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Should I stay or should I go? Using bibliometrics to identify the international mobility of highly educated Greek manpower

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Abstract

This paper explores the mobility of the highly educated young Greek scholars. This is made possible through a bibliometric analysis of the affiliation countries of scholars who have published in peer reviewed journals indexed in Scopus. Approximately half of the researchers are identified from publications covered in Scopus for the period 2000–2019. A general taxonomy model is followed for analysing scientific mobility using affiliation changes. The greatest share of researchers (78.3%) appear to be static (74.6% in Greece and 3.7% abroad), whereas the mobile researcher category (21.7%) is divided into migrants (8.9%)—researchers who have left their country of origin—and travellers (12.8%)—researchers who gain additional affiliations while maintaining affiliation with their country of origin. According to the findings, the majority and especially the researcher elite (90.5%) did not sever ties with their country of origin, Greece, but instead built a chain of affiliations that linked nations together. Such chains are represented as groups of countries (clusters), in which the scientific connections between different countries can be visualised. It can be reasoned that the majority of researchers (70.3%) have a tendency to publish to a group of countries with 'traditionally' significant scientific impact.

Keywords Bibliometrics · Young scholars · International mobility · Public funding

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Introduction

The unprecedented growth in the volume and complexity of available data is a fact which requires a combined multi-disciplinary approach. Within a data science framework, designing an overall strategy aimed at transforming data into useful information, would have a significant impact on Research, Development and Innovation. In an effort to develop such a strategy, bibliometrics played a main methodological role within the sphere of science.

Scientific networks, collaboration and exchange patterns have been the spotlight in numerous research studies and conference discussions. The main reason these topics are becoming a focal point has been the premise that such types of knowledge exchanges benefit scientific progress in that they foster innovation, stimulate and enable the flow of ideas between scientists in different institutions (Moed and Halevi 2014; Armijo-Olivo 2012). In addition to the actual scientific growth, there have been serious efforts to investigate how such exchanges reflect on sections such as science policy and economy (Gibson and McKenzie 2014).

Apart from the ability to track and sketch scientific collaborations between institutions, the availability of author profiles, as well as their affiliation details in databases such as Web of Science (WoS) and Scopus, has also made plausible the exploration of scientific mobility from country to country. One of the primary studies on the exploration of the scientific mobility within the frame of bibliometrics was published by Laudel (2003). Later studies followed by Moed and Halevi (2014) and Robinson-Garcia (2019) in which scientific migration trends between developing and developed countries and different taxonomy mobility models are respectively explored. Such research has a meaningful impact on studies dealing with scientific migration as an 'informative effect' on science policy and economy.

This paper delineates the scientific mobility of the highly educated young Greek researchers. Mobility is a contemporary paradigm in the social sciences that explores the movement of people (human migration, individual mobility, travel, transport), ideas and things (transport), as well as the broader social implications of those movements. Mobility can also be thought as the movement of people through social classes, social mobility or income, income mobility (Sheller and Urry 2006). Herein, the concept of mobility is framed within a specific context relevant to science and its prime enablers—the human capital. As such, scientific mobility focuses on the plausible changes in the institutional affiliation of a researcher throughout his/her scientific career by means of a bibliometric analysis of their publications in peer reviewed journals indexed in Scopus. This is attempted by utilising bibliometric data and employing data science techniques. The paper is structured as follows: In "Data collection" section the methodology followed for retrieving the data is described, outlining the whole data collection process. "International scientific mobility; definitions, model and analysis" section after reporting certain bibliometric conventions, it provides an overview of the main outcomes of the exploratory study stating the various mobility patterns identified. Moreover, it covers the taxonomy model upon which the international scientific mobility analysis is based, and, unfolds the conducted bibliometric analysis' approaches. "Results" section contains descriptive statistics on the researchers' affiliations, publications, as well as graphs concerning the depiction of scientific connections between the affiliated countries. Additionally, it provides insights into the main outcomes of the object of study; scientific researcher mobility, the scientific connections between the affiliated countries, the distributed publications as well as the most productive and consistent authors' (the researcher elite's) affiliation status over time. Finally, "Discussion" section draws conclusions on the potential and limitations of the method, suggests the development of certain policies and formulates questions for further research.

Methods

In order to identify scientific mobility patterns we employ data science techniques. By retrieving and using certain bibliometric indicators (number of publications, affiliation of a research unit) information relevant to the research study was obtained. Descriptive analysis was performed with the purpose of detecting the mobile portion of researchers, assessing the scientific mobility of the researcher elite, delineating the scientific connections for Greece as well as different groups of countries. Mobility graphs were constructed within the Python (3.7.3) environment taking into consideration the various mobile researcher classes. For each case, an undirected graph was constructed in which each node represents the country and each edge represents at least one publication from the current country to another. After constructing the mobility graphs, the VOSviewer framework was employed (Eck and Waltman 2014). This allowed illustration of the scientific connections between the countries as well as visualisation of the tendencies of the researchers to publish in a specific neighbourhood of countries. By using such framework, nodes (countries) were mapped in such a way that countries with strong scientific connections are located close to each other and therefore clusters (group of countries) were built accordingly.

Sample

The initial dataset (*Dataset* I) contained information about the recipients of Greek state scholarships funded by 2014–2020 National Strategic Reference Framework as part of the "Tertiary Education Initiatives". These scholarships have been the primary public mechanism to financially support the various highly educated Greek sub-populations engaging in Research and Development activities. These sub-populations are PhD candidates, postdoctoral researchers, groups of new researchers. It is a widely accepted assertion that these research steps are mostly undertaken during the early stages of researchers' (professional) life. These activities have been identified in the context of the "Evaluating NSRF's Tertiary Education Initiatives" project, which monitored various characteristics of these beneficiaries. The project was co-financed by Greece and the European Union (European Social Fund-ESF) through the Operational Programme "Human Resources Development, Education and Lifelong Learning 2014–2020". The total number of the recipients of these state scholarships amounted to **2.742** individuals. This population comprises *Dataset* I that includes the following variables:

- Author's first name
- Author's last name
- Father's name
- Author's email
- Author's Institution
- Author's Department
- Author's academic profile category (PhD holders, new researchers, postdoctoral researchers)
- Year of the PhD award

Data collection

A *two-stage* process was used to collect the bibliometric data of the young researchers. Regarding the first stage, a two-phase process was performed in order to identify our target population. At a second stage within the context of the data collection, certain variables relevant to the researchers' profile were retrieved from Scopus database for analysis purposes.

Target population

Regarding the *first stage*, given our sample (*Dataset* I), the identification of each and every individual inside the Scopus database took place. Therefore, the objective at this stage was to retrieve the Scopus authors ID's. In the first phase, we made use of the Greek National Archive of PhD Theses (EADD).[1] EADD provides access to the PhD theses from all Higher Education Institutions (HEIs) in Greece as well as PhD theses awarded to Greek scholars by foreign HEIs and certified by the Hellenic NARIC/DOATAP (national agency for the recognition of academic and professional qualifications). EADD's archive ranges from 1985 to the present and refers to approximately 45.000 doctorate holders. The database contains data about the doctorate holders (personal details) along with their Scopus ID. In conjunction with our initial dataset (*Dataset* I) and in order to obtain the corresponding Scopus author's IDs from EADD, data matching methods (namely SQL joins) were performed. Out of 1.297 authors that were identified in the EADD database, **606** of them had a Scopus author ID attached.

