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Article

Collaboration patterns of mobile academics: The impact of international mobility

Jue Wang [1,*], Rosalie Hooi[1], Andrew X. Li [2] and Meng-hsuan Chou[1,3]

[1]Division of Public Policy and Global Affairs, Nanyang Technological University, 14 Nanyang Drive, Singapore; [2]Department of International Relations, Central European University, Budapest, Hungary and [3]Fung Global Fellow, Princeton University, USA

*Corresponding author. E-mail: wangjue@ntu.edu.sg

Abstract

Countries have developed a variety of policies to attract and retain foreign talents who can bring multiple benefits to the host country, including knowledge assets and international network. It is in their interest if the talents contribute both to the development of local research community while continuing the connection with international community. Using a sample of highly mobile academics in Singapore, the study tracks the evolution of local and international collaboration after an international career move. In particular, the study examines the change in research collaboration in the current host country in comparison to collaboration with prior host countries. By analyzing the bibliometric, survey and profile data of 378 faculty members, we found that local collaboration increases quickly after a scholar moves to a new country, but this increase is at the cost of decreasing international collaboration. Collaboration with prior countries remains but gradually fades out after the move.

Key words: international mobility; research network; mobile academics; local collaboration; international collaboration

1. Introduction

The international mobility of highly-skilled human resources has been an area of strong interest for researchers and policy makers in recent decades. Among the most internationally mobile groups of highly-skilled professionals are scientists, for whom a stay abroad has become an integral part of their career. Scholarly interests in the scientific diaspora and the impact of their migration have focused on scientific production and collaboration. Research has shown that internationally mobile researchers are likely to be more productive (Baruffaldi and Landoni 2012; Basu 2013; Gibson and McKenzie 2014; Hoisl 2007; Jonkers and Tijssen 2008; Teichler 2017; Yasuda 2016). Innovative discoveries and new knowledge are often generated by refining and re-combining novel and existing knowledge elements. Since 'knowledge travels along with the people who master it' (Breschi et al. 2010), international exposure is more likely to bring about perspectives often missing domestically (Franzoni et al. 2017), ultimately integrated to create opportunities for knowledge brokerage and novel knowledge combinations (Slavova et al. 2015). Mobile researchers are thus seen as able to match their specialized knowledge with others and work in places where their expertise are met with complementary resources (Van Der Wende 2015). The arrival of internationally mobile researchers is hence assumed to generate positive ripple effects within the organization: these new productive scientists, perceived as being similar by short-tenured incumbents, induce peer effects on performance.

Besides conveying tacit knowledge, mobile researchers also bring their social capital along with their move. Foreign scientists tend to be tied with their home countries while returnee scientists are more likely to have networks in their prior host countries (Jonkers and Tijssen 2008; Jöns 2009; Marmolejo-Leyva et al. 2015; Melkers and Kiopa 2010). The social capital that researchers possess is generally not organization-specific, making it easily transportable and usable across organizations. Additionally, researchers have much autonomy concerning with whom they work and which projects they undertake; and the communities they belong to are persistent and span organizational boundaries (Tartari et al. 2018). As such, when researchers move they gain new connections while often retaining prior ones. This increases the researcher's scientific social capital as the number of scientists with whom they are in contact increases, and as the quality or intensity of the relationship becomes stronger (Jonkers and Tijssen 2008). The greater social capital could therefore be a possible explanation behind their higher citation counts in comparison to nonmobile researchers (Gibson and McKenzie 2014; Sugimoto et al. 2017). Their overseas network resources could be mobilized to benefit the individual, the employer, and ultimately, in today's knowledge-based economy, the country (Fontes et al. 2013); thus helping embed the host country more firmly in the global science system (Jonkers and Tijssen 2008; Scellato et al. 2015).

In view of the benefit of international mobility, many countries, individually or collectively, have developed policies and programs to attract talents from abroad and their own highly-skilled nationals with the hope to mobilize their knowledge and international networks to benefit the local research community (Fontes et al. 2013). For instance, the USA has its long-established J and H visas for short-term academic exchange and long-term employment of the highly skilled. China has launched the Ten Thousand Talents Program in 2012 (following the perceived success of its 2008 Thousand Talents Program), and more recently the many university alliances within the context of its new Belt-Road initiative—all to lure its talented nationals and foreign talents to the country. At the regional organization level, the European Union (EU) has adopted the Blue Card and Scientific Visa directives to harmonize the reduction of administrative barriers for the highly skilled (Cerna and Chou 2014). The development of both local and international research network thus becomes an interesting point for observation, an area worth further exploration.

Using Singapore as a case, our study explores the relationship between mobility and academic collaboration, specifically their changing state of collaboration with researchers in previous and current host countries following a career move. Singapore is an interesting case for several reasons. First, Singapore has a large expatriate population, in particular among academics. It is a small country about two-thirds the size of New York City, with a population of 5.6 million, of which 40% are non-Singaporeans (Department of Statistics Singapore 2018). Aligned with the nation's aim to increase university research capabilities, and for reasons of diversity, Singapore's universities actively recruit international researchers (Matthews 2013; Tan and Sharma 2014). As other countries scale down university research funding (Howard and Laird 2013; OECD 2016), Singapore government's unabated support for research is attracting many foreign researchers. Between 50 and 70 per cent of the two largest Singapore universities are staffed by foreign academics (Matthews 2013), and, among faculty members, 90 per cent earned their PhDs overseas (37 per cent from the USA and 17 per cent from the UK). Before moving to Singapore, most faculty members have had prior experience working in other countries. The international and diverse faculty population makes Singapore a revealing case for studying highly mobile academics.

Singapore is also characterized as having a high level of openness (Wagner and Jonkers 2017). Small economies tend to have more international collaboration than larger ones (Melin and Persson 1996; Narin et al. 1991) as the probability of finding a potential national collaborator is lower in economies with fewer scientists (Mattsson et al. 2008). Indeed, Singapore has substantial international collaboration, and both the number and share of Singapore's publications co-authored with other Asia-Pacific Economic Cooperation (APEC) economies have steadily increased since the late 1970s according to the Scopus database (Radloff 2016). Of all publications published between 2011 and 2015, more than 40 per cent of publications with a Singapore affiliation were co-authored with researchers in other APEC economies, much higher than the overall share (9 per cent) for all APEC economies (Radloff 2016). Similarly, we also examined the Web of Science database and found half of the publications in Singapore during 2002–14 were from international collaboration. In particular, 36 per cent of the publications involved one author from outside Singapore and 15 per cent were co-authored with collaborators from at least two other countries, with the top co-authors coming from China, USA, and Australia (Fig. 1). The fields where most collaborations were taking place were business (66 per cent) and natural sciences (52 per cent) and the least collaborative field was arts and humanities (45 per cent); these results are consistent with what was reported in Radloff (2016). As such, Singapore is a suitable case for studying collaborative links.

