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Transfer of formal knowledge through international scientific mobility – introduction of a network-based bibliometric method[1]

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Introduction

Geographic mobility enables the acquisition and recombination of knowledge (Laudel, 2003; Gläser, 2006) and is essential when the knowledge to be transferred is tacit and demands personal contact, observation of colleagues and interaction (Collins, 1974, 2001). International mobility may become a necessity when the knowledge to be transferred is located in another country and requires physical mobility across state borders. It is therefore hugely important to examine whether and how international mobility leads to the transfer of scientific knowledge across national borders. Even though the circulation of knowledge at the transnational level is often encouraged and funded, the relationship between international mobility and knowledge transfer has not been sufficiently investigated empirically. This is mainly because there are so far no reliable methods to measure knowledge transfer.

However, bibliometrics provides a promising instrument for analysing characteristics of scientific communication and intellectual influences of research activities by offering a variety of data. Assuming that co-authorship constitutes one instance through which knowledge transfer can take place, my paper aims at contributing to the development of a new method that is able to indicate formal knowledge transfer between co-authors. Working abroad and being embedded in a research group may facilitate scientific collaboration that leads to co-authorship and potential knowledge transfer due to intense communication and interaction that is often inherent to collaboration.

In this paper, I address the research question of how formal knowledge transfer resulting from international scientific mobility can be identified between actors involved. Therefore, I examine co-authorship as an opportunity for knowledge transfer and present a method to identify the transfer of formal knowledge. In the following, I provide a theoretical background, present my hypotheses on the relationship between international mobility, collaboration and knowledge transfer and carve out the role that bibliometrics plays. In the remainder of the paper, I present my database, methods, empirical results and conclusions.

Theoretical background

Scientific communities often have members in various countries working on a common set of research questions. Each scientist contributes to the collective body of knowledge by publishing and referencing knowledge claims (Gläser & Laudel, 2001). The contribution to new knowledge may require collaborative networks and international mobility as one mode to establish these networks.

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Although science has always been a social rather than a solitary activity due to the reliance on sharing ideas and validating scientific findings with peers, the production of knowledge is more and more characterized by the relevance of scientific collaboration. Research collaboration that requires international mobility is often motivated by the desire to increase knowledge, to exchange data and skills, and to advance the professional career (Luukkonen et al., 1993). Collaboration brings scientists together to observe, discuss and reflect research work and to combine elements of existing knowledge.
The effective integration of internationally mobile scientists into research groups abroad can be documented by co-authored publications. Joint research publications reflect successful scientific collaboration and are likely to be indicators of knowledge transfer between scientists. Whenever two or more authors are listed as co-authors on the same publication, it is likely that they have collaborated and exchanged knowledge (Laudel, 2002).
Co-authorship is thus an indicator of collaboration, which in turn enables the exchange of different types of knowledge, i.e. tacit knowledge that is not yet codified in publications and formal knowledge such as the hint and recommendation to read a specific publication. Informing colleagues about relevant literature is one specific form of knowledge transfer and is operationalized in this study as the "passing on of references". The absorption of a reference in one's own work (reference list) is analyzed in this study irrespective of the multidimensional reasons to cite, ranging from recognition of a work to utility or persuasion (van Raan, 2006). Citing a specific work may be also influenced by social factors, e.g. authors cite primarily works by those with whom they are acquainted (White, 2001). However, if we assume that scientists adopt the knowledge coded in the publication they cite, references indicate an increase in the knowledge base of the citing author.

Data and methods

Data base
The analysed data were retrieved from Scopus (Elsevier). It is licensed as custom data at the Competence Centre for Bibliometrics[2] and integrated in an in-house database version. Scientists under study are identified by their author ID in Scopus. The author ID is supposed to combine all publications of an author under a single ID to handle common first and last names (Moed et al., 2013). This allows for precise analyses that built upon publication data. A number of studies report that Scopus author ID enables reliable analyses (Moed et al., 2013; Conchi & Michels, 2014; Aman, 2017). Internationally mobile scientists are identified as those whose affiliation changes from one country to another. The country relates to the geographic location of the institute as stated in publications.