The second phase of the first stage involved a transliteration process from Greek to English. i.e., given the researchers' personal details, the authors transliterated their name and surname following the methods employed by Karakos (2003) and Chalamandaris et al. (2006) (1.044 author names). This was essential for enabling a Scopus ID search. Then, data scraping techniques (namely HTML Parsing) were used within the Scopus website. This two-phased process allowed the identification of the Scopus author ID of each researcher indexed in Scopus. As is shown in Fig. 1, 401 author names were already transliterated to English, whereas 1.044 author names were written in Greek. With regard to each case, by scraping the Scopus website, a further **188** and **612** researchers respectively with a Scopus author ID were identified. Hence, considering both methods, the total number of researchers attached with a Scopus author ID was **1.406** (Table 1). This is the population of young researchers that constitutes our target population.

Variables

As a *second stage*, the retrieval of the Scopus author IDs enabled the research and allowed the locating and downloading of information relevant to researchers' bibliographic profile. Bibliometric analysis can yield different types of information depending on the bibliometric indicators used. Since the main objective of the analysis is to assess the mobility patterns of the highly educated scientific manpower, following Waltman and Noyons (2018) these (three) bibliometric variables were selected:

[1] https://www.didaktorika.gr/eadd/?locale=en.

Fig. 1 Scopus Author ID Retrieval—a step by step approach

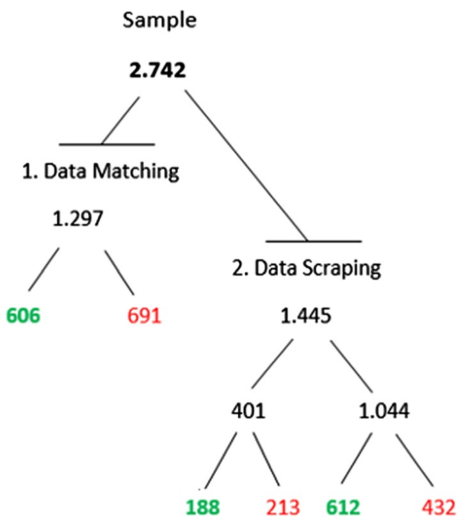


Table 1 Total number of Scopus Author ID's identified in the *Dataset* I

Authors *Dataset* I	Frequency	Percentage (%)
With Scopus ID (green)	1.406	51.3
Without Scopus ID (red)	1.336	49.7
Total	2.742	100

- *Mobility* The publication year for each individual throughout their scientific career (1) as well as the affiliation country for each year (2).
- *Scientific output* The number of publications produced by a researcher each year (3).

To download the variables an algorithm using the Scopus author IDs as input was implemented within the Python environment (3.7.3). A private API key[2] was constructed. This was used to gain access to the Elsevier interactive documentation.[3] To retrieve the country in which each paper was published (i.e. affiliation country) the author's affiliation needed to be extracted. This is based on the assumption that geographic location of the affiliated institution named by the author as her/his postal address stands as the country to which the specific article should be 'measured' for—this is an important assumption that cuts through the entirety of this paper. Furthermore, this affiliation was parsed (forming XPath queries) to obtain the corresponding affiliation country. All authors' article ID's were downloaded. By creating certain queries (utilising built-in XML parser), each author profile was parsed and all the aforementioned bibliometric variables were retrieved.

Within the Python (3.7.3) environment, two nested dictionaries for each Scopus author ID were created. The main one used the Scopus author IDs as "keys". The second used

[2] https://dev.elsevier.com/.

[3] https://dev.elsevier.com/scopus.html.

Table 2 Theoretical concepts and their bibliometric construct regarding the objects of study

Theoretical interpretation	Bibliometric constructs
Researcher	Author's Scopus ID/Author
Active researcher in a particular year	Publish at least an article in that year
Researcher's activity is over the period t_{start}–t_{final}	Published articles starting from t_{start} till t_{final}
Country	The affiliation country that corresponds to author's affiliated institution

the publication year as "keys". The number of publications for each country were used as "values". Below, an example describing the structure of the finalised author profile is presented.

Dictionary structure

$$\{\}\text{Scopus author ID}' : \{\text{Year: }(\}\text{Country}', \text{Publications per Country}), \}\text{Total Publications}' : \}\}$$

e.g. Author with Scopus ID '12345' has in total 10 publications; 4 of which were published in Greece in 2018 while the remaining 6 in Italy in 2019.

$$\{\}12345' : \{2018 : (\text{'Greece'}, 4), 2019\text{: }(\text{'Italy'}, 6), \text{'Total Publications':}10\}\}$$

As a result, the new dataset (*Dataset* II) contained information about the three aforementioned variables together with the Scopus Author IDs.

International scientific mobility; definitions, model and analysis

Definitions

Within the scope of this paper, necessary conventions are made in order to readily capture the relevant conceptual framework. Specific notions are defined as a first step in studying mobility and subsequently analysing its patterns (Moed and Halevi 2014). Since certain bibliometric tools are used, the connection between the theoretical concept and the bibliometric one is specified in Table 2.

An important note should be made concerning some notions. Hereafter, researchers with publications affiliated to a specific *institution*, *organisation*, *foundation* are abbreviated to 'researchers having publications affiliated with a specific *country*' (e.g 'Konstantinos Sioumalas' has one (1) publication affiliated with the 'National Technical University of Athens, Greece', is abbreviated to ' 'Konstantinos Sioumalas' has one (1) publication affiliated with Greece '). Researchers with publications affiliated to a specific *country* at a particular period constitutes the researcher *affiliation status*. Moreover, the collection of the affiliation *countries* that correspond to a researcher's activity over a specific time period (see Table 2), are abbreviated to 'researcher's scientific career path'. Another convention is applied for researchers who have a Scopus author ID and are included in the finalized dataset (see below, *Dataset* F). This concept is transcribed as 'total population of researchers'.

Before noting various patterns identified in the *Dataset* II, three, distinct affiliation instances that were observed are defined:

1. *Single-affiliation* The researcher is affiliated with only one country in all publications in a given year (either Greece or any other single country).
2. *Multiple-affiliation* The researcher has many publications in different countries within the same year.
3. *Co-affiliation* The researcher is affiliated with two or more different countries within a single publication.

Based on the instances defined, four distinctive patterns were detected.

These are:

- *Pattern* 1 Authors with single-affiliation instances. This pattern was observed for 1.196 authors
- *Pattern* 2 Authors with multiple-affiliation instances. This pattern was observed for 101 authors.
- *Pattern* 3 Authors with multiple-affiliation and co-affiliation instances. This pattern was observed for 74 authors.
- *Pattern* 4 Authors where no affiliation was detected. This pattern was observed for 35 authors.

It was decided to exclude the 35 authors where no affiliation was detected (Pattern 4)) from the collected dataset since there was no adequate information for our object of study. As a result, the finalised dataset (*Dataset* F) which was used for analysis purposes included **1.371** authors. Authors identified as fitting Pattern 1 represent 87.2% of the total, authors falling into Pattern 2 7.4% and 5.4% fall under Pattern 3.

