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# Gender-Based Homophily in International Research Collaborations

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**Abstract:** Women researchers in postdoc career stages still do not participate to the same extent in international academic mobility as men do. As a novel approach to better understand gender inequalities in international academic mobility, we investigate the structure of research collaborations and bring into focus the host researchers. Our central theoretical tool is the distinction between compositional and behavioral homophily. Using quantitative data from two German Humboldt Foundation programs sponsoring collaborations between international researchers and academic hosts in Germany, we ask (a) to what extent are gender-homophilous research collaborations caused by compositional or behavioral homophily; (b) what factors influence gender-based homophily; and (c) whether men or women tend more towards gender-homophilous collaborations. We detected behavioral homophily in research collaborations mainly when taking the potential pool of eligible women researchers as the reference group. The results on influencing factors are ambiguous and need further investigation. Furthermore, our results show that men tended more towards gender-homophilous collaborations than women. Our results suggest that gender inequalities in international academic mobility are linked to behavioral homophily and that exploring the role of host researchers is crucial to understanding—and overcoming—the under-representation of women in international academic mobility.

**Keywords:** international research collaboration; international academic mobility; gender homophily; gender inequalities

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## 1. Introduction

As recent data show, women in post-PhD career stages in Europe still do not participate to the same extent in international research collaborations as men. Whereas, at European Union level (EU-27) in 2019, the international mobility rates of women and men PhD students differed by 0.31 percentage points (p.p.) in favor of women (European Commission 2021a, pp. 162–63, based on the MORE4 EU Higher Education (HE) Survey, see PPMI et al. 2021, pp. 41–44; European Commission 2021b, pp. 93–98, for the survey and the calculation), the proportion of women researchers who had spent a research period of at least three months in another country in post-PhD career stages was 5 p.p. lower than that of their male peers, with significant country differences ranging from 11 p.p. in favor of women in the Netherlands to 13 p.p. in favor of men in Germany (European Commission 2021a, pp. 163–64). International mobility is essential for a successful academic career, and unequal access can reinforce gender inequalities (Cohen et al. 2019; Herschberg et al. 2018; Leemann 2010). Thus, an understanding of gender inequalities in international academic mobility is crucial to fostering gender equality in science and research.

Recent studies on gendered patterns in international academic mobility have examined the effects of institutional barriers such as gender disparities in financial and temporal resources for research, women's responsibility for unpaid care work, precarious employment conditions, dual-career couples' family arrangements, and social prejudices against female performance (Bauder 2020; Prozesky and Beaudry 2019; Toader and Dahinden 2018; Uhly

et al. 2015; Zippel 2017). In political discourse, women's ascribed family responsibilities are often perceived as the main obstacle to their international mobility. Contrary to this assumption, recent studies on international academic mobility have pointed to men's and women's need to balance conflicting demands of family and mobility and the importance of institutional characteristics such as a family-friendly work culture (Cohen et al. 2019; Toader and Dahinden 2018). Another strand of research has shown that national contexts and the gender regime influence how family commitments affect academic careers and the international mobility of female researchers (Di et al. 2021; Nokkala et al. 2020; Prozesky and Beaudry 2019). Uhly et al. (2015, p. 14) concluded that the partner's employment status within or outside academia had a more decisive influence on the mobility of women researchers than the presence of children. The very assumption that international research stays abroad is, per se, not possible for women with children and has an exclusionary effect on those women (Nikunen and Lempiäinen 2020).

In this article, we take a novel approach to studying gendered patterns in international academic mobility by examining collaborations between academic hosts in the destination country and (prospective) guest researchers. In focusing on hosts and their institutions, we respond to Shen et al.'s call to pay more attention to sending and receiving institutions (Shen et al. 2022, p. 1327). To investigate the gender composition of these collaborations, we rely on the concept of homophily, which refers to the tendency of individuals to form relationships with similar others. Knowing that international academic mobility refers not only to the cross-border movements of academics and academic communities, but also to infrastructures, equipment, ideas, or knowledge (see Shen et al. 2022, p. 1321), we focus nevertheless on the international mobility of researchers in post-PhD career stages.

We use data from the German Humboldt Foundation, which sponsors academic collaborations between individual international researchers and researchers in Germany by granting research fellowships and awards. These data are especially valuable for our purpose, as the foundation's sponsorship programs promote international academic collaboration mainly by enabling international researchers to stay 6–24 months at a German university or non-university research institution. Once sponsored by the foundation, international researchers and their academic hosts become life-long members of the Humboldt Network. The oldest and largest program (about 500 grants yearly) of the foundation—the Humboldt Research Fellowship—invites postdoctoral and experienced researchers to apply for research stays in Germany. Another well-known program, the Humboldt Research Award, addresses internationally recognized researchers from abroad who may be nominated by established researchers at research institutions in Germany. Women account for just under one-third of all international researchers sponsored under the Humboldt Foundation programs, with significant differences across global regions and programs. Between 2010 and 2019, almost 30 percent of Humboldt Research Fellowships went to female researchers. In the case of the Humboldt Research Award for internationally recognized researchers, the proportion of women award winners was just 11 percent in the same period (Löther et al. 2022, p. 23).

Before presenting our data and methods and reporting and discussing the results of our analysis, we will explain the value of homophily as a theoretical framework for investigating gender imbalances in international research collaborations and mobility, review the state of research on gender-homophilous networks, and outline our research question and hypotheses.