This article is organized as follows. First, we review the existing literature on collaboration and mobility to generate testable hypotheses. Next, we describe our research method and the key variables used in the empirical analysis before presenting the models and results of the analysis. We conclude with policy implications and limitations of our study.

2. Collaboration and mobility

Publications resulting from collaboration are growing at the international level in terms of the number of authors, organizations, and countries associated with each publication (Gazni et al. 2012; Glänzel and De Lange 2002; Wagner et al. 2017). Researchers collaborate for different motivations and considerations, including adapting to changing funding requirements (Defazio et al. 2009; Ponds et al. 2007), coordinating and sharing funding for costly experiments (Melin and Persson 1996), reducing costs and time savings through division of labor, pooling intellectual resources, coping with the increasing need for specialization (Hara et al. 2003; Hollis 2001; Leahey and Reikowsky 2008), increasing visibility (Franzoni 2009), for recognition and networking (Beaver 2001), for cross-fertilization of ideas (Katz and Martin 1997), or for fun (Beaver 2001).

Collaboration has been positively related to many metrics of academic quality. Papers with a larger number of co-authors are more likely to be published in higher-quality journals (Abramo and D'Angelo 2015; Bordons et al. 1996; Franceschet and Costantini 2010; Liao 2011), and attract more citations (Abramo and D'Angelo 2015; Didegah and Thelwall 2013; Glänzel and Schubert 2001; Katz and Hicks 1997; Larivière et al. 2015; Wang and Shapira 2015). Collaborative teams are more productive (Barjak and Robinson 2008; Bordons et al. 1996; van Beers and Zand 2014), with productivity increasing with an expansion in team size (Adams et al. 2005).

Spatial distance matters for collaboration, but its hindrance may be less than it was in the past (Wagner et al. 2017) as the distance-related barriers are mitigated by the Internet (Sonnenwald 2007), thereby increasing academic mobility (Jonkers and Cruz-Castro 2013) and increasing funding opportunities for engaging international partnerships (Frenken et al. 2009). Mobility triggers collaboration by connecting scientists from different places with whom they may establish partnership (Breschi et al. 2010) and by reinforcing authors' social relationships (Agrawal et al. 2006; Autant-Bernard et al. 2007). Empirical evidence can be found abundantly in the literature. For example, returnee scientists are found to be more likely to have international co-authored publications than their non-mobile peers; an observation confirmed in China (Jonkers and Tijssen 2008), Germany (Jöns 2009), the Philippines (Ynalvez and Shrum 2011), and in Argentina (Jonkers and Cruz-Castro 2013). The diaspora literature also shows foreign background and experience as positively associated with international collaboration, such as the study of migrant scientists in sixteen countries (Scellato et al. 2015), or country-specific studies such as US-based scholars (Melkers and Kiopa 2010), foreign scholars in Italy and Portugal (Baruffaldi and Landoni 2012), Mexican diaspora (Marmolejo-Leyva et al. 2015), and Chinese diaspora in Australia (Yang and Qiu 2010).

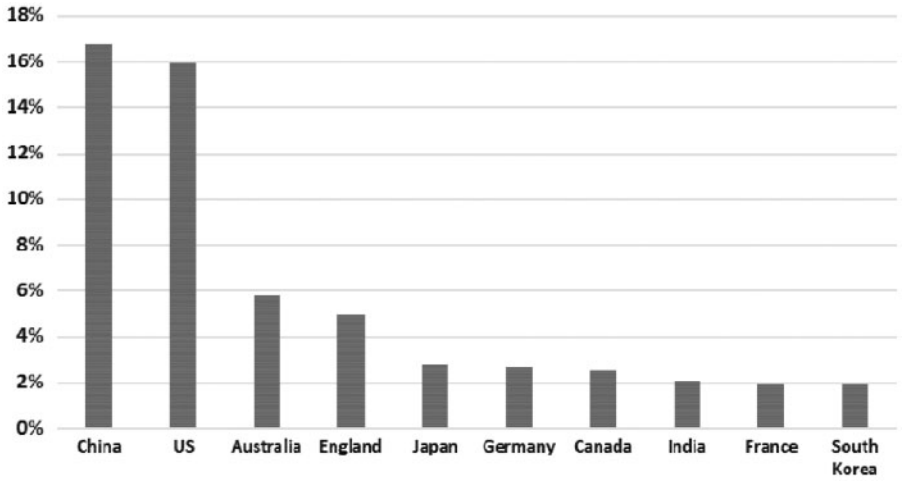

Figure 1. Distributions of co-authored publications 2002–14. *Source*: WoS publications; computed by authors.

While the role of mobility network formation has been largely confirmed, there have only been a few attempts to track how collaboration networks evolve over time. Following Jonkers and Tijssen (2008), our study intends to introduce the time dimension and examines the relationship between the duration of migration, local collaboration and collaboration ties with prior countries.

2.1 Hypothesis development

Proximity facilitates collaboration. Being in the same geographical location provides opportunities for people to meet each other, as there are avenues for meetings, casual conversations, and idea sharing. Face-to-face interaction facilitates the building of social capital (Putnam 2000) and is important for individuals to develop trust and intimacy (Urry 2002). It increases the efficiency of information diffusion through minimizing redundancy (Burt 1992), and reduces the costs of transaction (Putnam 1993) by diminishing the probability of opportunism and reducing the need for costly monitoring (Nahapiet and Ghoshal 1998). Therefore, co-location increases the probability of knowledge flows between individuals and leads to more collaboration (Agrawal et al. 2008; Autant-Bernard et al. 2007; Ivarsson and Alvstam 2005; Katz 1994; Knoben and Oerlemans 2006; Ponds et al. 2007; Wang and Zhang 2018). The longer the stay in a host country, the researcher's personal and professional lives become more embedded in the host country, which should result in an expanding collaboration network. Similar to Andújar et al. (2015) who found that longer stays result in more collaboration links, Tian (2016) also found that, the longer Chinese researchers lived in foreign countries, the higher the likelihood of engaging in collaborative activities outside of China. Therefore, we hypothesize that:

> *H1: The longer researchers stay in a new host country, the more collaboration they will have with local researchers.*