Model

The mobility pattern of a researcher can be determined by different mobility events. In this paper, a taxonomic model similar to that discussed by Robinson-Garcia (2019) is used. It proposes a general classification for analysing scientific mobility using institutional affiliation changes and provides a brief analysis in delineating the various mobility patterns. Adopting the categorisation of the mobility events described in Robinson-Garcia (2019) the researcher classification model has been modified in accordance with the patterns detected. Regarding our research study and in comparison with the mobility events described in Robinson-Garcia (2019), a subset of the mobility events arose (see below), each of which has been categorised accordingly.

A *mobility event* refers to each of the different possible combinations of affiliation instances a researcher can have in a specific time interval. The following basic notation is proposed in the scope of identifying different mobility events.

Mobility events

Notation

- **A**: Author's first affiliation country
- **B**: Any other affiliation country (or set of countries) different from A
- $\mathbf{t_p}$ and $\mathbf{t_{p+1}}$: Each refer to a particular point in time (in this case the year of publication). Specifically, the snapshot of time at $\mathbf{t_p}$ the affiliated country is considered

Table 3 Taxonomy of mobility events tracked through affiliation countries given each consecutive publication time points $\mathbf{t_p}$ and $\mathbf{t_{p+1}}$

Mobility Events	t_p	t_{p+1}	Directionality	Country Rupture
Taxonomy mobility model				
$\mathbf{E_1}$	A		No	No
$\mathbf{E_2}$	A	A	No	No
$\mathbf{E_3}$	A	B	Yes	Yes
$\mathbf{E_4}$	A	A;B	Yes	No
$\mathbf{E_5}$	A	A*;B*	Yes	No

the initial country where the author began publishing, $\mathbf{t_{p+1}}$ refers to the *next* tracked point in time (year) in the publication record of the author.

- **A;B**: Author has at least one publication affiliated with A and another publication affiliated with B in the *same* year t_i, $i \in \{2000, ..., 2019\}$.
- **A*;B***: Author has at least one publication co-affiliated with A and B at the same year t_i.

Two additional elements can be related to such mobility events over time. These are:

- *Directionality*: Indicates whether it is possible to reliably establish if the author has chronologically published first to **A** and then to **B**.
- *Country rupture*: Indicates when an author's affiliation country(ies) at t_p is not found among the affiliation country(ies) of the author at t_{p+1}. In other words, there is a *rupture* in the countries between $\mathbf{t_p}$ and $\mathbf{t_{p+1}}$.

Adding the variable of time to each researcher's scientific profile (as derived from the patterns in "International scientific mobility; definitions, model and analysis" section), five (5) distinct mobility events emerge. Table 3 are shows the classified events $\{E_j\}_{j=1}^{5}$ which delineate the overall scientific mobility of the researchers. All researchers started their scientific career with affiliated publications that concerned a single country ($\mathbf{t_p}$). Events $\mathbf{E_1}$ and $\mathbf{E_2}$ concern publications affiliated only with a single country at a specific year or interval respectively. In regards to events $\mathbf{E_3}$, $\mathbf{E_4}$, $\mathbf{E_5}$ researcher publications are affiliated with more than one country associated with a specific affiliation type.

Researcher classification

With the aim of classifying each researcher according to the mobility event that delineates her/his profile (Table 3) the proposed taxonomy was based on the researchers activity (Table 2) for the time interval between 2000 and 2019. Breaking down this time interval into $(t_i, t_{i+1}), \forall i \in \{2000, ..., 2018\}$, 19 pairs of consecutive time intervals were obtained. So, as explained above, when $i = p$ the time instant $\mathbf{t_p}$ represents the time in which researcher began publishing and $\mathbf{t_{p+1}}$ the time point of the next publication (when it exists). The fit of each researcher to a particular class of a mobility event E_j, $j \in \{1, 2, 3, 4, 5\}$ is examined according to the following rules:

$$\forall j = 1, \text{if } \exists!\, i \in \{2000, ..., 2018\} \text{ such that } (t_i, t_{i+1}) \in E_j.$$
$$\forall j \in \{2, 3\}, \text{ if } \exists\, i \in \{2000, ..., 2018\} \text{ such that } (t_i, t_{i+1}) \in E_j$$
$$\text{and } \nexists i^\star \in \{2000, ..., 2018\} \text{ such that } (t_i^\star, t_{i^\star+1}) \in E_j^c.$$
$$\forall j \in \{4, 5\}, \text{ if } \exists\, i \in \{2000, ..., 2018\} \text{ such that } (t_i, t_{i+1}) \in E_j.$$

then the class of researchers R_j is said to satisfy the mobility event E_j.

After applying the taxonomy mobility model to the total population of researchers, the following research categories emerged.

- $\mathbf{R_1}$: Researchers who have been active only one year through their scientific career.
- $\mathbf{R_2}$: Researchers who have been active more than one year and their affiliated country did not change.
- $\mathbf{R_3}$: Researchers who have been active more than one year and their affiliated country changed.
- $\mathbf{R_4}$: Researchers who have been active more than one year and have at least one multiple-affiliation instance.
- $\mathbf{R_5}$: Researchers who have been active more than one year and have both co-affiliation and multiple-affiliation instances.

For each of these sets of researchers the following holds (Ω representing all authors):

$$R_1 \cap R_2 \cap R_3 \cap R_4 \cap R_5 = \emptyset \tag{1}$$

$$R_1 \cup R_2 \cup R_3 \cup R_4 \cup R_5 = \Omega \tag{2}$$

Based on the categorisation explained above it is possible to define certain individual-level mobility classes based on the presence of specific mobility events in the profile of the researcher. The classification system below is proposed so as to define mobility at the level of the individual researcher as measured across their overall scientific output.

Mobility classification schema

- *Static inside out* Researchers lacking any mobility event while showing affiliation instances only one specific country i.e researchers exclusively attributed to the classes $\mathbf{R_1}$ and $\mathbf{R_2}$.
- *Migrants* Researchers associated with a *directional* mobility event and at least a point or period of *rupture* with their country of origin i.e., researchers attributed to the class $\mathbf{R_3}$.
- *Travellers* Researchers associated with a *directional* mobility event but no *rupture* with their country of origin i.e. researchers attributed to the classes $\mathbf{R_4}$ and $\mathbf{R_5}$.

The researcher classes *'Migrants'* and *'Travellers'* are further defined as the *'Mobility Class'*, whereas the *'Static inside out'* simply as the *'Static Class'*.

Bibliometric analysis

The conducted bibliometric analysis was twofold. First, a descriptive analysis of the researchers' affiliation as well as publication status was performed. The purpose was both to identify the share of researchers constituting the *'Mobility Class'* and to assess the strength of the scientific connections of the most significant research group (researcher elite) with the country of origin, Greece. 'Scientific connection' is defined as the distribution of the volume of scientific knowledge exchange that corresponds to the scientific career path of each researcher. Secondly, in terms of the sub-population group of the mobility class, a graph analysis of the affiliation countries with the aim of depicting such scientific connections as distributed between group of countries (clusters) was performed.

Descriptive analysis

With regard to descriptive analysis, as an initial step, the researchers' affiliation status was examined. This status is characterised by researchers who have:

1. *only foreign* affiliations (researcher's indexed publications that have been produced with an affiliation with only non-Greek institutions)
2. *only Greek* affiliations (researchers have had authored/co-authored publications indexed in Scopus only under a Greek institutional affiliation)
3. *Greek and foreign* affiliations (authors that have been identified as having produced/co-produced a paper with both Greek and foreign institutional affiliation(s)).

