulation of researchers between the EU and the UK that Brexit has erected. ■

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