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International research collaboration among women engineers: frequency and perceived barriers, by regions

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Abstract International research collaboration is on the rise—and at the same time, women face potential barriers. Based on responses to surveys conducted among groups of women engineers, this article addresses (1) women's frequency of international research collaboration; (2) the barriers to collaboration reported for both self and for other women; and (3) the patterns among women students as well as professionals, by national regions. Findings of this study have implications for policies to broaden participation in the increasingly important arena of international research collaboration, based on women in engineering, the scientific field in which women are most underrepresented. This makes the case focal for the study of women, science, and policy.

Keywords Women · Research collaboration · International · Engineering · Science · Policy

JEL Classification O32 · O35 · O38

1 Introduction

International research collaboration is on the rise. The National Science Board (2012) estimated that the percentage of the world's publications with international research coauthors was 8 % in 1988, and by 2012, 23 %. A study, based on 14 million Web of Science documents (not limited to sciences), found that multi-national collaborations accounted for 14 % of total articles in 2000, rising to 18 % in 2009 (Gazni et al. 2012).

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However, international research collaboration varies by national regions. The propensity for international research collaboration has been stronger in smaller, compared to larger, countries (Frame and Carpenter 1979); countries with less developed scientific infrastructures (Glanzel 2001; Jappe 2007; Luukkonen et al. 1992); and those actively seeking transitions to knowledge-intensive economies and increased scientific and technological capacities (Luukkonen et al. 1992; National Science Board 2012).

At the individual-level, gender also shapes patterns of international research collaboration. Data from the US National Science Foundation's (2006) Survey of Doctoral Recipients indicate that 33 % of men, compared to 23.5 % of women, had experience with international research collaboration (Frehill and Zippel 2010). Studies of European scientists report that, compared to men, women are less likely to coauthor articles with those outside their own countries (Abramo et al. 2013; Caprile et al. 2012; Larivière et al. 2013; Prpić 2002). Notably, this gender disparity in international research collaboration exists despite small differences between women and men scientists in their probabilities of collaborating (coauthoring articles)[1] with others in their own national regions (Abramo et al. 2013; Bozeman and Gaughan 2011; Corley 2005; Smykia and Zippel 2010), which, in turn, reflects the predominance of collaborative (compared to solo) research in scientific fields (Beaver 2001; Bozeman et al. 2013; Fox and Mohapatra 2007).

Challenges can exist for international research collaboration particularly, and these are consequential in systems of science and engineering that put a premium on international collaboration as a metric of "excellence" and "quality," as does the European Commission's European Research Area (European Commission 2007). Further, impediments to international research collaboration hamper advancement within a wide range of institutions that use "international reputation," linked potentially to international research collaboration, as a criterion for promotion (Smykia and Zippel 2010). Relatedly, articles with international authors tend to have higher citations than those with authors from a single nation (Abramo et al. 2011; Glanzel and de Lange 2002), and barriers to international collaboration could be notable for research impacts achieved (although some debate exists on this [Bozeman et al. 2013]).

Given these issues, we address the following questions about international research collaboration among women engineers who were respondents to on-line surveys, conducted in 2009–2012 as part of their applications to participate in summits on collaboration and gender equity. First, what is the frequency of international research collaboration that these women engineers report, and how does the frequency vary by region (US, Europe, nations outside US and Europe)? Second, what are the barriers to international research collaboration that the women engineers perceive/report to be important both for themselves and for other women in their home institutions? How do the patterns vary by region and status as professionals compared to students? These questions are at the level of the individuals in Bozeman's et al. (2013) framework of studies of research collaboration. In keeping with their emphasis on "context" needed, but frequently absent, in studies of individuals' collaboration, we address key patterns by national regions of the respondents (as well as their status/stage), and implications of the findings for effective policies.

This article is one of the few (or sole) inquiries about international research collaboration among women engineers. Engineering is at the center of the development and applications of technology, with implications for data banks, energy and environmental

[1] Coauthorship is a common indicator of collaboration, but other forms of collaboration exist that result in knowledge creation, including technologies, patents, and software (Bozeman et al. 2013; Katz and Martin 1997).

controls, housing, irrigation, and health care (Garrison 1991; Grayson 1993), and for societies broadly (Mackenzie and Wajcman 1999; Silim and Crosse 2014). Yet, in numbers of nations, women are more under-represented in engineering than in any other scientific field (UNESCO Institute for Statistics 2011). In an analysis of fields of study in 44 nations, Charles and Bradley (2009) find that women are more under-represented in engineering than in fields including mathematics, natural sciences, social sciences, and health. This makes women engineers a focal group for efforts to heighten participation in science (Mattis 2007; Silim and Crosse 2014). Our study's particular focus is warranted because of the importance of engineering fields; women's under-representation in these fields; previous research that points to lower international research collaboration among women scientists; and implications of the findings for policies to enhance participation in the increasingly important global arena. In short, although we lack a comparable male sample for the study, the findings inform understandings of patterns and perceptions on international research collaboration among women engineers, who constitute an important group for the study of women, science, and policy.