Ties once formed can persist after individuals move away and allow knowledge exchanges to proceed at a distance (Fontes et al. 2013). Continued physical proximity is not necessary although temporary co-location of researchers through short visits or conferences may nurture the relationship. As Williams et al. (2004) suggest, human mobility is temporally and spatially sticky due to the time required to develop social networks, learn new skills, or because of place attachments connected to social relationships and discourses. Scholars need to retain their collaboration with previous network if they wish to continue on projects with researchers in prior host systems (Jonkers and Tijssen 2008), or if they have limited local resources (Melkers and Kiopa 2010) and would like to access unique skills or facilities overseas (Georghiou 1998). The potential reputational benefits from prior collaborators and collaborating institutions could be another incentive (Georghiou 1998). Several empirical studies have provided evidence for persistent ties through collaborative links with former colleagues after researchers move away (Agrawal et al. 2006; Breschi et al. 2010; Jöns 2009; Marmolejo-Leyva et al. 2015; Oettl and Agrawal 2008). These studies indicate that knowledge flows return to those who were associated with the individual's prior organization and are a clear indication that personal relationships formed within an institutional context can endure over time, space, and organizational boundaries, an evidence of how crucial social ties are for maintaining working relationships. Previous connections developed through social networks increase the likelihood of collaboration between researchers (Crescenzi et al. 2016). Some studies confirmed that returnee scholars collaborate primarily with researchers in the former host country (Jonkers and Tijssen 2008; Jonkers and Cruz-Castro 2013). Therefore, we hypothesize that:

> *H2: Collaboration with prior host countries persists after researchers move to a new country.*

We expect collaboration with previous networks to remain after relocation, but how lasting is this relationship? In academic trajectories, researchers frequently move more than once, and two or three moves are not uncommon. This should translate to a widening collaborative network that expands with each move as new colleagues are acquired, trust is established, and new (collaborative) relationships are developed. Scholars have, however, identified that there is a limit to the number of individuals with whom we have a defined personal relationship, a key circle consisting of friends, relatives, and acquaintances. As more friends are added, there is decreased closeness with old friends (Roberts and Dunbar 2015) because personal relationships require significant time investment to develop and maintain. As time is an inelastic resource (Nie 2001), maintenance costs place a crucial constraint on the number of relationships an individual can maintain at a certain level of intensity at any one time. As researchers move to a new country, the need to set up labs

and build teams locally will deviate the attention from prior collaborators. In addition, starting new research lines in directions specified by funding agencies in the new host country will also move researchers away from their previous network (Georghiou 1998).

The geographical distances with prior countries may still be a hindrance. While some studies showed that spatial distance was not related to the decisions to collaborate (Agrawal et al. 2006; Autant-Bernard et al. 2007; Choi 2012), longer distances undoubtedly lead to increased financial costs, administration costs (communication and coordination of activities), and travel time for face-to-face meetings (Katz and Martin 1997). Physical separation from others in daily life and work reduces the likelihood of voluntary collaboration (Kraut et al. 2002). In a study of Japanese researchers in the USA, only 10 per cent of the ties were maintained by those who returned and more than half of them were severed within three years after return (Murakami 2014). Somewhat contrary to H2, we expect that:

H3: Researchers' collaboration with previous host countries will fade out with time after moving to another host country.

3. Data and variables

Our study uses three different sets of data to test the above hypotheses. First, in 2015, we developed a profile database consisting of basic demographic information (i.e. name, gender, title, education and employment history, and contact information including email, telephone, and office addresses) of tenured and tenure track faculty members with full-time employment in Singapore's three public research-intensive universities—National University of Singapore, Nanyang Technological University, and Singapore Management University. We identified 2,691 faculty members by searching departmental websites. Second, we created and sent out a survey in November 2015 to these faculty members to gather their views on their mobility experiences. We received a total of 707 responses by March 2016 (response rate of 26 per cent). Close to 70 per cent of our respondents are non-Singaporeans, which is in line with these universities' faculty demographics, and 83 per cent received their PhDs outside of Singapore. In order to have a time window that is sufficiently wide for us to analyze their research activities in Singapore, we focused only on those who have lived in Singapore for at least five years at the time of analysis. That is, they moved to Singapore no later than 2012. A total of 480 academics in our sample fulfilled this criterion.

We used publication data to capture collaboration activities. While co-publications may only be a partial indicator of collaborative networks because not all joint research is published and not all co-authors need to have contributed equally (Jonkers and Tijssen 2008), it is nevertheless one of the more tangible ways to measure collaboration. To generate corresponding data for their publications, we searched for the respondents' names in the Scopus database in 2017. Scopus assigns a unique and persistent digital identifier, termed 'author identifier', to groups of documents written by the same author using an algorithm that matches authorship based on certain criteria. This enabled us to disambiguate authors and find publications from researchers in our survey. Respondents' institutional affiliations in the latest publications were used to verify that the correct individual was identified. As Scopus does not entirely cover all publications, 102 respondents did not have an author identifier with which to trace their publications, and we excluded them from our analysis.

Subsequently, we collected the publication data for the remaining 378 authors, namely those survey respondents who arrived in Singapore no later than 2012 and have been assigned an author identifier by Scopus. We limited our search to journal articles published in English and retrieved 24,195 publications. For each publication, we recorded the institutional affiliations and base countries of the focal author as well as his/her co-authors. We later aggregated this data by year and obtained 4,370 author-year observation points. That is, for each focal author, we have his/her total number of publications and total number of co-authors for each publication year. We also counted—on a yearly basis—the number of co-authors from the same country as the focal author, which serves as an indicator of the intensity of local collaboration. Finally, we counted the number of co-authors from the focal author's previous base countries for each publication year after the focal author had left that country. This series provided us with an indication of the changes in a focal author's research network in his/her previous base country.

We note that, however, the algorithms used by Scopus to link authors to publications may affect matching accuracy. In particular, two types of errors are noted for Scopus author profiling: split authors and merged authors (Moed et al. 2013). The former refers to the multiple Scopus IDs assigned to the same researcher, while the latter is the opposite—multiple researchers assigned with a single Scopus ID. To address this, we verified affiliations reported in publications for each Scopus ID with employment history found in our profile database. For publication affiliations not matching employment history, or for a certain period of employment without publications, we manually searched for possible omissions and removed the publications not belonging to the researcher under study. While the 'merged authors' problem is easier to spot based on affiliations, we acknowledge that we may have missed some Scopus IDs belonging to researchers under study due to the 'split authors' problem. However, according to Moed et al. (2013), the principal Scopus ID should have captured a majority of publications. The missing ID only contains a few papers and there is no reason to believe the missing papers are particularly related to local or international collaboration. Hence, these missing observations should not affect our results systematically.