Researchers were further categorised with respect to their affiliation status as described by the mobility classification schema. As a result, two different classes have emerged. The *'Static Class'* and the *'Mobility Class'*. In order to investigate the behaviour of researcher mobility before and after the Greek economic crisis (taken to be at its peak in 2010), descriptive analysis was performed for the relevant time intervals (2000–2010 and 2011–2019). In addition,in the direction of having a clearer overview and inspecting plausible interrelation between the Greek economic crisis and scientific mobility the per annum publication affiliation status of every researcher was examined.

With regard to the mobile researchers, a significant sub-category was further analysed, the researcher elite. In the context of this analysis, researcher elite is taken to mean (a) the most productive researchers, i.e. those with the greatest number of publications, and (b) the most consistent, i.e. those who have been continuously publishing during the last 9 years (2011–2019) with at least one publication per year. This has taken place in order to assess the level of strength of the scientific connection with the country of origin, Greece. In an effort to outline the relation between productivity (in terms of number of publications) and scientific mobility, specific details regarding the researchers' scientific career per country are reported.

Graph analysis

In order to schematically point out the scientific connections between the target country, Greece, as well as different groups of countries, two graphs were constructed. These, in relation to the *'Mobility Class'*, depict the scientific connections of researchers' scientific career paths associated with the *'Migrants'* and the *'Travellers'* class. For each case an undirected graph was constructed in which each node represents the Country (as defined in Table 2) and each edge represents at least one publication from the current country to another. As a result, two nodes (different countries) are linked if a researcher has shared at least one publication. The graphs were constructed within the Python (3.7.3) environment.

Both were then saved in an output file (.gml) and used as input for the software visualisation tool VOSviewer (hereafter abbreviated to 'VOS'). As a first step of the conducted graph analysis, the associated strength was selected as the most appropriate similarity measure. Such measure was used for normalising the co-occurrence frequencies between every pair of nodes (countries), thus meaning, the frequency of any *linked* pair of nodes. Both theoretical and empirical results indicate that cooccurrence data can best be normalized using a probabilistic measure. This provides strong support for the use of the association strength in scientometric research (Eck and Waltman 2009). Formally, given two nodes i and j, their association strength is given by Van Eck et al. (2010):

$$s_{ij} = \frac{2mc_{ij}}{c_i c_j} \tag{3}$$

Here s_{ij} denotes the association strength of nodes i and j, c_{ij} denotes the number of links (co-occurrence links between countries in this case) between nodes i and j ($c_{ij} = c_{ji} \geq 0$), where c_i denotes the total number of links of node i (for node j similarly) and m denotes the total number of links in the network, that is:

$$c_i = \sum_{i \neq j} c_{ij} \quad \text{and} \quad m = \frac{1}{2} \sum_i c_i \tag{4}$$

Let p_i denote the probability that object i occurs in a randomly chosen network, it is clear that $p_i = \frac{c_i}{m}$. Hence, if two objects i and j occur independently of each other, the probability that they cooccur in a randomly chosen network equals $p_{ij} = p_i p_j$. The expected number of cooccurrences of i and j then equals $e_{ij} = mp_{ij} = mp_i p_j = \frac{c_i c_j}{m}$. The association strength is proportional to the ratio between, on the one hand, the observed number of cooccurrences of objects (countries) i and j and, on the other hand, the expected number of cooccurrences of objects i and j under the assumption that occurrences of i and j are statistically independent. Therefore, this results in a measure that is proportional to c_{ij}/e_{ij}. This measure has a straightforward probabilistic interpretation. If $c_{ij}/e_{ij} > 1$, i and j cooccur more frequently than would be expected by random chance. If, on the other hand, $c_{ij}/e_{ij} < 1$, i and j cooccur less frequently than would be expected by chance. Hence, considering also Eq. (3), for any two nodes the probability that there is an edge connecting them is $p_{ij} = \frac{2c_{ij}}{ms_{ij}}$.

After the construction of the normalised network, the next step was to define the position of the nodes in the network in a two-dimensional space in such a way that strongly related nodes (countries) are located close to each other while weakly related nodes (countries) are located far away from each other. Among the various approaches with regard to mapping and clustering of bibliometric networks, a unified approach of VOS mapping and clustering technique was selected (Waltman et al. 2010).The clustering algorithm used is a smart local moving algorithm (Waltman and Eck 2013) and is based on a weighted and parametrised variant of the modularity function of Newman and Girvan (2004).

In the case of node mapping, VOS aims to locate items in a low-dimensional space in such a way that the distance between any two items reflects the similarity. For each pair of nodes i and j, it requires a similarity s_{ij} ($s_{ij} \geq 0$) as input. VOS treats the similarities s_{ij} as measurements on a ratio scale. The similarities s_{ij} were calculated using the association strength defined in Eq. (3). Using VOS we find for each node i a vector $x_i \in \mathbf{R}^p$ that indicates the location of node i in a p-dimensional map (here $p = 2$).

In VOS, this unified approach to mapping and clustering is based on minimizing

$$V(x_1, .., x_n) = \sum_{i<j} s_{ij}\, d_{ij}^2 - \sum_{i<j} d_{ij} \tag{5}$$

with respect to $x_1, \ldots, x_n$. In the case of mapping, d_{ij} represents the distance between nodes i and j and is given by:

$$d_{ij} = \left\| x_i - x_j \right\| = \sqrt{\sum_{k=1}^{2} (x_{ik} - x_{jk})^2} \tag{6}$$

Equation (5) can be interpreted in terms of attractive and repulsive forces between nodes. The first term in (5) represents an attractive force, and the second term represents a repulsive force. The higher the association strength of two nodes, the stronger the attractive force between the nodes. Since the strength of the repulsive force between two nodes does not depend on the association strength of the nodes, the overall effect of the two forces is that nodes with a high association strength are pulled towards each other while nodes with a low association strength are pushed away from each other.

In the case of clustering, for each node i it was necessary to find a positive integer x_i that indicates the cluster to which node i belongs. Here the distance d_{ij} in Eq. (5) is defined as follows:

$$d_{ij} = \begin{cases} 0 & \text{if} \quad x_i = x_j \\ \frac{1}{\gamma} & \quad x_i \neq x_j \end{cases} \tag{7}$$

The parameter γ in (7) is referred as the resolution parameter ($\gamma \geq 0$). VOS offers a selection among different values of the resolution parameter γ. Setting the value of γ greater than 1 means searching for larger number of smaller clusters while setting γ less than 1 means searching for smaller number of larger clusters. In our case, due to the small size and the low complexity of the network and after trying out also different values as suggested in Eck (2019), the resolution parameter value was set equal to 1. This value yields the most appropriate level of detail in terms of network modularity.

The (unified) methods of mapping and clustering allow us to visualise in a largely comprehensive manner the scientific mobility of researchers. Specifically, in addition to the identification of countries with strong scientific connections (as a result of the application of the mapping technique), one can additionally distinguish various mobility patterns (as a result of the application of the clustering technique). That is, groups as well as neighborhoods of countries that constitute focal points on researchers' scientific career path.

In our case, the closer two countries are located to each other, the stronger their scientific connection.