Our extensive review of the literature on international research collaboration, specifically, has pointed to key potential barriers (or conversely, facilitators): (1) funding, (2) finding collaborators, (3) communications, (4) managing personal/family commitments, (5) managing work commitments (obligations in the place employed), and (6) time commitments to initiate/conduct the collaboration.

First, funding is essential for international projects and it is a crucial component for agencies promoting international collaboration (Wagner 2006) and for institutions planning to promote internationalization (Childress 2010). Thus, funding appears consistently in the literature as a potential driver for research collaboration that crosses national boundaries, and lack of funding is a significant barrier (Jeong et al. 2014). Second, locating research partners is essential to the human resources involved in international research collaboration (Bozeman et al. 2013), and finding collaborators across distant regions is recognized as a potential challenge (Hennemann et al. 2012; Jeong et al. 2014). Third, active communications are a notable dynamic. Even with the Internet and forms of technology, collaborations tend to begin with face-to-face meetings at conferences or research sites (Wagner and Leydesdorff 2005), and continuing communication supports international collaboration (Jeong et al. 2014). Correspondingly, absence of this communication may impede collaboration (Ynalvez and Shrum 2011). Fourth, home and work conflict can shape international research collaboration through constraints on geographic mobility, and in turn, international collaboration (Ackers 2008). This is because household and family demands can make geographic mobility difficult to manage, especially if the mobility is a more ongoing, compared to temporary, arrangement (Ackers 2008). Fifth and sixth, work commitments and time commitments—dedicated to research goals and expectations—are demanding as well in international research collaboration (Bagshaw et al. 2007; Jeong et al. 2014; Peterson 2009). Bringing people together around a shared research topic does not result in collaboration without considering commitments of work and time (Bagshaw et al. 2007).

In these ways, international research collaboration is subject to challenges and opportunities of human and material resources that exist in research collaboration, broadly (Bozeman et al. 2013; Fox and Faver 1984; Katz and Martin 1997; Lee and Bozeman 2005). But barriers to collaboration are compounded when the research involves scientists from different countries, regions, and educational systems (Bagshaw et al. 2007). Gaughan (2006) points to the importance of understanding "barriers to participation" for women in science. Our study, focusing on perceived barriers to international research collaboration,

does this and also distinguishes between the levels of importance of barriers that women engineers report for themselves compared to other women in their home institutions. This is a nuanced and consequential distinction. Research indicates that self-evaluations evolve in a process of oneself compared to others (Brown 1986). People assign more "positive attributions" for themselves, and this is especially likely to occur among persons with relatively high esteem (Brown 1986) and with higher socio-economic status (educational, occupational levels). This issue is applicable for engineers, who tend to have high levels of self-esteem (Twenge and Campbell 2002). Finally, the less ambiguous the attribute being assessed, the smaller the difference in evaluations for self compared to others (Brown 1986). For these reasons, we expect three patterns for barriers reported for self-others: (1) that differences between assessments of the importance of barriers for self and others will occur among women engineers; (2) that, given the relatively strong sense of esteem that exists in the identities of women scientists who are "exceptional" for their gender (Ellemers et al. 2004), barriers will tend to be reported as more important for other women than for selves; and (3) that gaps between reported importance for self and others for barriers of funding and finding collaborators (the least ambiguous barriers) will be smaller than for family/personal issues (the more ambiguous barriers).

Thus, this article contributes to understandings of international research collaboration by (1) focusing on the frequency of this collaboration among women in engineering, a field that is important for broadening scientific participation; (2) addressing barriers perceived to exist in international collaboration among this group; (3) distinguishing between barriers perceived for self compared to other women; (4) investigating patterns as they vary by regions, as well status of professionals compared to students; and (5) considering the implications of the findings for policies for broadening participation in the increasingly critical international arena.

2 Methods

2.1 Data

The data are from three on-line surveys (2009, 2011, 2012), conducted as part of three waves of international summits for women engineers focusing on gender equity and research collaboration. In keeping with the protocol of the institutional review board at the institution at which the surveys were conducted, the completion of the survey was optional for submitting an application for participation in the summits. However, 76 % of women who applied[2] (across the three waves) responded to the survey, thus constituting a strong response rate.