## 2. Theoretical Framework, State of Research, and Research Questions

To examine international academic mobility through a knowledge lens, Shen et al. (2022) proposed a framework that links international academic mobility to the national, regional, and global knowledge systems. They described people participating in mobility in the sending and receiving regions, countries, and institutions as "'knowledge agents' who have the agency to acquire, circulate, produce knowledge, and navigate through knowledge networks and geopolitics of knowledge" (Shen et al. 2022, pp. 1326–27). In this

framework, our study focuses on the cross-border movements of academics and analyzes one-to-one collaborations between incoming researchers and host researchers at receiving institutions in Germany. In the case of the Humboldt Foundation, the respective host researchers and receiving institutions have significant control over establishing these collaborations. By accepting or nominating an international researcher, they act as gatekeepers, especially for incoming early-career researchers. Considering Shen's argument that "since various forms of inequity, inequality, and injustice exist in knowledge systems [...], the acquisition, transfer, circulation, production, networks, and geopolitics of knowledge in international academic mobility are also characterized by power and politics" (Shen et al. 2022, p. 1327), **we investigate whether gender inequalities structure collaborations within the framework of the two Humboldt Foundation programs.**

To analyze the gender structure, we rely on the concept of homophily. Lazarsfeld and Merton (1954) coined the term "homophily" to describe "a tendency for friendships to form between those who are alike in some designated respect" (see also McPherson et al. 2001, p. 23). Mickey (2019) explained that "the theory of homophily argues that people are attracted to similar others to facilitate trust, communication, and reciprocity" (see also Horta et al. 2022, p. 2; McPherson et al. 2001). As Y. S. Wang et al. (2023) noted, "homophily [...] has been found to structure professional as well as socio-emotional relationships" (p. 2). Although homophily can facilitate communication, make behavior more predictable, promote reciprocity, and increase trust, it also limits one's pool of potential contacts and social interactions and hinders access to diverse perspectives (Kwiek and Roszka 2021; McPherson et al. 2001). Moreover, homophilous networks may lead to the exclusion of women ('old boy networks') and social minorities in particular (Mickey 2019, pp. 2–3).

Homophily may be induced either by the structure of the respective population or by individuals' (conscious or unconscious) decisions. To analyze this difference, McPherson et al. (2001) distinguished between "homophily effects that are created by the demography of the potential tie pool as *baseline homophily* and homophily measured as explicitly over and above the opportunity set as *inbreeding homophily*" (p. 419; emphasis in original). Based on this distinction, Y. S. Wang et al. (2023) developed the concepts of structural, compositional, and behavioral homophily to better understand the underlying patterns. Structural homophily reflects "structural aspects such as gender distribution, the number of documents and authorships, and the number of authorships for each document" (Y. S. Wang et al. 2023, p. 4). Compositional homophily refers to demographic structures below the population level, such as varying gender distribution across disciplines. Behavioral homophily describes deviations of homophily from its [random] distribution "under structural and compositional homophily", which "may include the effect of both explicit and implicit consideration of gender" when forming relationships (Y. S. Wang et al. 2023, p. 7). Similarly, Holman and Morandin (2019) urged that gender ratios in sample subsets (e.g., disciplines) be considered when analyzing gender homophily in co-authorships, as otherwise, it may appear "as if authors publish with same-gendered colleagues disproportionately often, even if collaboration is completely random with respect to gender" (p. 2).

Homophily and the differentiation between compositional and behavioral homophily have already been used to analyze research collaborations using bibliometric data. Reviewing the literature, Kwiek and Roszka (2021) noted that "most recent bibliometric studies on gender differences in research collaboration patterns suggest that men tend to co-author with men and women with women" (p. 4). These patterns result not only from the composition of the potential pool of authors in the respective research fields but also from (conscious or unconscious) decisions to choose someone as a co-author. In their study of gender-based homophily in co-authorships, Y. S. Wang et al. (2023) reported: "When controlling for the latent hierarchical structure of scholarly communities, field specific cultures of collaboration, and changing gender representation across time, we find statistically significant behavioral gender homophily in co-authorships across the JSTOR corpus" (p. 15). Holman and Morandin (2019) reported a similar finding: "We found evidence that

researchers work with same-gendered co-authors more often than expected under the null model, even after implementing stringent controls for Wahlund effects" (p. 9).

Gender-homophilous research collaborations have been investigated mainly through bibliometric analysis (but see Hartlep et al. 2017 as an exception). Our approach and data set allow us to study collaborations between (prospective) international incoming researchers and their academic hosts/nominators, thereby combining research collaboration and international academic mobility. For this purpose, we rely on Y. S. Wang et al.'s concept of structural, compositional, and behavioral homophily, which goes beyond merely statistical observations and helps us to study underlying social structures like gender inequalities. Nevertheless, the present paper focuses on compositional and behavioral homophily and omits structural homophily because the latter calls for sophisticated bibliometric data and refers to complex co-authorship relations, whereas our research object is one-to-one collaboration. **We aim to measure gender homophily in international research collaborations sponsored by the Humboldt Foundation and ask, first, to what extent gender-homophilous collaborations are caused by the gender distribution in the potential pool of international researchers and hosts/nominators (compositional homophily) or by (conscious or unconscious) decisions on the part of the individuals involved (behavioral homophily).** Based on the findings of recent bibliometric studies, we hypothesize the following:

**H1:** *Research collaborations sponsored by the Humboldt Foundation are gender-homophilous more often than expected under random distribution.*

The varying proportions of women in different disciplines can influence the extent of gender-homophilous research collaborations. For this reason, the above-mentioned studies control their results in relation to research fields. On the other hand, the extent of homophily can vary in different fields of science due to gender distribution and collaboration cultures. Holman and Morandin (2019, p. 5) detect that "[j]ournals with a balanced or female-biased author gender ratio tended to have [. . .] stronger homophily [. . .] than journals with a male-biased author gender ratio". Further factors besides discipline might influence homophily in international research collaborations. Concerning career stages, Lerchenmueller et al. (2019) found that gender homophily among women stems from female leaders of scientific projects assembling their teams, whereas Holman and Morandin (2019) found no effect of career stage. Following the observation of Lerchenmueller, Hoisl, and Schmallenbach, we might assume that advanced researchers expand their networks during their career and become more independent of the gender of the host than those at less advanced career stages. Regional origin might influence whether international researchers and hosts prefer research collaborations with persons of the same gender due to (a) reputation hierarchies and the external ascription of scientific performance (Gerhards et al. 2018; Zippel 2017, pp. 53–73), (b) differential research conditions in the country of residence, and (c) gender stereotypes in the countries of residence and from hosts about women from different backgrounds. Finally, the institutional background—the type of research institution, its share of women, and its research intensity—might influence the extent of homophilous collaboration. Kwiek and Roszka (2021, pp. 9–16) found in their study about Polish academics that the proportion of publications in co-authorship with other men was exceptionally high among scientists at research-intensive institutions, whereas female scientists at such institutions published less frequently in homophilous networks. In sum, the literature points to different factors influencing homophilous research collaborations, but the extent and direction of the influence have not yet been determined.