Results

Adopting the taxonomy model and utilising the researchers' classification scheme, the results in regards to researcher mobility and affiliation status through time, scientific mobility of the researcher elite, delineation of the scientific connections for Greece as well as different groups of countries are reported below.

Table 4 Distribution of authors identified fitting the taxonomy of the mobility events tracked through publication countries between the period 2000 to 2019

Authors' classes	Frequency	Percentage (%)
Time interval 2000–2019		
$\mathbf{R_1}$	240	17.4
$\mathbf{R_2}$	834	60.9
$\mathbf{R_3}$	122	8.9
$\mathbf{R_4}$	101	7.4
$\mathbf{R_5}$	74	5.4

Table 5 Distribution of authors with respect to their affiliation status (see definition in "International scientific mobility; definitions, model and analysis" section) over the time interval 2000–2019

Authors	Frequency	Percentage (%)
Time interval 2000–2019		
Only foreign	51	3.7
Only Greek	1.023	74.6
Greek and foreign	297	21.7
Total	1.371	100

Table 6 Distribution of researcher mobility classification with respect to their affiliation status over the time interval 2000–2019

Authors	Frequency	Percentage (%)
Time interval 2000–2019		
Static inside out	1.074	78.3
Travellers	175	12.8
Migrants	122	8.9
Total	1.371	100

Researcher classification

Applying the taxonomy mobility model to the *Dataset* F (**1371** authors) and making use of the researchers' classification scheme introduced in "International scientific mobility; definitions, model and analysis" section, the relevant summary statistics are cited in Table 4. By summing up the number of researchers identified to fit in the mobility events $\mathbf{E_1}$,...,$\mathbf{E_5}$ - Frequency column - the total number of authors observed is **1.371**. This is expected when considering equation *(B)*. Comparing the results obtained from the classification of the researchers in Table 4 and the ones obtained in Table 5 two important findings emerge.

First, having observed the defined taxonomy and summing up the authors with classes $\mathbf{R_1}$ and $\mathbf{R_2}$, we obtained **1.074** authors. This category, cross checking Table 5, represents the (super)category of authors who have either only Greek or only foreign affiliations throughout their scientific career. In particular, such authors constitute a broader class defined as the *'Static Inside out'* (1.074 authors, 78.3%, Table 6).

As a second observation, author classes $\mathbf{R_3}$, $\mathbf{R_4}$, $\mathbf{R_5}$ as distributed in Table 4 amount to **297**. This number constitutes the total number of authors that were identified with having Greek and foreign affiliations throughout their research activity (see also Table 5). Specifically, class $\mathbf{R_3}$ (122 researchers, 8.9%), represents the *'Migrants'*, whereas classes $\mathbf{R_4}$ and

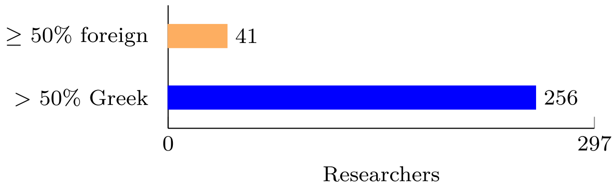


Fig. 2 Distribution of researchers of the Mobility class in relation with their number of publications through the time interval 2000–2019

Table 7 Distribution of authors with respect to their affiliation status over the time interval 2000–2010

Authors	Frequency	Percentage (%)
Time interval 2000–2010		
only foreign	51	7.7
only Greek	547	82.3
Greek and foreign	66	10.0
Total	665	100

Table 8 Distribution of authors with respect to their affiliation status over the time interval 2011–2019

Authors	Frequency	Percentage (%)
Time interval 2011–2019		
Only foreign	51	4.0
Only Greek	1.002	78.0
Greek and foreign	237	18.0
Total	1.290	100

$\mathbf{R_5}$ (175 researchers, 12.8%) the *'Travellers'* (see Table 6). All three classes, $\mathbf{R_3}$, $\mathbf{R_4}$, $\mathbf{R_5}$ represent the *'Mobility Class'* (297 researchers, 21.7%).

Hence, the Mobility Class represents 21.7% of the total researchers, while Travellers represent 60% and Migrants 40% of Mobile researchers.

Regarding the researchers falling under the Mobility Class (297), Fig. 2 indicates that the majority (256 researchers, 86.2%) has more than 50% of the publications affiliated with Greece, whereas the remaining (41 researchers, 13.8%) has more than 50% of the publications affiliated with a foreign country throughout their scientific career. This signals that although this population (297 researchers, 21.7%) constitutes the Mobility Class, the majority of mobile researchers (86.2%) have publications affiliated mostly with Greece rather than any other foreign country (13.8%) ***(claim 1)***.

Publications' affiliation status through time

In Tables 7 and 8, the time interval (2000–2019) is divided into two sub-time intervals: 2000 to 2010, and 2011 to 2019. It is divided in that manner in order to examine whether the Greek economic crisis (taken to be at its peak in 2010) affected the mobility pattern of those researchers. Table 7 shows that during the 2000–2010 period, the greatest percent of

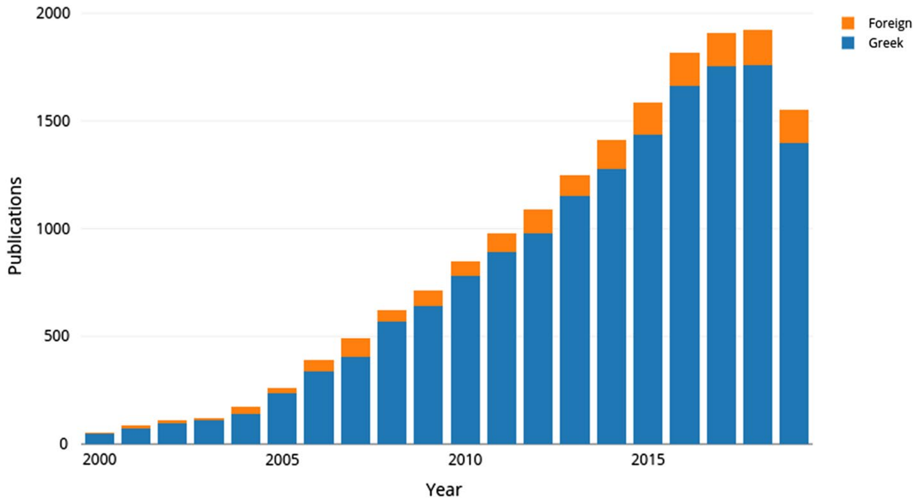


Fig. 3 Frequency distribution of publication affiliation status per annum corresponding to total researchers