Data selection
The data builds primarily upon a previous study (Aman, *forthcoming*) but had to be adjusted to meet the purpose of the method of this paper. Assuming that a typical international stay such as a post-doc lasts for three years in most natural science disciplines, I focus on all German scientists who have been abroad between 2010 and 2012. Apart from this mobility phase ranging from 2010 to 2012, I distinguish a pre-mobility phase that lasts from 2007 to 2009 and a post-mobility phase from 2013 to 2015. To measure effects of international mobility on knowledge transfer, all German scientists under study had to have published in the phase prior to international mobility as well as after the mobility phase exclusively from German institutions. In the mobility phase, publications have to be affiliated to non-German institutions.

[2] Competence Centre for Bibliometrics. http://www.forschungsinfo.de/Bibliometrie/en/index.php?id=home

In addition, these authors had to have at least two publications in each of the three phases. Only journal articles, reviews and conference proceedings are considered.
Co-authors under study are identified as those who have at least two joint publications with German scientists. The co-authorship can be either intra-mural, national or international. Co-authors are assigned to one of the three phases dependent on the publication year of the first publication co-authored with the German scientist. For the mobility phase (2010-2012) only intra-mural co-authorship is considered to make sure that the German authors were active at the same institution abroad as their co-authors. These co-authors from the mobility phase are hereafter referred to as 'co-workers', whereas co-authors from the phase 2007-2009 and 2013-2015 are not necessarily co-workers and can be affiliated to other institutions than the German scientist under study. The restriction of co-authors to co-workers in the mobility phase guarantees that the German scientist under study interacted with the co-workers abroad so that formal knowledge could have been passed on.

Method to measure formal knowledge transfer
In the model to be presented, German authors being mobile are assumed to function as receivers and transmitters of formal knowledge. Knowledge transfer is operationalized as the passing on of references between actors. Necessary to this end is co-authorship resulting from collaboration between actors. Co-authorship functions as a mechanism of interaction and a condition to transfer knowledge.
In a first step, the references that were first used between 2010 and 2012 were identified for all German scientists as delineated above. These references must have been used already before 2009 by their co-workers from abroad, thus before the German scientist and the co-worker had interacted. In this case I assume that knowledge transfer has taken place because it is highly probable that co-workers from abroad have pointed at these references and thus passed on this formal knowledge. In a second step, I calculated how many times each of the references was used up to 2015 by co-authors of the German scientists and all other authors covered in Scopus. In a further step, I study those references that were first used in the 2010-2012 period by German authors being abroad and that were again used in the 2013-2015 period by other co-authors of the German scientist. The type of co-author receiving the formal knowledge in 2013-2015 is of no importance in this model, i.e. the first co-authored publication (between the German scientist and the co-author who cites the reference in 2013-2015) can be traced back to the 2007-2015 period.
Finally, the co-authorship networks using the references under study are limited to those that are rarely used throughout the scientific community, i.e. according to Scopus there are few authors citing the reference. The basic idea here is that the probability is higher that a co-worker informed the German scientist about the formal knowledge.
The findings are expressed as network-based representations. The graphs facilitate the understanding of the network structure and include detailed information about co-authorship patterns and the passing on of references. This is achieved by the use of node and edge colours to distinguish actors, time periods, and the specific layout of the network. The network diagrams are produced with Gephi 0.9.2 using the Force Atlas algorithm, which is a variant of the Fruchterman-Reingold force-directed algorithm (Bastian et al., 2009). The nodes representing authors are positioned on the basis of repulsion and attraction. Thus, authors not co-publishing are pushed to the outskirts, whereas authors co-publishing a lot are pulled together (Cherven, 2013).

Findings
In the following, a network-based visualization of authors using a specific reference is presented. The analysis of the findings entails the detection of co-authors and co-workers from

different phases and the identification of the knowledge transfer, i.e. the passing on of the reference under study. Figure 1 represents a network of co-authors citing a rarely used reference in Scopus from the field of psychology (see footnote)[3].