Based on the literature, we hypothesize the following:

**H2:** *The field of science, regional origin, and career stage of the international researcher, and the host/nominator, as well as the host's/nominator's institutional background, influence the extent of gender-homophilous collaboration.*

Despite its conceptual benefits, the concept of homophily suggests symmetry when men collaborate with men and women with women and neglects gendered structures, such as differential access to economic and time resources or recognition hierarchies (Paulitz and Braukmann 2020; van den Brink and Benschop 2014; Moss-Racusin et al. 2012), that influence inclusion in or exclusion from academic networks. On the one hand, gender differences can consist of whether men or women have a stronger tendency towards homophilous collaborations. On the other hand, gender homophily can be rooted in gendered science structures and have different effects on men and women.

One strand of studies has examined whether men or women tend more towards homophilous networks. The results of these studies are inconsistent. Some have found that women collaborate more often in homosocial networks than men do (Boschini and Sjögren 2007; Fell and König 2016; Holman and Morandin 2019; Jadidi et al. 2017; see also Kwiek and Roszka 2021; Lerchenmueller et al. 2019); others have demonstrated that men researchers have a higher probability of collaborating with same-gendered colleagues than have their female counterparts (Araújo et al. 2017; Kwiek and Roszka 2021; Queupil and Muñoz García 2019; van den Brink and Benschop 2014). Kwiek and Roszka (2021) found that Polish male academics were three times more likely than women to produce publications in homosocial co-authorship. This pattern persisted when differentiated by age or academic position (Kwiek and Roszka 2021, pp. 9–16). A survey of professors in the German state of North Rhine-Westphalia found that male professors were more frequently members of gender-homogeneous networks than female professors (Kortendiek et al. 2013, p. 331). The demographic composition of the professoriate ("compositional homophily" in the terminology of Y. S. Wang et al. 2023) may be one reason for gender-homophilous networks. Thus, the distinction between compositional and behavioral homophily, as proposed in this paper, helps to obtain evidence of whether men or women tend more toward gender-homophilous research collaborations.

Concerning gendered structures leading to gender homophilous networks, Berger et al. (2015) showed that men connected primarily with men in male-dominated industrial collaborations and that "participants routinely draw from those cultural gender practices that reinforce gender inequalities" (p. 574). Through qualitative interviews, Paulitz and Braukmann (2020) found that women professors faced obstacles to accessing informal research networks or influential institutional positions, as participation was based mostly on the principle of "the personal approach"—and thus on informal ties—rather than on professional expertise (p. 36). The authors noted that the lack of inclusion of women professors in informal networks was due not to conscious exclusion but rather to preconscious frames that led men to initially have primarily other men on their radars (pp. 38–39). Kwiek and Roszka (2021, p. 21) suggested that their finding of men in research-intensive organizations cooperating especially often with men "may tend to indicate the uniqueness of the massively expanded and relatively gender-balanced Central European research systems". However, the publishing patterns of scientists at research-intensive institutions also point to gender differences in power, resources, and recognition. Lower recognition is reflected, for example, in the fact that publications with women as lead authors are cited less frequently (Lerchenmueller et al. 2019). This leads to gendered outcomes for homophilous networks. Both male and female researchers tend to have gender-homophilous networks, "but for women, their gender-homophilous networks are negatively associated with organizational status, and thus provide them with lesser quality information and resources" (Mickey 2019, p. 3). Queupil and Muñoz García (2019) noted that "women are more diverse in their networks. But, because male contacts are more valued, this impacts women's ability to advance in their careers or attain higher salaries" (p. 118).

The gendered structures leading to homophilous research collaborations and their outcomes frame our analysis and interpretation. In this paper, we focus on the question of whether there are gender differences in the preference for homophilous collaboration. Research results to date on this question are inconsistent. Due to the context (interna-

tional research collaborations with an under-representation of women researchers), we hypothesize the following:

**H3:** *Male researchers are more often in a gender-homophilous research collaboration than female researchers.*

## 3. Data and Methods

### 3.1. Data

Among the various scholarship and fellowship programs offered by the Humboldt Foundation, we examined two programs for this analysis: first, the Humboldt Research Fellowship, which sponsors postdoctoral researchers up to 4 years after their PhD and experienced researchers up to 12 years after their PhD; second, the Humboldt Research Award, which addresses internationally recognized researchers (see the foundation website: https://www.humboldt-foundation.de/en/explore/about-the-humboldt-foundation (accessed on 25 August 2024) and the program information files (dating from 2017 and 2019 and covering the investigation period) added in the Supplementary Materials for information about the programs).

We compiled the data set from an anonymized extract from the Humboldt Foundation's administrative data; it comprises data on 19,321 applications and nominations between 2010 and 2019. We decided to focus on applications/nominations rather than only successful applicants/award recipients for three reasons: First, the applications/nominations already presuppose the existence of some degree of research collaboration between the two parties at the time of the application/nomination. Second, there was no gender gap in success rates in the period under review (Alexander von Humboldt-Stiftung 2023, pp. 11, 26), which means that the shares of women among applicants/nominees and grant/award recipients were similar. Third, using a larger sample allows for more differentiated analysis. The data contain personal information about the Research Fellowship applicants and Research Award nominees, their sex, age, field of science, country of residence at the time of application/nomination, the year of their PhD, and information on the selection process. The Humboldt Foundation uses a binary definition of sex, with the categories 'female' and 'male'. It does not differentiate between biological sex and the social construct of gender. Table 1 summarizes the applicants/nominees by sex and program category and shows the under-representation of women.