Our final dataset consists of 378 authors who have lived in Singapore for more than five years in their careers. Figure 2 shows the number of academics moving to Singapore in each year. Forty-seven per cent of the sample have been in Singapore since 2000, and another 42 per cent arrived during 1990–9. Figure 3 presents the comparison of the sample and the faculty population in terms of gender and discipline distribution. The shares of science, social sciences, and medical science are very close to those in the population. Only engineering is over-represented while law and business are under-represented, due to the lack of publication records in Scopus. Around 23 per cent of the sample are local Singaporean, the rest are mostly from other Asia-Pacific countries (Fig. 4). The group of Asia-born scholars working in Singapore shows a pattern of quasi-return migration, which allows them to be 'close enough' to aging parents while working in a 'good enough' university (Ortiga et al. 2018). Good job aspects such as research funding, university reputation, and family concerns (raising children and moving closer to parents) are among the top factors attracting scholars to Singapore (Fig. 5) (see also case study 1 in Appendix drawn from interviews with selected researchers).

Close to half of them have published in at least two countries, and 20 per cent have published in three countries. A maximum of

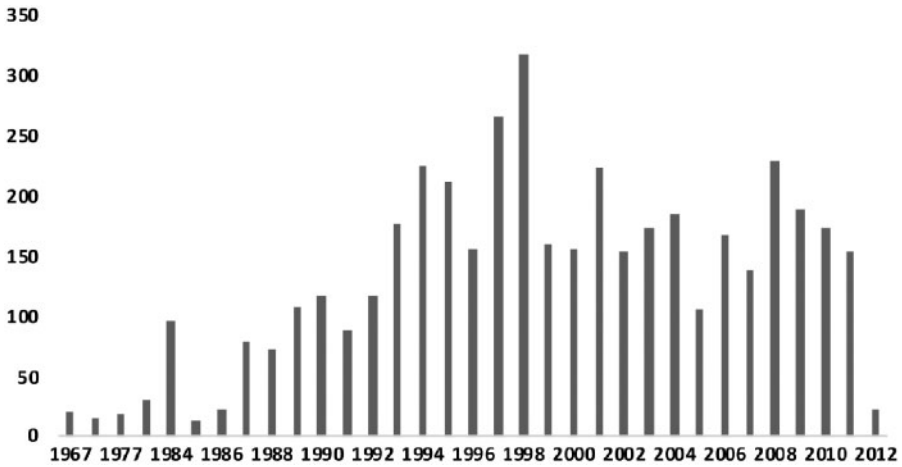

Figure 2. The year of arrival in Singapore.

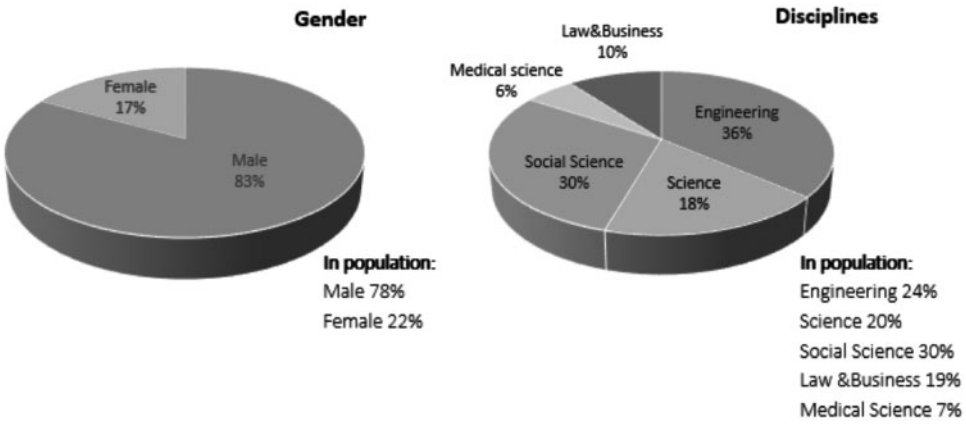

Figure 3. Profile of the sample.

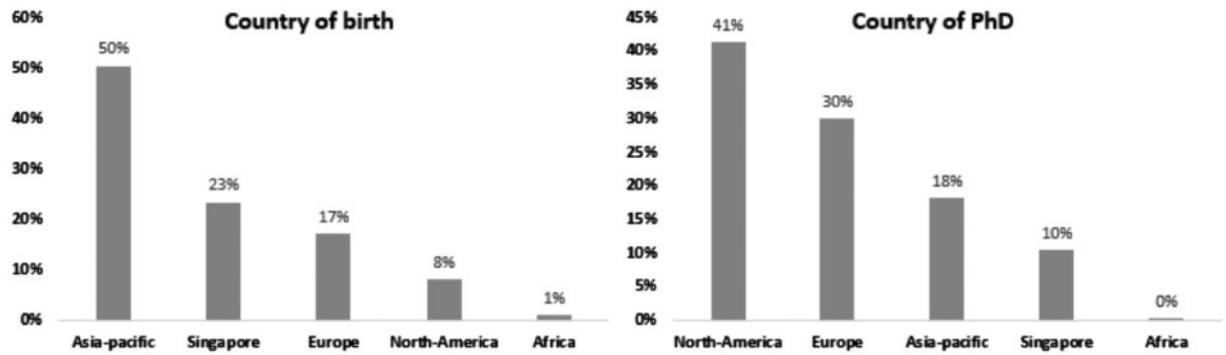

Figure 4. Country distribution.

six countries was identified in our sample. Interestingly, we also found that 32 per cent of them publish only in Singapore, despite having worked or obtained their PhDs overseas.

Tables 1 and 2 present the variables and their descriptive statistics. The dependent variables are $CoAuthors\_SG_{it}$, and $CoAuthors\_Prior_{it}$. $CoAuthors\_SG_{it}$ refers to the number of local co-authors in Singapore in a given year. It is the aggregated number of authors from Singapore across all publications for the focal researcher in that particular year. If the same co-author appears in two publications, we counted as two instead of one to capture the intensity of local collaboration. Similarly, $CoAuthors\_Prior_{it}$ measures the number of co-authors from countries that the focal researcher previously stayed in a given year.

The measure of mobility is constructed using survey and profile data. Mobility is a complex term which has been used variously to refer to different periods of stay outside the home country. Following Baláz et al. (2004), we refer to mobility as the move to another country in order to stay for an indefinite time as a result

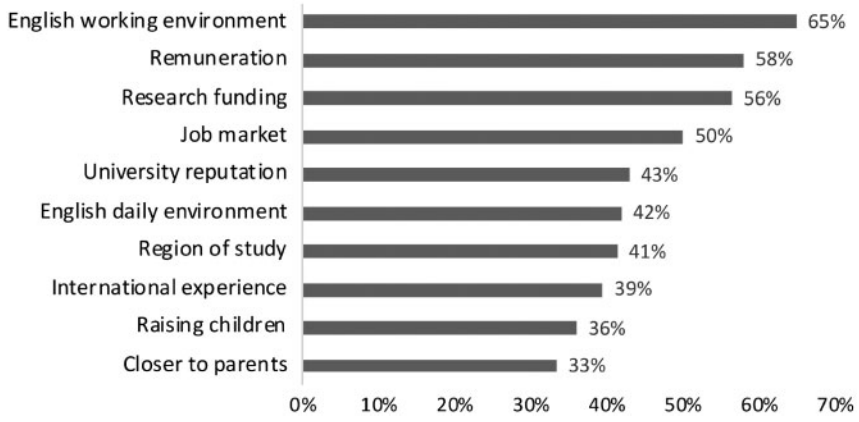

Figure 5. Top motivations for moving to Singapore (important or very important).