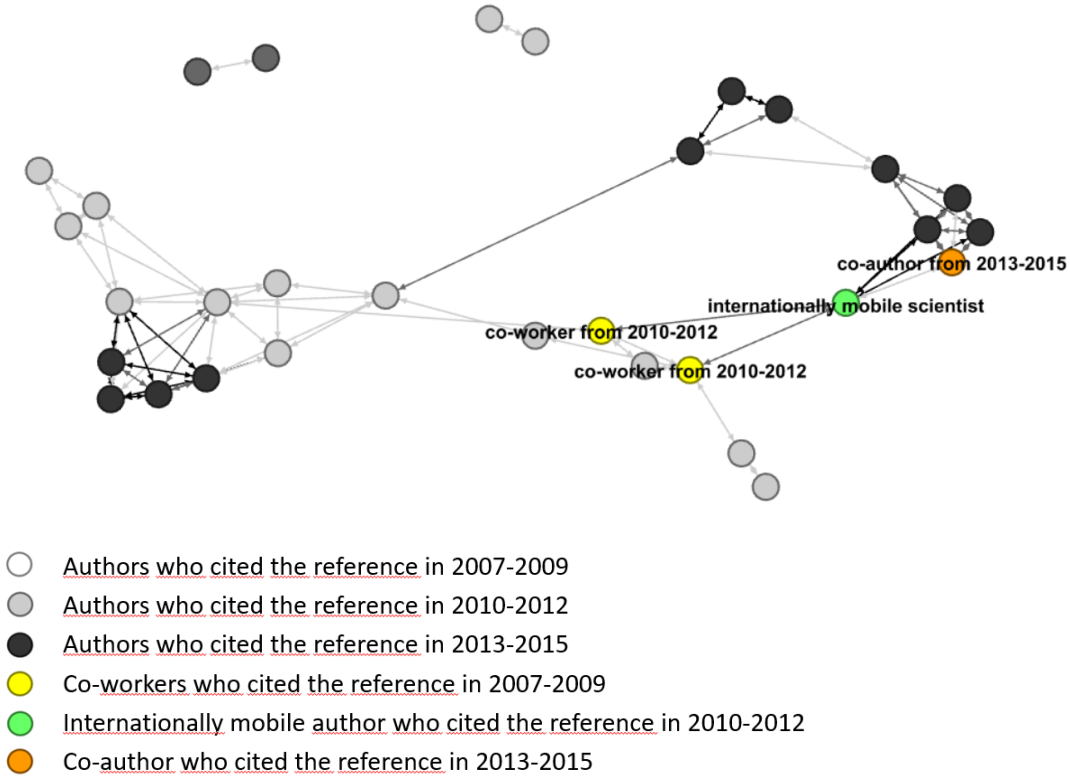

Figure 1. Exemplary network of co-authors citing a reference in psychology.

Each node in the network represents an author using the reference under study. The colours of the nodes represent the three different time phases in which the reference of interest was used in a publication for the first time. The time period before 2009 is represented by nodes in light grey, the time period between 2010 and 2012 by nodes in dark grey, and the time period 2013-2015 by black nodes.

A node is connected to another node if and only if the authors represented by these nodes have a co-authored publication. In this binary co-authorship network, the edges are not directed. The colours of the edges reflect the phases in analogy to the node colours. However, the colour represents the first co-authored publication between the two authors. Light grey means that the first co-authored publication between two nodes occurred up to 2009. Dark grey edges connect authors who first co-authored between 2010 and 2012, and black edges stand for nodes that are first connected by a co-authored publication from 2013 on. The node clusters can be interpreted as research groups. A few unconnected nodes are pushed to the outskirts and are thus not displayed in Figure 1. However, two of the components, one in light grey and one in dark grey, are visible in the upper part of the network diagram.

The green node represents the German scientist who has been abroad between 2010 and 2012. The yellow nodes stand for co-workers the German scientist has interacted with abroad. The

[3] Dickinson, A., & Mackintosh, N. J. (1979). Reinforcer specificity in the enhancement of conditioning by posttrial surprise. *Journal of Experimental Psychology: Animal Behavior Processes*, 5(2), 162-177.

orange node symbolizes a co-author of the German scientist who first used the reference in the phase 2013-2015 (see also legend in Figure 1).
Visual inspection of the network shows that the co-workers from 2010-2012 (yellow nodes) are close to the German scientist (green node) working abroad between 2010-2012. Similarly, the orange node representing the co-author from the phase 2013-2015 is connected with the green node. We can derive from the network that the two co-workers have used the reference under study for the first time in 2007 to 2009 and passed it on to the German scientist who used the same reference in her publications between 2010 and 2012 for the first time. There is no guarantee that formal knowledge transfer has taken place but it is very likely if the reference is not commonly picked up in the scientific field. Upon return to Germany, the internationally mobile scientist passed the reference on to one of her co-authors who has not used the reference before. In this case we can assume that international mobility lead to the acquisition of formal knowledge that was passed on upon return, because the green and orange nodes are connected by the shortest path. Again, there is no guarantee that the internationally mobile scientist acted as a transmitter of formal knowledge because there is an additional and longer path on the upper side of the graph that connects the co-workers from 2010-2012 with the co-author of the German scientist using the same reference in 2013-2015. However, this is not very likely, because the reference must have been passed on between more than 5 co-authors. In contrast, it is more likely that the author picked the reference up on her own.
The following figure depicts another case where we can assume that knowledge transfer has taken place. Nodes that are unconnected are not displayed in Figure 2. The small amount of nodes reveals that the reference (see footnote)[4] used in this example was rarely cited by all authors covered in Scopus identified on the basis of the Scopus author ID.