**Table 1.** Applicants/nominees by sex and program category (2010–2019).

| | Humboldt Research Fellowship Applications | | | | Humboldt Research Award Nominations | |
|---|---|---|---|---|---|---|
| | HFST-P | | HFST-E | | | |
| | N | % | N | % | N | % |
| Women | 4048 | 30.1% | 1251 | 28.7% | 176 | 11.5% |
| Men | 9393 | 69.9% | 3104 | 71.3% | 1349 | 88.5% |
| Total | 13,441 | 100% | 4355 | 100% | 1525 | 100% |

Note: HFST-P = Humboldt Research Fellowship (postdoctoral researchers); HFST-E = Humboldt Research Fellowship (experienced researchers).

As can be seen from Table 2, the gender distribution of the applicants/nominees in the period under review varied across the fields of science: the percentage of women was lower in the natural sciences and engineering than in the social sciences, humanities, and the life sciences.

**Table 2.** Applicants/nominees by field of science and program (2010–2019).

| | | Humboldt Research Fellowship Applicants | | Humboldt Research Award Nominees | |
|---|---|---|---|---|---|
| | | N | Women in % | N | Women in % |
| Field of science | Social sciences and humanities | 4768 | 38.3% | 400 | 21.0% |
| | Life sciences | 3679 | 40.1% | 192 | 17.2% |
| | Natural sciences | 2367 | 18.8% | 698 | 6.2% |
| | Engineering | 6982 | 22.2% | 235 | 6.8% |

Between 2010 and 2019, over 9,000 academic hosts/nominators at German universities and non-university research institutions supported the applicants/nominees. The data contain information on the host's/nominator's sex and institution. Table 3 summarizes the hosts and nominators by sex and program.

**Table 3.** Collaboration hosts and nominators by program and as multi-hosts/nominators.

| | Total Hosts/Nominators | | Humboldt Research Fellowship Hosts | | Humboldt Research Award Nominators | | Multi-Hosts/Nominators | |
|---|---|---|---|---|---|---|---|---|
| | N | % | N | % | N | % | N | % |
| Women | 1670 | 18.3% | 1610 | 18.6% | 161 | 13.2% | 589 | 16.2% |
| Men | 7431 | 81.7% | 7048 | 81.4% | 1056 | 86.8% | 3045 | 83.8% |
| Total | 9101 | 100.0% | 8658 | 100.0% | 1217 | 100.0% | 3634 | 100.0% |

In total, 18.6% of the hosts in the Research Fellowship program and 13.2% of the nominators in the Research Award program were women. Nearly 40% of all hosts and nominators (N = 3634) supervised more than one applicant/nominee (multi-hosts/nominators). Women supervised more than one applicant/nominee less often, which leads to a lower proportion of women among the multi-hosts compared to the total number of hosts/nominators.

### 3.2. Methods

The Humboldt Foundation's research collaborations involve one host/nominator (a researcher at a German research institution) and one international researcher. Four different gender compositions are thus possible (see Table 4).

**Table 4.** Collaborations within the Humboldt Research Fellowship program and Humboldt Award program by the sex of hosts/nominators and applicants/nominees.

| | | | | Hosts/Nominators | | |
|---|---|---|---|---|---|---|
| | | | | Men | Women | Total |
| | | | | (1) | (2) | (3) |
| Applicants/Nominees | Men | (a) | N | 12,092 | 1754 | 13,846 |
| | | (b) | % | 62.6% | 9.1% | 71.7% |
| | Women | (c) | N | 4308 | 1167 | 5475 |
| | | (d) | % | 22.3% | 6.0% | 28.3% |
| | Sum | (e) | N | 16,400 | 2921 | 19,321 |
| | | (f) | % | 84.9% | 15.1% | 100.0% |
| Total Hosts/Nominators * | | (g) | N | 7431 | 1670 | 9101 |
| | | (h) | % | 81.7% | 18.3% | 100.0% |

* The total hosts/nominators equal the data displayed in Table 3.

To measure behavioral homophily, we must compare the observed values shown in Table 4 and the values expected under random distribution. We calculated the expected values through marginal distribution with the following formula:

$$\text{Exp.}H_sA_s = \frac{A_s}{A_t} \times \frac{H_s}{H_t}$$

where s ∈ (m, w), H = hosts/nominators, A = applicants/nominees, w = women, m = men, and t = total.

For the hosts/nominators, we used the total number of hosts/nominators (row g) because this displays the actual number of people who were engaged as hosts/nominators. By contrast, the sum of hosts/nominators supervising male and female applicants (row f) contains some people several times due to being multi-hosts/nominators.

Table 5 displays the observed and expected values and the differences in percentage points.

**Table 5.** Collaborations within the Humboldt Fellowship and Humboldt Research Award programs by the sex of the host/nominator and the applicant/nominee: observed and expected values and the differences in percentage points (p.p.).

| | | **Hosts/Nominators** | | | |
|---|---|---|---|---|---|
| | | **Men** | | **Women** | |
| | | **Observed** | **Expected** | **Observed** | **Expected** |
| Applicants/Nominees | Men | 62.6% | 58.5% | 9.1% | 13.1% |
| | | 4.1 p.p. | | −4.1 p.p. | |
| | Women | 22.3% | 23.1% | 6.0% | 5.2% |
| | | −0.8 p.p. | | 0.8 p.p. | |

For the calculation displayed in Table 5, we used the gender distribution among those who applied or were nominated and those who acted as hosts/nominators as the base for expected values. As we assumed that gender-homophilous collaboration might be one reason for the under-representation of women in international collaborations, we looked for a reference group that represents those who might apply, be nominated, or act as a host/nominator: the potential pool. The reference to a potential pool assumes that women researchers should apply in the same share as male researchers. We took the percentage of women professors in Germany as a reference for the potential pool of hosts/nominators. However, as the Humboldt Foundation sponsors international researchers irrespective of nationality, and worldwide statistics on women researchers do not exist, we estimated the potential pool of international researchers based on data for 14 key countries and the EU-28. Table 6 displays the reference data.