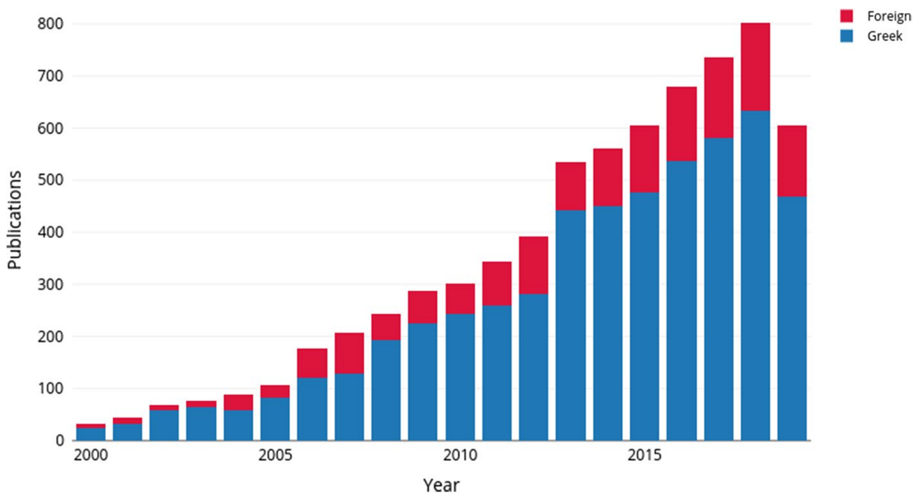


Fig. 4 Frequency distribution of publication affiliation status per annum corresponding to the Mobility Class

researchers (82.3%) have publications affiliated with Greek institutions, whereas 10% has both Greek and foreign affiliations while the total population was 665 authors. An important observation, comparing both Tables 7 and 8, is that the number of researchers (51) associated with only foreign institutional affiliations remained the same throughout the entire interval 2000–2019. This signifies that all of these researchers have been active (as defined in Table 2) over the two time intervals (2000–2010 and 2011–2019)—hence they reappeared in the 'Frequency' tables. Noticing further the results of Table 8, one can point

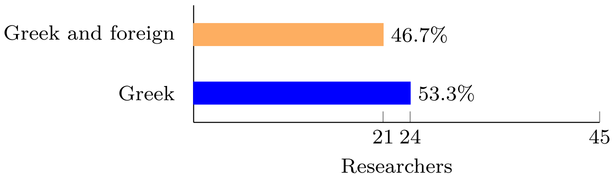
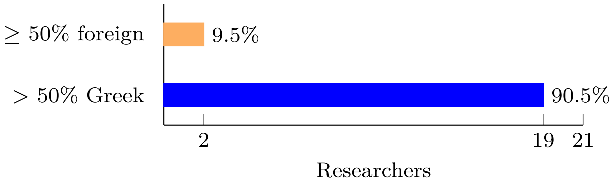


Fig. 5 Distribution of the most productive and consistent researcher (researcher elite) affiliations. Those who have the greatest number of publications are considered to be the most productive researchers, whereas as consistent researchers are defined as those who have published continuously over the last 9 years (2011-2019), with at least one publication per year

Fig. 6 Distribution of affiliations of the elite *mobile* researchers (those with Greek and foreign affiliations, see Fig. 5) with respect to the number of publications



out an overall increase in the proportion of the active researchers. The increase is at least 50% (again, some researchers had publications throughout both time intervals) with respect to the years 2000 to 2010; from 665 to 1.290 authors.

Significantly, from 2011 to 2019 authors having both Greek and foreign affiliations are on the rise. The relative increase is 8% (from 10 to 18%) and follows the slight decrease of 4.3% of authors with exclusively Greek affiliations (from 82.3 to 78%). However, one cannot ascribe those changes only to mobility reasons. Both Figs. 3 and 4, considering both time intervals, capture a linear relationship between the time (in years) and the number of publications. Throughout both graphs there is an apparent growth in publications each consecutive year, except for the year 2019. The frequency at which the publications are recorded in the database, combined with the timeline during which this paper was authored (before the year 2019 was out) may constitute the reason for this slight decrease in the number of publications in 2019. Nevertheless, the positive correlation among the variables of time and publications appears to be the cause of the percentage increase in the number of authors who constitute the Mobility Class. Since our dataset mainly consists of young researchers it is probable that the majority of them started their scientific activity at a later stage of their life.

Status of the researcher elite

Figures 5 and 6 provide information about the researcher elite (most productive and consistent researchers) and their distribution according to their affiliations. As is evident from Fig. 5, 46.7% (21 out of 45 researchers) have Greek and foreign affiliations while publishing continuously during the last 9 years, 90.5% of whom have more than 50% of their publications affiliated with Greece (Fig. 6). Hence, it can be deduced that the vast majority of the most productive and consistent authors (the researcher elite) that fall into the Mobility Class have publications affiliated mostly with Greece rather than any other country (claim 2).

As a result, both claims (claim 1 and claim 2) suggest that researchers' (and especially the elite's) scientific links with their mother country, Greece, are still solid.

Researchers' scientific career paths

Both graphs ((a) and (b)) depict the scientific connections between countries (as defined in "International scientific mobility; definitions, model and analysis" section). By visualising Fig. 7, observing Table 9, and being guided as well by the node size, it is clear that countries such as the United States, the United Kingdom, France, Cyprus, Germany, Italy, Spain, Belgium and the Netherlands are the countries in which the majority of researchers (*'Travellers'*) tend to publish throughout their scientific career. This is evident also from Table 11. Such countries have a strong scientific connection with our target country (Greece), whereas countries such as Japan, the Democratic Republic of Congo, Malta, Portugal, Peru, China, the Russian Federation, Luxembourg, the United Arab Emirates and the Czech Republic appear to have a weaker scientific connection.

Additionally, one can detect patterns rising from the tendency of researchers to publish in a certain 'neighborhood' of countries (see clustered countries in Table 9). All clusters consist of more than 2 items (countries) apart from the Coral cluster - Poland. From the positioning in the network map and the size of the node, one can assume that this country had a low co-occurrence frequency with the target (Greece) and failed to establish linkages with any other country through the scientific career path of the researcher(s) (Fig. 7).

Similarly, Fig.8 indicates that the researcher's (*''Migrants''*) affiliated countries with the strongest scientific connection with Greece are the United Kingdom, the United States, Italy, Germany, France, Cyprus, Belgium, Canada, Spain and the Netherlands. The remainder, appear not to have such a strong strong scientific connection with the target. In comparison to the previous graph (a), Fig.8 appears to be sparser. As a result, here, the majority of the clusters consist of fewer than 2 items (countries) (Table 10). In such cases, the rupture with the target country, Greece, has been made by only a single country throughout the researcher's activity. This difference can be explained by recalling that the 'Travellers' class contains researchers associated with multiple and co-affiliation instances, whereas 'Migrants only single-affiliated researchers.

As regards to both graphs ((a) and (b)), it is observed that networks consist of a focal node ('ego'), the nodes to which ego is directly connected ('alters') along with the ties among the alters. In both cases the focal node is 'Greece' while the 'alters' represent the remaining countries identified in both categories of the Mobility Class. Not all countries (nodes) have ties with each other. For example, in graph (a), countries included in the Light Blue cluster (China, Russian Federation), Green cluster (Australia, Portugal, India and Malta), Red cluster (Japan, Denmark, Sweden and Democratic Republic of Congo), and in graph (b), countries included in the Green cluster (Spain, France, Peru) and Red cluster (Hungary, Ireland, Sweden). This, taken together with the fact that the network is structured into clusters, is particularly useful in distinguishing certain links - researcher career paths - and identifying further focal nodes ('egos') - countries with significant scientific connection inside *each* community (cluster). As indicated above, such 'ego' nodes constitute mainly countries in which the majority of researchers tend to publish throughout their scientific career.