Table 1. Description of variables.

Variable	Description	Source
$CoAuthors\_SG_{it}$	Number of collaborators in the current country (Singapore) in Year *t*	Scopus
$CoAuthors\_Prior_{it}$	Number of collaborators from previous countries in Year *t*	Scopus
$CoAuthors\_Int_{it}$	Number of international collaborators in Year *t*	Scopus
$Year\_in\_SG_{it}$	Number of years in the current country (Singapore) by Year *t*	Survey&CV
$Year\_in\_SG\_2_{it}$	Square term of Year_in_SG in Year *t*	Survey&CV
$Year\_of\_Phd_i$	The year obtained PhD	Survey&CV
$\#\_Publications_{it}$	Number of publications in Year *t*	Scopus
$\#\_CoAuthors_{it}$	Number of co-authors from publications in Year *t*	Scopus
$\#\_Countries_i$	The number of countries have stayed (including the current one)	Scopus
$Motive\_network_i$	1 if research network in the region is an important/very important motivation for moving to the country (Singapore); 0 if not	Survey
$Born\_SG_i$	1 if born in Singapore; 0 if not	Survey
$Born\_Asia_i$	1 if born in the Asia-Pacific region (excluding Singapore); 0 if not	Survey
$Male_i$	Gender; 1 if male; 0 if female	Survey
$Engineering_i$	1 if in the fields of engineering; 0 if not	CV
$Science_i$	1 if in the fields of sciences; 0 if not	CV
$Social\_sciences_i$	1 if in the fields of humanities, arts and social sciences; 0 if not	CV
$Medical\_sciences_i$	1 if in the fields of medicine and dentistry; 0 if not	CV
$Professionals_i$	1 if in the fields of law, finance and business; 0 if not	CV

Table 2. Descriptive statistics.

Variable	Obs	Mean	Std. Dev.	Min	Max
$CoAuthors\_SG_{it}$	4,370	13.4	22.6	0	250
$CoAuthors\_Prior_{it}$	4,370	1.7	5.8	0	99
$CoAuthors\_Int_{it}$	4,370	4.3	11.1	0	214
$Year\_in\_SG_{it}$	3,448	9.4	6.5	0	36
$Year\_in\_SG\_2_{it}$	4,370	120.2	169.7	0	1681
$Year\_of\_Phd_i$	4,370	1995	8.7	1966	2015
$\#\_Publications_{it}$	4,370	5.5	6.4	1	57
$\#\_CoAuthors_{it}$	4,370	24.9	37.2	1	390
$\#\_Countries_i$	4,370	2.0	0.9	1	6
$Motive\_network_i$	4,370	0.3	0.5	0	1
$Born\_SG_i$	4,334	0.2	0.4	0	1
$Born\_Asia_i$	4,291	0.2	0.4	0	1
$Male_i$	4,370	0.9	0.3	0	1
$Engineering_i$	4,370	0.5	0.5	0	1
$Science_i$	4,370	0.2	0.4	0	1
$Social\_sciences_i$	4,370	0.2	0.4	0	1
$Medical\_sciences_i$	4,370	0.1	0.2	0	1
$Professionals_i$	4,370	0.1	0.3	0	1

of employment change. Given this definition, we do not study short-term international mobility, such as visiting positions to another institution. In our survey, we asked the respondents to indicate when they joined their current institutions in Singapore—information which is also available in our profile database. We used these two datasets to cross-check before calculating the number of years an author has stayed in Singapore by a given year for the independent variable $Year\_in\_SG_{it}$, which is also the number of years since he/she left the previous host country. We included $Year\_in\_SG\_2_{it}$, a squared term of $Year\_in\_SG_{it}$, to test for the curvilinear relationship.

A set of control variables are included to control factors that may influence research collaboration. The variable $\#\_Countries_i$ indicates the number of countries where the researcher has worked. It is retrieved from the publication affiliation field because we need to capture the effect of research network in a particular country. Therefore, a country where the researcher has lived but without active research activities as evidenced by publications is not counted in this indicator. In a small number of cases, the author returns to Singapore for the second time after having worked there previously.

In such cases, we do not count the return as a new move because the author can tap on previous research networks in Singapore. The variables $\#\_Publications_{it}$ and $\#\_CoAuthors_{it}$ refer to the number of publications and the number of co-authors in these publications respectively in a particular year. They are included to control the effect of research productivity and co-authors' cohort size. Scholars who are more productive or collaborative tend to have more co-authors, which is likely to affect the numbers of co-authors both locally and abroad. In addition, as the move to a new location might be motivated by a desire to work with certain co-authors, the variable $Motive\_network_i$ is included to capture this effect on the development of collaboration network. The variable is derived from a survey question that asks respondents to assess whether moving closer to the research network in the region is an important motivation for moving to Singapore using a 5-point Likert scale. It is coded 1 for those selecting research network as an important or a very important factor, and 0 for those selecting otherwise. Lastly, several demographic variables are included. The variable $Year\_PhD_i$ is the year of receiving the PhD, which generally indicates the seniority of the scholar in terms of academic rank. Established faculty tend to have larger and more diverse collaboration networks (Bozeman and Corley 2004). The variables $Born\_SG_i$ and $Born\_Asia_i$ refer to the researchers' birth countries, from Singapore or from the region of Asia-Pacific (not including Singapore), which might affect the length of stay in the region and the extent of local collaboration. The gender variable $Male_i$ and discipline dummy variables (engineering, science, social sciences, medical sciences, and professionals) are used to control possible variance across gender (Melkers and Kiopa 2010) and disciplinary fields (Glänzel and De Lange 2002).

4. Models and analysis

Our dataset has a typical time series cross-sectional structure with each author-year uniquely identifying an observation. It is an unbalanced panel as the number of years varies across authors. The earliest year of publication observed in this sample is 1967 and the latest is 2017, with 85 per cent of the author-years being post-2000. Since the number of publication years has to do mainly with an author's age and career trajectory, it is exogenously determined. Thus, we believe that the unbalanced nature of the panel does not pose the threat of selection bias.