**Table 6.** Reference data for the calculation of the expected values through marginal distribution.

| | |
|---|---|
| **Hosts/nominators** | |
| Professors in Germany, 2010–2019 | 22.4% women |
| **Applicants/nominees** | |
| Humboldt Research Award: grade A academic staff in higher education in 14 key countries * | 25% women (approximated value) |
| Humboldt Research Fellowship: academic staff, all grades in 14 key countries * | 40% women (approximated value) |
| Humboldt Research Award + Humboldt Research Fellowship: academic staff, all grades in 14 key countries * | 40% women (approximated value) |

* Algeria, Chile, Colombia, India, Mexico, Morocco, Netherlands, Nigeria, Poland, South Africa, Spain, Tunisia, United Kingdom, and USA. Source: (Löther et al. 2022, pp. 118–19).

Based on these data, we calculated the expected values for the potential pool in the same way as for the sample as a reference group (see Table 5). Table 7 displays the data.

**Table 7.** Collaborations within the Humboldt Fellowship and Humboldt Research Award programs by the sex of host/nominator and the applicant/nominee: observed and expected (potential pool) values and the differences in percentage points (p.p.).

| | | Hosts/Nominators | | | |
|---|---|---|---|---|---|
| | | Men | | Women | |
| | | Observed | Expected | Observed | Expected |
| Applicants/Nominees | Men | 62.6% | 46.6% | 9.1% | 13.4% |
| | | 16.0 p.p. | | −4.4 p.p. | |
| | Women | 22.3% | 31.0% | 6.0% | 9.0% |
| | | −8.7 p.p. | | -2.9 p.p. | |

To analyze if research collaborations are gender-homophilous more often than expected under random distribution, and to test H1, we use the kappa-coefficient that J. Cohen (1960) initially created to measure inter-rater reliability, but which was already used to measure homogamy (Lengerer 2001). Kappa normalizes the difference between observed and expected values so that the values lie between −1 and +1. The value 0 indicates that the expected and observed values match. Kappa is calculated as follows:

$$\text{Kappa (K)} = \frac{(O_m + O_w) - (E_m + E_w)}{1 - (E_m + E_w)}$$

where O = observed percentages of same-sex collaborations, E = expected percentages, m = man–man collaboration, w = woman–woman collaboration.

We calculate the kappa-coefficient for the sample ($K_1$) and for the possible pool ($K_2$) and also calculate standard errors using the formula described by Fleiss et al. (1969).

As a further estimation of the prevalence of behavioral homophily and to test hypothesis H1, we computed a dissimilarity index (Duncan and Duncan 1955) separately for hosts/nominators ($DI_H$) and applicants/nominees ($DI_A$) to measure the percentage of persons who would have to switch to a different collaboration partner in order to achieve a gender balance.

$$DI_H = \frac{1}{2}\sum_i \left| \frac{H_{wi}}{H_w} - \frac{H_{mi}}{H_m} \right| = \frac{1}{2}\left( \left| \frac{H_{wAw}}{H_w} - \frac{H_{mAw}}{H_m} \right| + \left| \frac{H_{wAm}}{H_w} - \frac{H_{mAm}}{H_m} \right| \right)$$

with i ∈ (Aw, Am).

$$DI_A = \frac{1}{2}\sum_i \left| \frac{A_{wi}}{A_w} - \frac{A_{mi}}{A_m} \right| = \frac{1}{2}\left( \left| \frac{A_{wHw}}{A_w} - \frac{A_{mHw}}{A_m} \right| + \left| \frac{A_{wHm}}{A_w} - \frac{A_{mHm}}{A_m} \right| \right)$$

with i ∈ (Hw, Hm), H = host/nominators, A = applicants/nominees, w = women, and m = men. $H_{wAw}$, for example, means women hosts/nominators with women applicants/nominees.

Because of the calculation formula, it is impossible to use the potential pool of women researchers for the dissimilarity indices.

To analyze if male researchers are more often in a gender-homophilous research collaboration than female researchers, and to test H3, we created an indicator GD which calculates the difference in the differences between observed and expected man–man collaborations and observed and expected woman–woman collaborations in percentage points:

$$GD = (O_m - E_m) - (O_w - E_w)$$

We calculate this indicator similarly to the kappa-coefficient using the sample ($GD_1$) and the possible pool ($GD_2$) as a reference group.

Table 8 provides an overview of all of the indicators.

**Table 8.** Overview of the indicators.

| Indicator | Explanation |
|---|---|
| $K_1$ | Kappa-coefficient calculated within the sample |
| $K_2$ | Kappa-coefficient calculated with reference to the potential pool of women researchers |
| $DI_H$ | Dissimilarity index for hosts/nominators |
| $DI_A$ | Dissimilarity index for applicants and nominees |
| $GD_1$ | Gender differences in behavioral homophily calculated within the sample |
| $GD_2$ | Gender differences in behavioral homophily calculated with reference to the potential pool of women researchers |

To analyze factors influencing gender-homophilous collaboration and to test H2, we calculated, in the first step, the presented indicators by program and field of science. However, an analysis that combines program category and field of science was not feasible because of the small number of cases in some cells of the Humboldt Research Award program.

We used a binary logistics regression model to study the influencing factors in detail and further test hypothesis H2. The binary dependent variable, gender-homophilous collaboration, had the value 1 if the sex of the academic host/nominator matched that of the applicant/nominee and 0 if the sex of the host/nominator and the applicant/nominee differed. The data used to estimate the influence of the field of science, region of origin, or career stage were issued from the data set itself. To estimate the influence of the institutions, we added two institutional variables linked to the data set by the name of the host institution. Although data on the share of women professors in Germany are available for individual universities, corresponding data for non-university research institutions are available only when clustered in larger associations of research institutions, such as the Max Planck Society or the Helmholtz Association. We created a dummy variable for research-intensive institutions, with a value 1 for (a) universities that received funding under the German Excellence Initiative (2006/2007 and 2012–2017) or its successor program, the German Excellence Strategy (2018); and (b) research institutions that received European Research Council (ERC) synergy grants in 2012, 2013, 2018, or 2019; all other institutions were assigned the value 0. In total, 62.5% of the hosts/nominators were classified as members of research-intensive institutions; of these, 18.5% were women. Because many hosts/nominators supervised multiple applicants/nominees, and some data are available only in clusters rather than on the institutional level, the variance in the institutional variables was low. The third institutional variable, a dummy variable for multi-hosts/nominators, approximated the host's/nominator's academic experience. The variance of this variable was also low.