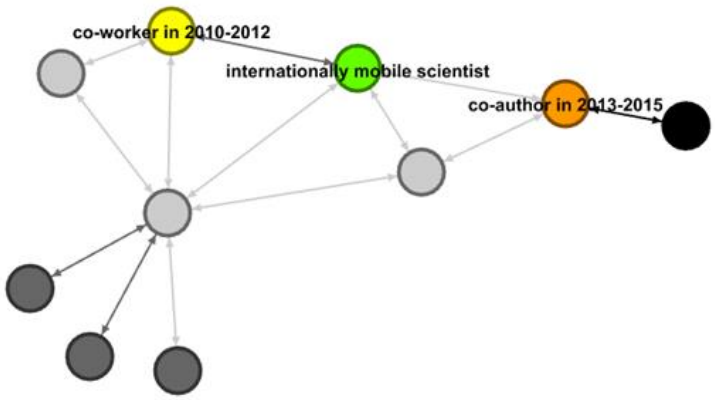

Figure 2. Exemplary network of co-authors citing a reference in computer science.

Figure 3 illustrates another network diagram where the labels are omitted but the colours represent the same types of actors as in the previous two figures. We can see that in all probability the internationally mobile author acted as a transmitter of the reference in cancer research.[5]

[4] Tobiska, L. (2006). Analysis of a new stabilized higher order finite element method for advection–diffusion equations. *Computer Methods in Applied Mechanics and Engineering*, 196, 538-550.
[5] Bazant-Hegemark, F. et al. (2008). Review: optical micrometer resolution scanning for non-invasive grading of precancer in the human uterine cervix. *Technology in Cancer Research & Treatment*, 7(6), 483-96.

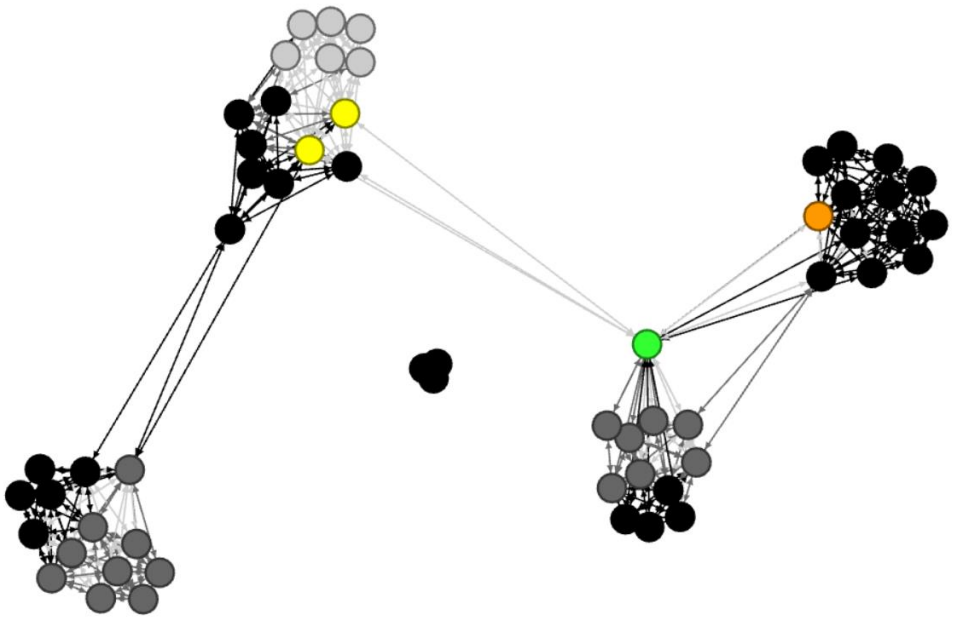

Figure 3. Exemplary network of co-authors citing a reference in cancer research.