For the benchmark models, we obtained fixed-effect estimators to minimize the omitted variable bias. Since all authors in the sample are based in Singapore and are affiliated with local universities, an author's collaboration pattern is reasonably tied to the country's broader academic community and other factors specific to a university or school/faculty. It would be realistic to expect different error variances for different panels and correlation of the contemporaneous error terms across panels. To address different error variances for different panels, we clustered the standard errors on the panel variable (author ID), thus relaxing the usual Ordinary Least Squares assumption that the observations are independent. In order to reveal the effect of additional factors on research network development, we further ran a random effect model that allows the use of time-invariant variables.

4.1 Results

The results of the fixed-effect estimation confirm curvilinear relationships between time and collaboration in both models (see Table 3; and Fig. 6 for visualization). Model 1 (Collaborators from the current country) shows that the number of domestic co-authors increases along with a researcher's stay following a move to Singapore at a decreasing rate in the first eight years and then decreases. Due to proximity with new colleagues, and greater familiarity and involvement with the local context and needs, the length of a researcher's stay in the country corresponds with an increase in local collaborations in the initial years. Model 2 (Collaborators from previous countries) shows that following a move to another country, there is still a good amount of collaboration with colleagues in previous host countries but this collaboration gradually reduces over time. The number of co-authors from previous host countries drops along with the time the researcher spends in the new host country up until the thirteenth year. Decreased opportunities for interaction, together with the demand on time for maintaining multiple relationships, contribute to the challenge of upholding the intensity of previous collaborations (see case study 2 in Appendix).

Table 3. Results from fixed-effect panel regression.

Variables	*Authors_SG* (1)	*Authors_Prior* (2)
$Year\_in\_SG_{it}$	0.211*	−0.236***
	(0.113)	(0.085)
$Year\_in\_SG\_2_{it}$	−0.013**	0.009**
	(0.005)	(0.004)
$Year\_of\_Phd_i$	–	–
	–	–
$\#\_Publications_{it}$	0.207	−0.106*
	(0.443)	(0.064)
$\#\_CoAuthors_{it}$	0.542***	0.066***
	(0.091)	(0.019)
$\#\_Countries_i$	–	–
$Motive\_network_i$	–	–
$Born\_SG_i$	–	–
$Born\_Asia_i$	–	–
$Male_i$	–	–
$Engineering_i$	–	–
$Science_i$	–	–
$Social\_sciences_i$	–	–
$Medical\_sciences_i$	–	–
Constant	−1.567**	1.803***
	(0.757)	(0.261)
Observations	3,412	3,412
R-squared	0.835	0.099
Number of authors	319	319

Robust standard errors in parentheses.
***P < 0.01, **P < 0.05, *P < 0.1.

The random-effect estimation suggests a similar pattern, except that the maximum of local collaboration and the minimum of prior collaboration are reached one year later (the ninth and fourteenth year respectively). A number of control variables have significant influence on the relationships. The number of moves a researcher has made seems to affect both local collaboration and prior collaboration. The more countries a researcher has stayed in, the higher the number of co-authors from prior host countries. Researchers develop more research networks along with their move across countries, which leads to a larger pool of ex-colleagues and thus more opportunities to collaborate with them (see case study 3 in Appendix). Singaporean (returnee) scholars are more active in developing local collaboration but less interested in maintaining prior collaboration. Discipline also affects collaboration patterns, with

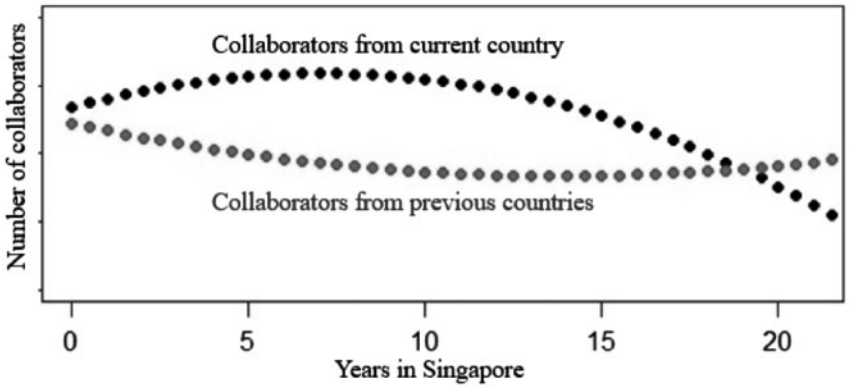

Figure 6. Collaborations with current and previous countries. Plot generated based on regression output in Table 3.

Table 4. Results from random effect GLS regression.

	Authors_SG		*Authors_Prior*	
Variables	(3)	(4)	(5)	(6)
$Year\_in\_SG_{it}$		0.252**		−0.269***
		(0.114)		(0.089)
$Year\_in\_SG\_2_{it}$		−0.014***		0.010**
		(0.006)		(0.004)
$Year\_of\_Phd_i$	0.096	0.126	−0.046	−0.068
	(0.068)	(0.095)	(0.061)	(0.082)
$\#\_Publications_{it}$	0.203	0.181	−0.179**	−0.181**
	(0.360)	(0.412)	(0.071)	(0.072)
$\#\_CoAuthors_{it}$	0.534***	0.542***	0.077***	0.084***
	(0.073)	(0.084)	(0.020)	(0.022)
$\#\_Countries_i$	−0.746*	−0.720	1.453***	1.413***
	(0.431)	(0.462)	(0.328)	(0.288)
$Motive\_network_i$	0.325	−0.143	−0.020	0.239
	(0.591)	(0.683)	(0.380)	(0.375)
$Born\_SG_i$	0.877*	1.534**	−0.820***	−0.668**
	(0.515)	(0.666)	(0.241)	(0.278)
$Born\_Asia_i$	0.518	1.140	−0.697	−0.979*
	(0.814)	(0.859)	(0.551)	(0.544)
$Male_i$	−0.733	−0.442	0.432	0.499
	(0.575)	(0.733)	(0.268)	(0.351)
$Engineering_i$	2.240***	2.372***	−0.398	−0.549
	(0.571)	(0.740)	(0.359)	(0.459)
$Science_i$	3.068***	3.208***	−1.431**	−1.554*
	(0.987)	(1.112)	(0.726)	(0.825)
$Social\_sciences_i$	−0.331	−0.662	0.564	0.671
	(0.665)	(0.810)	(0.552)	(0.650)
$Medical\_sciences_i$	0.443	1.212	−0.066	−0.796
	(1.571)	(1.409)	(1.060)	(0.777)
Constant	−193.4	−253.5	91.09	134.9
	(135.5)	(189.6)	(122.3)	(163.3)
Observations	4,280	3,412	4,280	3,412
Number of authors	368	319	368	319

Robust standard errors in parentheses.
***P < 0.01, **P < 0.05, *P < 0.1.

engineering and science having more local collaboration than social or medical sciences. This is understandable as science and engineering are fields that require teamwork in laboratories. It is a convention that team members involved in the project will be listed as co-authors in the publication, which leads to a high number of local co-authors, most likely from the same institution—the lab's home.