The following regression equation for the binary logistics regression model includes seven independent variables to test for influencing factors in the probability of gender-homophilous collaborations, listed in Table 9.

$$\ln\left(\frac{p}{1-p}\right) = \beta_0 + \beta_1 x_1 + \beta_2 x_2 + \beta_3 x_3 + \beta_4 x_4 + \beta_5 x_5 + \beta_6 x_6 + \beta_7 x_7 + u$$

We calculated the average marginal effects with robust standard errors in Stata and assessed model quality through pseudo-R-squared and the classification matrix. In Stata, pseudo-R-squared, according to McFadden, is given by default. However, McKelvey–Zavoina pseudo-R-squared performed best in mimicking R-squared in binary logistic models (Veall and Zimmermann 1994). Both estimates—0.331 (McFadden) and 0.40 (McKelvey–Zavoina)—showed a relatively high pseudo-R-squared. For the calculation of the classification matrix, the model was used to predict the outcome of the dependent variable for each case in our data set. The comparison of the expected and actual values showed that 85% of the cases were correctly classified.

We chose a binary logistics regression model for the analysis. A linear probability model with the same variables produced similar results. The variance inflation factor (VIF) in the linear probability model showed a small linear correlation between the independent variables (VIF between 1 and 3.3). We checked the robustness of the model by changing the reference group of the field of science, which produced different results for statistical significance. Regarding the institutional variables, the same model was calculated for the percentage of women researchers in the institution rather than the percentage of women professors, with no changes in the results.

**Table 9.** Independent variables of the regression analysis of collaborations.

| Variable | Description | Reference Category |
|---|---|---|
| p | Probability of gender-homophilous collaboration | |
| $x_1$ | Sex of the applicant | Female |
| $x_2$ | Field of science of the applicant/nominee | Social sciences and humanities |
| $x_3$ | Region of residence of the applicant/nominee at time of application/nomination | North America |
| $x_4$ | Program category (Humboldt Research Award, Humboldt Research Fellowship (postdoctoral researchers), Humboldt Research Fellowship (experienced researchers) | Humboldt Research Award |
| $x_5$ | Institutional variable: percentage of women professors at German universities | |
| $x_6$ | Institutional variable: dummy variable research-intensive institutions | Research-intensive institutions |
| $x_7$ | Institutional variable: dummy variable multi-hosts/-nominators | Not multi-host/-nominator |
| u | Error term | |

## 4. Results

Table 10 shows the results for all indicators.

**Table 10.** Kappa-coefficient, dissimilarity indices, and gender difference indicator.

| | $K_1$ | $K_2$ | $DI_H$ | $DI_A$ | $GD_1$ | $GD_2$ |
|---|---|---|---|---|---|---|
| HPT + HFST | 0.135 (0.0001) | 0.295 (0.0001) | 0.137 | 0.086 | 3.2 | 18.9 |
| **By program** | | | | | | |
| HPT | 0.161 (0.0012) | 0.496 (0.0007) | 0.129 | 0.137 | 0.9 | 23.5 |
| HFST (P+E) | 0.129 (0.0001) | 0.269 (0.0001) | 0.134 | 0.083 | 3.2 | 17.3 |
| **By field of science** | | | | | | |
| Social sciences and humanities | 0.131 (0.0002) | 0.241 (0.0002) | 0.137 | 0.106 | 3.1 | 20.3 |
| Life sciences | 0.067 (0.0003) | 0.201 (0.0002) | 0.082 | 0.052 | 2.0 | 15.5 |
| Natural sciences | 0.096 (0.0002) | 0.317 (0.0002) | 0.065 | 0.037 | 2.6 | 15.9 |
| Engineering | 0.114 0.0007) | 0.230 (0.0006) | 0.089 | 0.041 | 2.4 | 7.4 |

$K_1$ = Kappa-coefficient within the sample; $K_2$ = Kappa-coefficient calculated with reference to the potential pool of women researchers; in brackets = standard errors; $DI_H$ = dissimilarity index for hosts/nominators; $DI_A$ = dissimilarity index for applicants and nominees $GD_1$ = gender differences in behavioral homophily calculated within the sample; $GD_2$ = gender differences in behavioral homophily calculated with reference to the potential pool of women researchers; HPT = Humboldt Research Award; HFST = Humboldt Research Fellowship; (P+E) = postdoctoral researchers and experienced researchers.

### 4.1. Prevalence of Gender-Homophilous Research Collaborations

The kappa-coefficient of 0.135 taken for both programs indicates that observed values deviate only slightly from the expected values and thus points to a small effect of behavioral homophily. The dissimilarity indices for hosts/nominators and applicants/nominees showed a slightly different picture: To eliminate gender differences, 13.7% of the hosts/nominators would have had to switch to an applicant/nominee of the other sex, and 8.6% of the applicants/nominees would have had to change host/nominator. Comparing this with the dissimilarity index on the horizontal segregation of European researchers (European Commission 2021a, p. 117), we might also estimate the dissimilarity index for gender-homophilous research collaborations as low: in 60% of the 42 countries included in the comparison, between 15% and 25% of researchers would have had to change their field of science to achieve gender balance.

The results of our analysis for the kappa-coefficient $K_1$ and the dissimilarity indices might suggest that the patterns of research collaboration are an effect of compositional rather than behavioral homophily. However, $K_2$, which was calculated with reference to the potential pool of women researchers, lies at 0.295 and indicates that gender-homophilous collaborations were higher than expected by chance. Compared with the potential pool of women researchers, we found a medium level of behavioral homophily, and H1 was confirmed.

### 4.2. Factors Influencing Gender-Homophilous Research Collaborations

The detected behavioral gender homophily might be linked to other factors that explain same-sex collaborations. When we control for these influencing factors in a binary logistic regression analysis, the difference of 66 percentage points between 87.3% of the male applicants/nominees and 21.3% of the female applicants/nominees engaged in a same-sex collaboration decreased to 65 p.p. (see Table 11). Across all individuals (average marginal effects), the probability of gender-homophilous collaboration was 65.0 p.p. higher for male applicants/nominees than for females. This effect was statistically significant.