However, observing the detected clusters in both network graphs, it seems that the group of countries that belong to each cluster do not follow any particular motif; there is no conceptual connection between the countries. To further specify, the motivation (scientific, geographic, etc) for the researchers that urges them to publish in a certain neighbourhood of countries is not direct. For example, someone would expect that a researcher's scientific agenda would have publications affiliated with a group of countries which have an important impact on the scientific community or countries famous for specialising in a scientific field. Alternatively, another example could pertain to researcher scientific career paths that include countries which have a relatively small geographical distance between them. However, the created clusters of countries regarding the Mobility Class (Migrants and Travellers) do not allow us to make a direct assumption/judgement regarding the researcher preferences when publishing.

It appears that the majority of researchers (Table 11) have a tendency to publish to a group of countries with 'traditionally' significant scientific impact. These are countries with a strong scientific connection with Greece (as mentioned above) and where at the same time many publications were authored (United Kingdom, United States, France, Germany, etc). Considering the intersection with the top 10 countries of the country list as displayed in Table 11 and those top 10 countries addressed by SCImago Journal Rank[4] (Falagas et al. 2008) (United Kingdom, United States, France, Germany, Italy, Spain, Canada) it can be concluded that the 70.3% of researchers have publications in countries with significant scientific impact. On the other hand, within the formed clusters, countries with a minor impact on the scientific community (Malta, Luxembourg, Hungary,United Arab Emirates, Singapore, Democratic Republic Congo, etc) exist. These are countries with a weaker scientific connection with Greece and are those with the lowest number of shared publications.

(a) *Travellers*

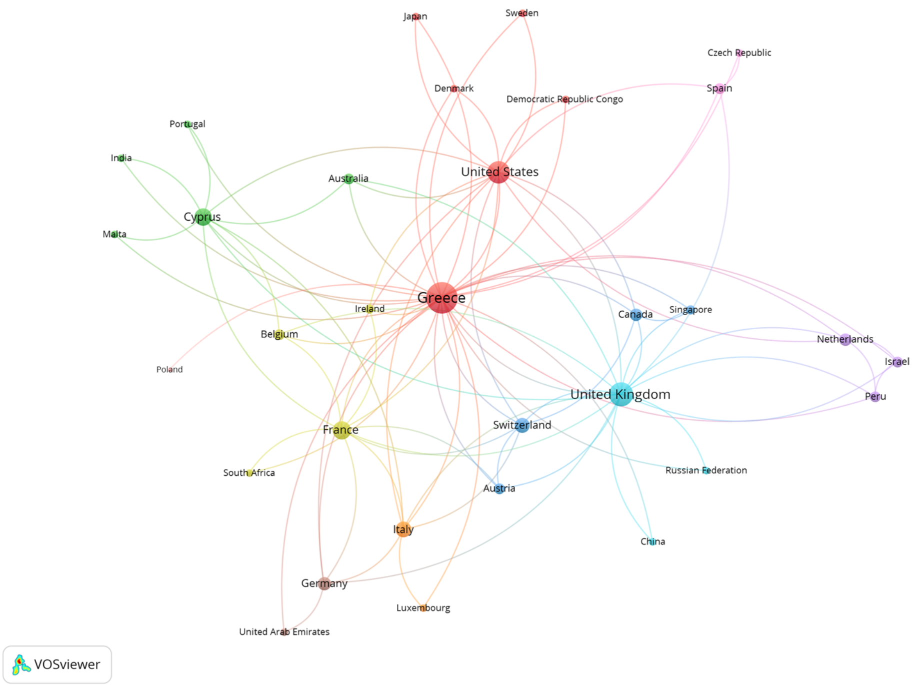


Fig. 7 Distribution of author scientific career paths corresponding to the class of Travellers

4 https://www.scimagojr.com/countryrank.php.

Table 9 Distribution of Cluster's Items of the Travellers Class

Clusters	Countries	Items
Class of travellers		
Red	Greece, United States, Sweden, Japan, Denmark, Democratic Republic Congo	6
Green	Cyprus, Australia, India, Malta, Portugal	5
Blue	Switzerland, Austria, Canada, Singapore	4
Yellow	France, Belgium, Ireland, South Africa	4
Purple	Netherlands, Israel, Peru	3
Light Blue	United Kingdom, China, Russian Federation	3
Orange	Italy, Luxembourg	2
Brown	Germany, United Arab Emirates	2
Light Pink	Spain, Czech Republic	2
Coral	Poland	1
Total clusters: *10*	Total countries: *32*	32

(b) *Migrants*

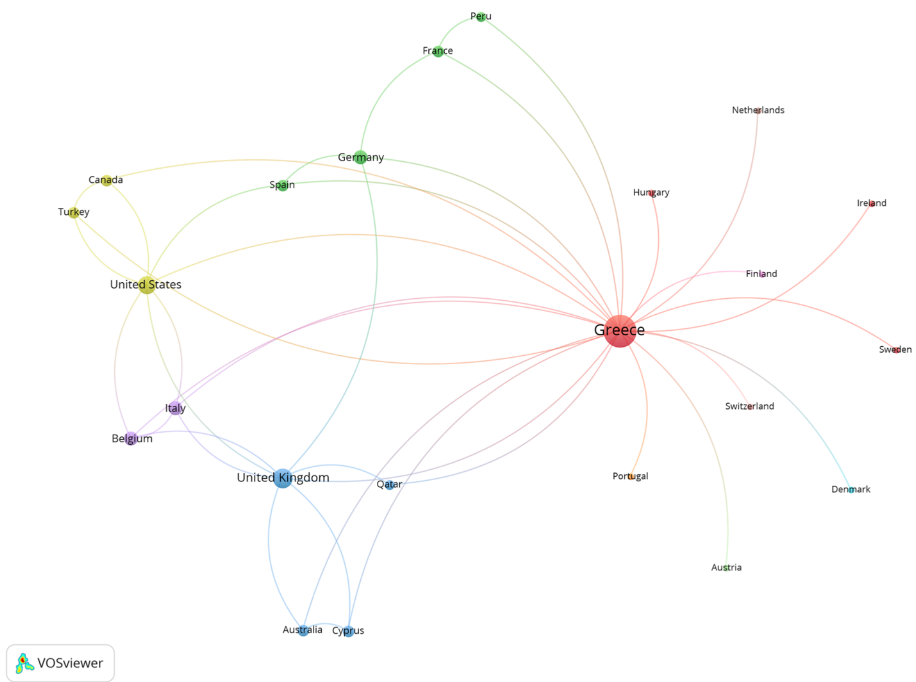


Fig. 8 Distribution of author scientific career paths corresponding to the class of Migrants

Table 10 Distribution of Cluster's Items of the Migrants class

Clusters	Countries	Items
Class of migrants		
Red	Greece, Hungary, Ireland, Sweden	4
Green	Germany, France, Spain, Peru	4
Blue	United Kingdom, Cyprus, Australia, Qatar	4
Yellow	United States, Canada, Turkey	3
Purple	Italy, Belgium	2
Light Blue	Denmark	1
Orange	Portugal	1
Brown	Netherlands	1
Light Pink	Finland	1
Coral	Switzerland	1
Light Green	Austria	1
Total clusters: *11*	Total countries: *23*	23

Scientific career paths versus researchers' publications

Table 11 displays information regarding the distribution of researchers of the Mobility Class and their publications across different affiliation countries. It also contains data about the average number of publications per research unit for all countries. This was computed by dividing the total number of publications per country by the number of researchers identified with publications affiliated to each country. To further clarify, the total number of researchers shown in the table does not add up to the total number of researchers that were identified as fitting into the Mobility Class (297). This is due to the fact that many researchers have publications affiliated with more than one country throughout their scientific career path.