4.2 Robustness check

We checked if our results are robust to alternative model specifications and measures of mobility. To deal with contemporaneous error correlation across panels, we obtained panel corrected standard error (PCSE) estimators proposed by Beck and Katz (1995), which are explicitly designed for data with a panel structure. The

Table 5. Results from PCSE regression.

Variables	(7) *Authors_SG*	(8) *Authors_Prior*
$Year\_in\_SG_{it}$	0.319***	−0.332***
	(0.069)	(0.052)
$Year\_in\_SG\_2_{it}$	−0.013***	0.011***
	(0.002)	(0.002)
$Year\_of\_Phd_i$	0.084***	−0.031
	(0.032)	(0.026)
$\#\_Publications_{it}$	0.187*	−0.287***
	(0.102)	(0.071)
$\#\_CoAuthors_{it}$	0.529***	0.114***
	(0.024)	(0.016)
$\#\_Countries_i$	−0.626**	1.265***
	(0.284)	(0.142)
$Motive\_network_i$	−0.469	0.010
	(0.429)	(0.165)
$Born\_SG_i$	1.017**	−0.347**
	(0.424)	(0.173)
$Born\_Asia_i$	0.631*	−0.464**
	(0.345)	(0.229)
$Male_i$	−0.768	0.587*
	(0.523)	(0.357)
$Engineering_i$	2.349***	−0.560**
	(0.525)	(0.236)
$Science_i$	2.703***	−1.465***
	(0.448)	(0.316)
$Social\_sciences_i$	−0.084	0.336
	(0.399)	(0.307)
$Medical\_sciences_i$	0.765	−0.969**
	(0.875)	(0.418)
Constant	−170.0***	61.68
	(63.23)	(52.72)
Observations	3,412	3,412
R-squared	0.815	0.199
Number of authors	319	319

Standard errors in parentheses.
***P < 0.01, **P < 0.05, *P < 0.1.

algorithm assumes that disturbances are, by default, heteroskedastic and contemporaneously correlated across panels when computing the variance–covariance matrix. In addition, we specified first-order autocorrelation (AR1) of disturbances within panels and when observations were missing due to panel imbalance, all available observations common to the two panels contributing to the covariance were used to compute the covariance matrix (Table 5). The results are consistent (the maximum of local collaboration is reached in the twelfth year), which again confirms our findings.

An alternative measure of mobility is constructed based on the change of publication affiliations. In our sample, authors with some mobility throughout their careers are mostly migrants and directional travellers (Robinson-Garcia et al. 2018). From bibliometric data, migrants are easily identified by a 'point of rupture' from previous countries. In the case of migration, multiple institutional affiliations and base countries for a single year could arise when an author is changing home institution and moving from one country to another (transition years). In these cases, the base countries before and after the transition years are different. For the transition years with dual affiliations, we use the new country as the base country for that year. Due to general publication time lags, we assume by the time that the new host country appears in the publication, the author should have already moved to the new country. Unlike migrants, directional travellers do not have ruptures with origin countries. In other words, there should be a continuity of base country and institutional affiliation during mobile years with multiple affiliations. In these cases, checks were made against the affiliations in a respondent's other publication years to disambiguate the host institution in which the respondent is based. We then ran the three models using this bibliometric measure of mobility and all the results were consistent with previous ones.

5. Findings and discussions

Our study uncovered dynamic patterns between researcher mobility and collaboration. Academics' migration across countries is often followed by the change in collaboration network. In our study, we found that local collaboration accumulated most substantially in the first few years and continued to grow until the eighth year, as a result of local team building in close proximity with new colleagues. However, an increase in local collaboration came at the cost of international collaboration. Publications co-authored with colleagues in previous countries dropped significantly in the first few years and continued to decline for over ten years. This is expected because relationships require maintenance, which necessitates time and energy, and thus it is not possible to maintain an infinite number of collaborators at the same intensity at any given point. While the connection with prior research network remained after leaving the country, it gradually faded over time. As former colleagues were no longer physically in the vicinity, both casual and deliberate interactions were severely curtailed. The geographical distance between previous and current host countries may also be substantial, requiring extra efforts for face-to-face meetings. Distance also implies time zone differences, which can make coordination of technological communication difficult, particularly for groups with widely dispersed researchers. Over time, former colleagues were likely to move away from the researcher's collaboration radar following the adage 'out of sight, out of mind'.

Our findings also showed that researchers who have made multiple international moves have less local collaboration and more collaboration with colleagues in previous host countries. These scholars have more diversified and extensive overseas experience, so naturally they have more prior networks to work with and are less dependent on local collaboration. Singaporean scholars are more eager to develop local collaboration but are less active in maintaining their ties with colleagues in prior countries (mostly western countries) once they moved back to the region. Previous literature shows that returnee scholars have more international research collaboration compared with their nonmobile peers, but our study adds that their international ties are less persistent compared with expatriate colleagues.

Our study contributes to the literature in two ways. It is one of the first to trace researchers through their careers in different countries to examine how their collaboration patterns evolve from publication activities. Many existing studies adopt a static approach to show that scholars with prior international experience are more likely to have international collaboration. But, as anyone with international mobility experience would confirm, collaboration patterns are dynamic. This study complements existing literature on mobility and collaboration by introducing the time dimension and provides compelling evidence of the changing relationships with co-authors in current and previous host countries.

Second, in contrast with existing mobility studies focusing either on educational migration to the traditional knowledge centers in the West, or the return migration to origin countries, Singapore is an emerging knowledge hub that attracts academics with work opportunities outside the traditional centers (Ortiga et al. 2017). The motivation for migration and collaboration might be different from other groups. This study thus complements the diaspora literature by going beyond a single ethnic group and introducing perspectives from academics migrating to a 'third' country after their graduate studies or work overseas.

The findings of this study also have practical implications. For policy makers, it is important to recognize the existence of researcher attention span for local and international collaboration. This recognition is important for deciding how to best maximize these attention spans given the difference in researchers' collaboration tendency. Migrant researchers become part of the international collaboration network once they leave. However, the connection does not last forever. In particular, returnee scholars are significantly less embedded in prior network compared with their expatriate colleagues. The fallout may be especially costly for those whose collaborators are high-quality researchers on whose spillover knowledge collaborators depend. When star mathematicians from Russia emigrated and ceased collaboration in the home country, the research output of their collaborators from the home country declined (Borjas and Doran 2015). How collaboration frequency affects the maintenance of ties after departure (Murakami 2014) should underscore the importance of encouraging intra-mural and inter-mural collaboration. Universities or funding agencies should appreciate the value of temporary relocations and increase opportunities for frequent interaction and networking initiatives to maintain prior connections. Attending professional conferences and short visits help to develop or maintain international ties (Melkers and Kiopa 2010), but it is also rather costly in terms of time and money. Providing more funding opportunities for travel, visiting fellowship, and joint projects will incentivize scholars to engage in more international collaboration. The Humboldt Foundation (Jöns 2009), Fulbright program (Kahn and MacGarvie 2012), Marie Curie program or EU research funding framework (Defazio et al. 2009) are such examples. In addition, this funding support must be organized in conjunction with reliefs from regular teaching and administrative duties, which can provide researchers more flexibility in arranging travels and meetings. The grant of sabbatical leaves or even unpaid leaves will allow researchers to further broaden their research network with new academic experience.