The first influencing factor under review is the research field of the applicant/nominee with varying proportions of women. The highest Kappa-coefficient $K_1$ and the highest dissimilarity indices were in social sciences and humanities (see Table 10), whereas $K_2$, which takes the potential pool as the reference group, was the highest in natural sciences. Comparing social sciences and humanities with life sciences demonstrates that the prevalence of gender-homophilous collaborations was not linked to the percentage of female researchers in a particular field. Although the ratio of female researchers is the same in both fields, all indicators are smaller for life sciences than for social sciences and humanities. Given these findings, we anticipated a negative effect on the field of science when choosing humanities and social sciences as the reference group in the regression analysis. The probability of gender-homophilous collaborations should be smaller in the three fields compared to humanities and social sciences. The results for the field of science show a small and partly insignificant effect size (see Table 11). On average, the probability for same-sex collaborations was 3.7 p.p. higher for applications in engineering, 1.6 p.p. lower for applications in life sciences, and insignificant for applications in natural sciences compared with applications in the social sciences and humanities. Like the indicator's analysis, the results of the regression analysis are inconsistent. Taking engineering, the field with the lowest percentage of women, as a reference group, all other fields of science had a significantly lower probability for gender-homophilous collaboration. These results are unexpected and unclear, indicating the need for further analysis. However, the differences between the fields of science were not so large that the values of any field counterbalanced those in the other fields. Thus, the Wahlund effects described by Holman and Morandin (2019) did not influence the overall prevalence of homophily.

**Table 11.** Regression results, logit regression (1), odds ratios (2), and average marginal effects (3).

| Variables | (1) Logit Coefficient | (2) Odds Ratio | (3) Average Marginal Effects |
|---|---|---|---|
| Sex of applicant/nominee = 0, applicant/nominee male | 3.195 *** (0.0439) | 24.41 *** (1.071) | 0.650 *** (0.00673) |
| Field of science = 1, engineering | 0.296 *** (0.0737) | 1.345 *** (0.0991) | 0.0367 *** (0.00917) |
| Field of science = 2, life sciences | −0.123 * (0.0674) | 0.884 * (0.0596) | −0.0161 * (0.00880) |
| Field of science = 3, natural sciences | 0.0887 (0.0585) | 1.093 (0.0639) | 0.0113 (0.00747) |
| Region of origin of applicant/nominee = 1, Europe | −0.105 (0.0669) | 0.901 (0.0603) | −0.0131 (0.00836) |
| Region of origin of applicant/nominee = 2, Australia, New Zealand, Oceania | 0.171 (0.141) | 1.187 (0.167) | 0.0208 (0.0169) |
| Region of origin of applicant/nominee = 3, Near and Middle East, North Africa | −0.394 *** (0.115) | 0.675 *** (0.0778) | −0.0514 *** (0.0155) |
| Region of origin of applicant/nominee = 4, Central and South America | −0.0344 (0.0945) | 0.966 (0.0913) | −0.00429 (0.0118) |
| Region of origin of applicant/nominee = 5, Asia | 0.0145 (0.0686) | 1.015 (0.0696) | 0.00179 (0.00849) |
| Region of origin of applicant/nominee = 6, Sub-Saharan Africa | −0.280 (0.182) | 0.756 (0.138) | −0.0359 (0.0241) |
| Program category = 2, Humboldt Research Fellowship (postdoctoral researchers) | −0.170 * (0.0880) | 0.844 * (0.0743) | −0.0209 * (0.0107) |
| Program category = 3, Humboldt Research Fellowship (experienced researchers) | −0.198 ** (0.0955) | 0.820 ** (0.0783) | −0.0245 ** (0.0117) |
| Proportion of female professors at institution | −0.00511 (0.00388) | 0.995 (0.00386) | −0.000640 (0.000487) |
| Research-intensive institution = 0, not research intensive | −0.0139 (0.0432) | 0.986 (0.0426) | −0.00174 (0.00542) |
| Multi-host/-nominator = 1, multi-host/-nominator | 0.0336 (0.0498) | 1.034 (0.0515) | 0.00421 (0.00626) |
| Constant | −0.985 *** (0.152) | 0.374 *** (0.0569) | |
| N observations | 18,708 | 18,708 | 18,708 |

Note. Standard errors in parentheses. *** $p < 0.01$; ** $p < 0.05$; * $p < 0.1$.

To analyze the influence of the level of experience on the probability of homophily, the program categories serve as a proxy, because the Humboldt Research Award program addresses internationally recognized researchers at an advanced career stage, and the Humboldt Research Fellowship addresses postdoctoral and experienced researchers. The theoretical reflection suggests that leading researchers should be more independent of the gender of the host/nominator than those at less advanced career stages, and therefore, early-career researchers should have a higher probability of gender-homophilous collaboration than internationally recognized researchers. The Kappa-coefficients $K_1$ and $K_2$ contradict this assumption. Especially, $K_2$, which considers the potential of women scientists, indicates that behavioral homophily is prevalent to a much higher extent in the program for advanced researchers (0.496 vs. 0.269). Taking the potential pool as the reference group, male researchers in the Humboldt Research Award tend much more to gender-homophilous research collaborations than their colleagues in the program for

early-career and experienced researchers. The results of the regression analysis support these observations. The effect of career stage was significant at the 5% level and was small overall. Early-career researchers had a lower probability of gender-homophilous collaboration than internationally recognized researchers. On average, the probability for same-sex collaborations was 2.1 p.p. lower for applicants for the Humboldt Research Fellowship (postdoctoral researchers) and 2.4 p.p. lower for applicants for the Humboldt Research Fellowship (experienced researchers) than for nominees for the Humboldt Research Award.