Figure 4 is based on a reference in dermatology[6] that was used by many other authors in Scopus. However, there is high evidence that a co-worker in 2010-2012 transferred the formal knowledge (reference) to the internationally mobile scientist. The nodes in the left cluster are in light grey showing that these authors used the reference up to 2009. It is highly probable that the co-author using the reference in 2013-2015 took over the reference by the internationally mobile scientist because all other co-authors of the orange node used the reference not earlier than 2013-2015 (black nodes).

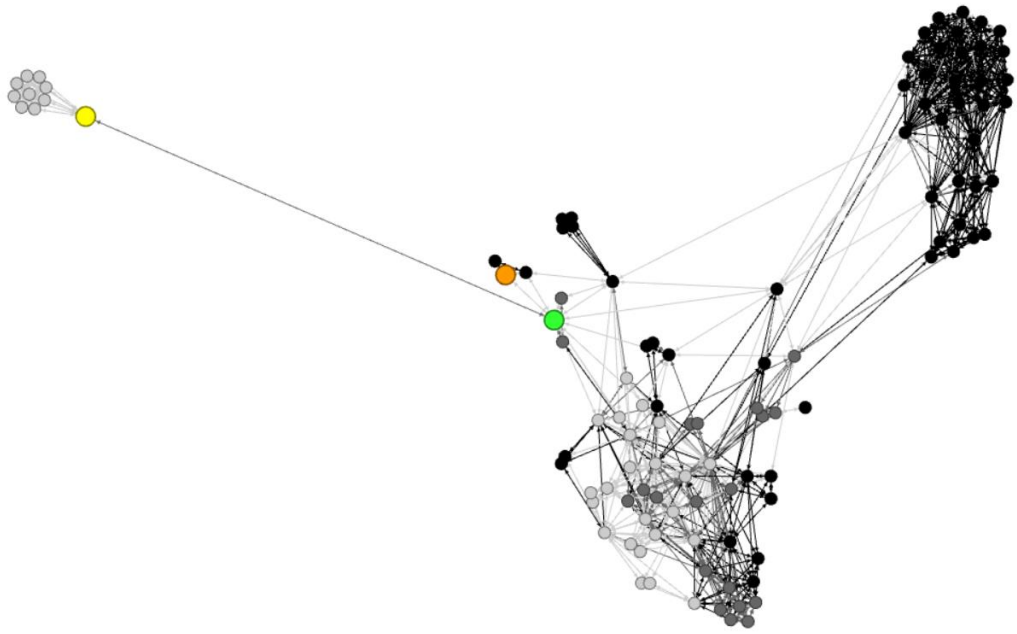

Figure 4. Exemplary network of co-authors citing a reference in dermatology.

[6] Augustin, M. et al. (2004). Validation of a comprehensive Freiburg Life Quality Assessment (FLQA) core questionnaire and development of a threshold system. *European Journal of Dermatology*, 14(2), 107-13.

Conclusion

This study aimed at testing a method to indicate the effect of international mobility on formal knowledge transfer. Knowledge transfer was operationalized as the passing on of references between co-workers abroad and German scientists as well as German scientists being mobile and their co-authors after the mobility episode.

The main objective was to identify and interpret knowledge transfer using an empirical analysis and the visualization and examination of co-author networks. To this end, I presented a model and characterized co-authorship networks by using rarely used references that were assumingly passed on through international mobility.

The proposed method proves to be useful to identify the transfer of formal knowledge between co-authors. However, the use of a reference does not necessarily mean that knowledge transfer has taken place. The reference might have been used independently of the co-authors, i.e. an author can discover the same reference individually or by reading publications the co-authors had cited already at an earlier point in time. Moreover, co-authorship does not imply that an intense exchange of knowledge or skills has taken place. Interviewing the actors and asking them about the use of references would enable the validation of the method presented.

There are further limitations of my approach that are inherent to the study of international mobility with bibliometric methods. I tried to minimise those limitations that are manageable, e.g. by restricting the period of examination to recent years (2007-2015) and by setting restrictions to publication counts of authors and co-authors. However, future research should also aim at delineating co-workers who are not necessarily co-authors but who can act likewise as transmitters of knowledge.

The method presented may still be regarded as a first important step in tracing knowledge transfer. The analysis of co-authorship and reference networks just as the knowledge flows can be improved in future research. It thus remains important to think of more advanced methods to examine whether and how international mobility leads to knowledge transfer.

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