At the same time, active migrant researchers should be encouraged to engage more intensely in local cross-disciplinary collaboration as their broad overseas experience and expertise can aid in the recombination of new and existing knowledge for innovation. Their understanding of the local situation together with their wider international exposure may reap greater knowledge benefits for boundary-spanning collaborations. This calibrated approach can more accurately steer the collaborative activities of researchers toward balanced collaboration with both local and international researchers, and may be an alternative to a general policy that may not be conducive to supporting individuals whose levels of collaboration with different sets of people vary at different stages.

We conclude with some limitations of our study. To start with, the host country in this study is a city country with a small domestic research community, which is likely to limit the level of local collaboration (Glänzel and Schubert 2005). Collaboration activities in large nations may reveal different patterns altogether. One future direction for those interested in unpacking the nexus between researcher mobility and collaboration is to examine the mediating effect of country size on the evolution of collaboration patterns. In addition, the mobility variable coded from survey and CV data only captures changes in full-time employment. Adjunct positions or short-term visits, which may contribute to maintaining international collaboration are not reflected. Hence, the capability to retain collaboration with prior countries would be over-estimated with the omission of such data. Lastly, the publication data used in this study is based on peer-reviewed journals retrieved from Scopus, which has a low coverage for disciplinary fields in the arts and humanities (Mongeon and Paul-Hus 2016) and thus biased our sample against these fields. To have a more comprehensive overview of the changing collaboration patterns as a result of researcher mobility, it is essential to include other types of publications for comparable results. The research agenda on unpacking the relationship between researcher mobility and collaboration is very exciting and we hope our study constitutes an invitation to examine this nexus to provide further findings for policy discussions.

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Appendix

Case study 1: Faculty member's motivation for moving to Singapore

A junior faculty from Southeast Asia who obtained his PhD in Singapore, moved to Australia and returned a few years later, shared his motivation to leave Australia for Singapore. When the faculty member left for Australia, he had already secured permanent resident status in Singapore. He knew that if he wanted to progress further within the Singapore academic hierarchy, he needed international experience.

However, he returned to Singapore for other reasons. First, he wanted to be closer to his aging parents, who lived in a neighboring country. His mother was able to visit him three to four times a year after he moved to Singapore, and he felt that he has more opportunities to interact with her. During the three years he was in Australia, his father did not visit and his mother visited only once.

Second, he felt that he would not be able to advance within the Australian academic structure due to his nationality. His perception was that Australia will prioritize Australians. His own experience in Singapore suggested that his promotion would be meritocratic.

'In the past, when I moved to Australia, come back to Singapore, I feel that it is important for me to be mobile, to be based in Australia, to learn something, to pick up new skills in terms of writing and so on. Then come back to Singapore also partly motivated or driven for professional reason, like career reason, [or] career related reason. But for the time being—for now, if you ask me that question, I think I feel that professional reason is not so much to be the main motivator for me to stay or to move somewhere else. It is more like, I don't know, I just want to find a place whereby I can settle and call home.'

Case study 2: How change in research focus results in ceasing collaboration with previous host country

A senior faculty who is from the UK and completed his PhD and postdoc there reported that he had not planned on going overseas, but realized in the middle of his postdoc that it would not be beneficial for his career to only stay in one place. Because his wife is from Asia, Asian universities came on his 'radar'.

After he accepted a faculty position in Singapore, he observed he was one of the few doing applied work in his department (versus theoretical work). As a result of this imbalance, he did not find many collaborators in his department. By moving to Singapore, he also changed his research focus and consequently no longer had contacts with his postdoc supervisor. Instead, he focussed on building local networks and now collaborates with hospitals and public health institutes. He has some international collaboration, but finds these networks difficult to maintain, and believes it is much easier to publish with Singapore-based researchers.

'You know, we are working on papers together with overseas, and I can see ... papers are always like much slower than the ones done here locally. Because it is a problem. It's easy to just call ... without worry about time zone, or just go into their office, or arrange meetings at Starbucks or whatever. Whereas you know like ... in the UK now we have to finish up some papers, even just like trying to arrange a time when we are both able to skype at the same time is a challenge.'

'Singapore ... from an academic perspective, is quite isolated. So when I was in [the UK], it was easy for me to go to London, like for a seminar, or meeting someone from the London universities. For me, for where I am just now ... the nearest university is like where, Hong Kong? And that's like four to five hours flight and—so that I think with Singapore researchers are at a disadvantage relative to those in Europe or North America, or from in Japan or China as well.'

Case study 3: A senior faculty member on his preference for international collaboration, and fewer perceived challenges working in Singapore

This is a senior faculty member who did his PhD in the USA and took up a position there before moving to Singapore due to a lack of funding at his previous university. He has been in Singapore for more than ten years.

He said he tends to work with colleagues from his previous university, but has also hosted and collaborated with researchers from his PhD institution, and from Germany and Lebanon. He feels it is less about where they are from than about research interest. Although there is a Singaporean in his group whose research is in his area, they have not collaborated because of his ongoing projects.

He feels that he has fewer challenges working in Singapore than in his previous job, attributing it to the resources available and flexibility. He does not have a lot of administrative work, which frees him up to do research. He has resources to attend conferences and collect data. There is academic freedom to investigate what he wants, and grants available, so he feels his job in Singapore is easier than it was in the USA where they had no resources and did not have money to attend conferences.

'I would most rather collaborate with someone not at (Singapore university), because I can send them the draft at night, it's their morning. I get it back—if I don't want to meet a deadline, they can't knock on my door, because they're in a different country, right? So sometimes it's better to work with people at a distance.'

'I think, any new collaboration has the same challenges. You have to learn each other's work styles and strengths. For example, one of my colleagues who I collaborate with, we've collaborated for the last 14 years, so I don't necessarily have challenges with him, because we know he can do the analysis quicker than I can, I can write the intro better, so we have all of that. But I have the same challenges that anyone would have with new students, right? So, I'm training them. They have different styles, but, challenges are opportunities however you frame it, right? They are the same, we need to understand each other's philosophy, and our interests.'