We further assumed that the applicant's region of residence would be another influencing factor. However—except for the region "Near and Middle East, North Africa", where the probability of same-sex collaborations was 5.1 p.p. lower than in North America—the regression showed no statistically significant effect for regional origin. The institutional variables (percentage of female professors, research-intensive institution, multi-host/-nominator) in the data set had the limitation of low variance. This might explain why no institutional variables statistically significantly affected the probability of gender-homophilous collaboration (see Table 11). Nevertheless, the direction of the effect on the proportion of female professors at the institutions is interesting. The probability of gender-homophilous collaboration decreased by 0.064 p.p. when the proportion of female professors increased by 1 p.p: Institutions with a higher proportion of women professors may encourage more cross-gender collaborations between hosts/nominators and the applicants/nominees.

The results of the regression analysis and the observed prevalence of homophily in the sample did not fully confirm hypothesis H2, which posited that the international researcher's field of science, regional origin, and career stage, and the host's/nominator's institutional background, would significantly influence the extent of gender-homophilous collaborations. The data on the fields of science are inconsistent and need further investigation. Contrary to theoretical expectations, our results revealed that advanced researchers are more likely to engage in same-sex collaborations than their younger colleagues. Conversely, the region of origin and the institutional variables included in our model did not demonstrate a significant impact on the likelihood of same-sex collaborations.

### *4.3. Gender Inequalities in Gendered-Homophilous Research Collaboration*

Looking at the prevalence of homophily among men and women ($GD_1$, see Table 10), in both programs and in all fields of science, men tended more towards homophilous collaboration than did women. Overall, the difference between observed and expected values of man–man collaborations exceeded that of woman–woman collaborations by 3.2 p.p. This figure increased to 19 p.p. ($GD_2$) when taking the potential pool of women scientists as the reference group. Social sciences and humanities display the highest differences, both when considering the sample and the potential pool of women scientists (3.1 and 20.3 p.p.). The small number of women scientists in the Humboldt Research Award program affects the indicator GD, resulting in a small value for $GD_1$ compared to the Humboldt Research Fellowship. However, the indicator increased significantly (0.9 and 23.5 p.p.) when taking the potential pool as the reference group. We can conclude that men tend more towards gender-homophilous collaboration than women do, and hypothesis H3 is confirmed.

## 5. Conclusions and Discussion

Our analysis showed ambiguous results regarding the prevalence of gender homophily among applicants for the Humboldt Foundation Research Fellowship and nominees for the Humboldt Foundation Research Award. Taking the applying or nominated international researchers as the reference group, gender-homophilous research collaborations were caused by the gender ratios in the sample (compositional homophily). However, taking the potential pool of women researchers as the reference, we detected behavioral homophily: Gender-homophilous research collaborations were due to (conscious or unconscious) decisions made by the researchers. Our data show clearly that men tended more

toward gender-homophilous collaborations than women did, while previous studies were inconsistent about this question.

Our findings align with previous bibliometric studies on the prevalence of behavioral homophily but uniquely apply the concept to the context of international academic mobility, offering a first-time nuanced analysis that distinguishes between compositional and behavioral homophily. This transfer pushed us to reflect on the reference group. The high prevalence of homophilous research collaborations, particularly when using the potential pool of women scientists as a reference, suggests that homophilous networks, in which men primarily have other men on their radar, may contribute to the under-representation of women in international academic mobility.

Regarding factors that influence the extent of gender homophilous collaborations, our analysis indicates that career stage and field of science are influencing factors. However, the influence of fields of science needs further investigation, as our results for this variable were ambiguous. Especially, the high amount of behavioral homophily in social sciences and humanities is worth further analysis and aligns with Holman and Morandin's findings of stronger homophily in journals with a balanced or female-biased gender ratio (Holman and Morandin 2019, p. 5). Our findings about career stage—recognized researchers tending more towards homophilous research collaboration than researchers in earlier career stages—are inconsistent with previous studies, and there is a need for more studies to obtain a consistent picture. Furthermore, although the results of our analysis indicate that institutional characteristics are not influencing factors, the low variance in these variables may have caused this finding. Institutional characteristics remain interesting topics for understanding gender homophily in research collaborations.

Detecting behavioral gender homophily in research collaborations and international academic mobility indicates that the decision to accept or nominate an international researcher for funding from the Humboldt Foundation or to choose a researcher in Germany as a host is at least partly influenced by gender stereotypes and biases. Understanding the underlying mechanisms requires further and mostly qualitative studies. Relating our results to knowledge about gender disparities in academic recognition and social and cultural capital can indicate the direction that further research should take. Gender bias in the visibility and recognition of women scientists may influence the perception of international women researchers as potential beneficiaries, as well as the perception of women professors as potential hosts/nominators (Aufenvenne et al. 2021; Duma et al. 2019; Herschberg 2019; Herschberg et al. 2015; Leslie et al. 2015). Furthermore, the gendered impact of networks may also affect the decision to supervise an international woman researcher or to choose a woman professor as a host. These gendered impacts consist of fewer citations of articles written by women than those written by men (Chatterjee and Werner 2021; Dion et al. 2018; Sá et al. 2020; Wang et al. 2021) and a higher appreciation of male contacts (Queupil and Muñoz García 2019). Thus, collaborations and networks with men may provide more social and cultural capital, explaining why men tend more towards gender homophily.

Putting these results into Shen et al.'s (2022) framework of international academic mobility and the global knowledge system shows that knowledge agents not only shape "knowledge acquisition, transfer, and circulation", "knowledge production", "transnational knowledge networks", and "science diplomacy" (p. 1325), but that in turn these structures affect gendered structures of international academic mobility. The results of the present study indicate that the under-representation of women in international academic mobility in post-PhD stages is linked to gender homophily in research collaborations. Studying the effect of gender and other inequalities in the different knowledge structures on international collaborations might help understand the mechanisms leading to the analyzed preferences. Finally, our results suggest that exploring the role of receiving researchers and institutions is crucial to understanding—and overcoming—the under-representation of women in international academic mobility.

The limitation of this paper lies, first, in the binary conception of sex categories due to data availability. People beyond a binary gender identity might experience specific

exclusion in seeking international research collaborations, but we could not integrate this perspective into this paper. In addition, and despite our efforts to analyze influencing factors, data on race or class were not available, and thus intersectional analysis combining gender with race or class inequalities was not possible. This causes further limitations to this paper.

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