It can be observed that the majority of the researchers have publications affiliated with the United Kingdom (25.99%), the United States (17.24%) and France (8.75%). However, the affiliated countries with the greatest number of publications per unit are China (18.5), Ireland (10.25) and Denmark (8.8). Combining the data provided from both Table 11 and the aforementioned network graphs, it can be reasoned that the countries with the strongest scientific connection with Greece (the United Kingdom, the United States, France, Cyprus, Germany, Italy, Belgium, Spain, the Netherlands etc) are the same countries in which the greater number of publications was authored. Similar reasoning applies to the remaining countries. In particular, countries that have a weak scientific connection with Greece are those in which researchers did not share many publications (Malta, Finland, Luxembourg, Singapore, Democratic Republic Congo, etc).

However, countries such as China, Ireland and Denmark which are in the top 3 countries with the most publications per research unit are not in the same rank (below the top 10) with respect to the researchers' scientific career paths (number of Researchers, Table 11). More explicitly, although such countries do not constitute researchers' top preferences (low co-occurrence with the target country), they stand out in terms of researchers' productivity (number of publications). Indeed, after observing the data of Table 11, the target population of the Mobility Class is 297 researchers, of which only 2 researchers (0.67%) were identified as having publications affiliated with China, while ranking 1st among the countries with the most publications per research unit. Similarly, 4 researchers (1.35%) with

Table 11 Distribution of the number of researchers of the Mobility Class who published at least once across the affiliation countries as well as of the total and average number of publications (publications per research unit) for all countries

Country name	Number of researchers	Percentage (%)	Total publications	Publications per unit
Mobility Class				
United Kingdom	98	25.99	389	4
United States	65	17.24	267	4
France	33	8.75	122	3.7
Cyprus	25	6.63	83	3.3
Germany	22	5.84	81	3.6
Italy	20	5.31	69	3.5
Spain	17	4.51	53	3
Belgium	13	3.45	68	5.3
Netherlands	11	2.92	29	2.6
Canada	10	2.65	36	3.6
Switzerland	9	2.39	40	4.4
Portugal	6	1.59	24	4
Austria	5	1.33	11	2.2
Denmark	5	1.33	44	8.8
Ireland	4	1.06	41	10.25
Russian Federation	4	1.06	15	3.8
Sweden	4	1.06	15	3.8
Australia	3	0.8	12	4
Japan	3	0.8	3	1
United Arab Emirates	3	0.8	6	2
China	2	0.53	37	18.5
Peru	2	0.53	7	3.5
Luxembourg	1	0.27	1	1
Singapore	1	0.27	1	1
India	1	0.27	3	3
Czech Republic	1	0.27	4	4
Democratic Republic Congo	1	0.27	1	1
Poland	1	0.27	4	4
Qatar	1	0.27	3	3
South Africa	1	0.27	6	4
Israel	1	0.27	1	1
Malta	1	0.27	2	2
Turkey	1	0.27	3	3
Finland	1	0.27	2	2
Hungary	1	0.27	1	1

Irish affiliations ranked 2nd in terms of number of publications per research unit followed by 5 researchers (1.69%) with Danish affiliations with a total number of 44 publications.

This very last observation can be useful in exploring the relation between scientific mobility and productivity (in terms of number of publications) as well as delineating the determinants of the international scientific mobility. However, since the main focal point of this paper is the delineation of scientific mobility such considerations constitute the object of future studies.

Discussion

This study delineates the scientific mobility of the highly educated young Greek scholars. This was made possible by utilising a completely novel dataset on Greek researchers participating in the publicly funded "Tertiary Education Initiatives" in recent years. Combining this dataset with a major bibliometric database allowed the authors to identify the domestic versus international publication patterns, as deduced from their institutional affiliations and their mobility patterns. Thus, it contributes in the current bibliometric academic discussion with a novel, empirically-based analysis on a country-level population for which empirical data remains scarce. In every case, this analysis can be fed into studies dealing with the topic of scientific migration – a topic that received much attention in the context of the decade-long economic crisis in Greece.

The findings presented in this paper confirm important conclusions drawn in previous research (Laudel 2003; Moed and Halevi 2014; Robinson-Garcia 2019) that bibliometric information in regard to author affiliation data is in principle a valuable source of evidence on studies within the context of international scientific mobility. The overall results indicate that the greatest share of researchers are static in the country of origin, Greece (74.6%). In relation to the findings of Robinson-Garcia (2019), the authors confirm that mobile researchers constitute a minor portion (21.7%) of the total population while travellers (60%) – authors who gained additional affiliations while maintaining affiliation with their country of origin, represent the majority of the mobile researchers. On the other hand, migrants – authors who have left their country of origin – represent 40% of the mobile researchers. The greatest portion of the researchers (86.2%) and especially the researcher elite (90.5%) maintained solid scientific links with Greece while building a chain of affiliations that linked nations together. Complementary to the taxonomy mobility model proposed by Robinson-Garcia (2019), the authors delineate the scholarly mobility by demonstrating and clustering scientific mobility patterns within nations, as well as internationally. In addition, in an effort to interrelate scientific mobility with productivity, the matter of the capacity of countries to attract or repel certain populations of researchers in the context of science policy is covered.

The present study in the field of bibliometrics, can be utilised not merely explanatorily for demonstrating maps of international scientific mobility trajectories among countries, but also functionally for studying the determinants and effects of scientific mobility, as well as the scientific connections between countries. In addition, such findings suggest that specific policies should be developed with respect to every researcher class. As regards the static class, under which the majority of the researchers fall, strategies that create incentives to be conceptually dynamic without cutting ties with the country of origin should be developed. On the other hand, mobile researchers should remain dynamic though maintaining solid scientific links with their mother country. Such perspectives, do not consider a temporary stay abroad as a migration process with clear winners and losers—brain gain and brain drain; rather a reciprocal process allowing individuals and countries or regions to benefit from current collaborations and future returns—brain circulation. Therefore, taking into consideration that a large proportion of researchers tend to publish in countries with typically significant scientific impact, international mobility should be encouraged (Sugimoto et al. 2017).

Concerning future studies, with regard to bibliometrics, the analysis can be extended to complementary bibliometric data sources (Altmetrics.com, conference proceedings, etc) in an attempt to broaden the scope of the identification of the geographical mobility of the specific manpower. Also, identifying potential publication variations in relation to sex, open versus closed access publications as well as changes in relation to the researchers' original field of science (as recorded during their education degrees) and the field of science of the journal wherein they have published stand as promising avenues.

The SQL database containing the researchers has been constructed in such a way that allows integration with bibliographic data, as well as 'output-relevant' variables found in various public registries such as patents and start-ups. The combination of such databases would enable future research to better understanding the business-relevant path of these researchers. Additionally, a rigorous analysis of migration and a better understanding of the relationship between scientific mobility and productivity could shed light on regional competencies and the way by which they attract migration. Generalising the last observation of our study, ("Results" section), future research could focus on assessing the way mobility is interrelated with productivity and on a second level scientific impact (Sugimoto et al. 2017). Findings of such studies will enable an in-depth look into the manner by which countries attract migration, the individual motivation behind migration and the level of global/regional competence.

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