The data available suggest that being married and that having children were not impediments to applying and intending to participate. Specifically, questions on family status appeared in the survey for the third summit (not in the surveys for the prior two summits). For those who answered the questions on family status in this third survey, 60.2 % report being married, and 50.2 % report having children. Respondents to the surveys include those who eventually did and did not attend summits.

The summits were advertised in a range of ways. A website of the summit was available, and deans of a span of engineering colleges (or their equivalents) were contacted to

[2] Of the 915 persons who applied, duplicate replies and surveys were removed (to the extent identified/known) and (4) replies and surveys of men were removed for this present analysis focusing on women.

advertise the summit to their faculty. Trifold informational flyers were distributed at professional conferences ranging from the American Society of Mechanical Engineers (ASME) to the European Commission's Information and Computer Technology (ICT). In addition, the National Science Foundation and the European Centre for Women in Technology identified principal investigators and co-investigators in focal engineering areas who, in turn, were sent the information (that included applications) for the summits.

Of the (689) women respondents to the surveys, 78.7 % were from the United States (US) or US territories, 12.2 % from European nations, and 9.0 % from other regions (Africa, Americas, Asia, Australia and Oceania, with one respondent not indicating region). Among these (689) women respondents, 69 % were non-students and 31 %, students. The students were in both doctoral and master's programs. The professionals include those presumably with doctoral degrees, particularly for the 91 % of all professional-level respondents located in academic institutions; but the survey did not contain a question on specific degrees attained. The relatively low proportions of respondents from regions outside of the US or Europe reflect, in part, the location of the first summit in Europe, the second in US, and a third scheduled for Europe—making costs and plans higher for applicants outside of Europe and US. The National Science Foundation provided funding (transportation, accommodations) for all US participants; and industry and university sponsors provided funding for many of the participants outside of the US.

For the analyses of this article, the responses are limited to 609 respondents (across the three waves of surveys) who answered each of the survey questions about the importance of six (6) barriers they face and the importance of barriers that they perceive for other women in their home institutions. Cases complete on the six barriers vary little by region of respondents (89 % are complete for US, 85 % for Europe, and 87 % for those outside of US and Europe).

Given that respondents are those who applied for participation in the summits, this group may be more interested in international research collaboration than women engineers, broadly. However, generalizability of findings among women engineers is enhanced by the inclusion of both students and professionals across engineering areas of sustainable energy and environments (25.2 %), simulation-based engineering/information technology (21.1 %), and nanotechnology/microtechnology (16.9 %), with the remainder of respondents in other engineering fields. The findings are more generalizable for those in academic, compared to industrial or government, settings, given that the students are in academic settings, as are 91 % of the professionals who are respondents.

2.2 Dependent variables

We assess *prior international research collaboration* with responses to the question about the frequency of experience with international research collaboration, specified in the survey as "joint research projects, research proposals or publications with persons outside one's home country." The response categories are: (1) "no prior international research collaboration," (2) "one or two," (3) "three or four," and (4) "five or more."

We assess *barriers to international research collaboration* with responses to a question about the extent to which respondents report the level of importance of six (6) barriers to international research collaboration for themselves and for other women in their current home institution. The question does not put limits on whether or not "other women in current home institution" are in scientific fields, so the reference point for "others" may vary to some extent.

The six barriers, as specified in the survey, are: (1) "identifying and finding funding to conduct international research collaboration"; (2) "finding collaborators who can contribute to the research by sharing students, collaborating on joint publications, and/or sharing

complimentary skills/expertise"; (3) "logistics in communications with collaborators (language and geographic challenges)"; (4) "managing personal and family responsibilities (child care, elder care, household responsibilities)"; (5) "managing work commitments (teaching, research, service obligations at home university"; and (6) "concern about time commitment to initiate and conduct international research collaboration." The response categories are a four-point scale of: "not at all," "slightly," "moderately," "very" important.

2.3 Independent/control variables

We assess *professional status* with response to questions[3] of whether a respondent is a graduate student or not a student, that is, a professional (faculty member, researcher, or other). Graduate students are an important group for inclusion because engineering work involves strong interdependencies between professionals and students in laboratories and because graduate students are training for futures in the fields.

Region is assessed through respondents' reports of country of address of current institution. These countries were coded into three categories: US and US territories, Europe, and not in Europe or the US.

2.4 Means of analysis

Tests of differences in values are assessed in three ways. Paired *t* tests assess the difference in values for paired observations; for example, differences between values (means) of a barrier to international research collaboration that respondents report for selves compared to others (see Note 2 in Figs. 3–5). Analysis of variance tests whether mean values for groups are equal or not; for example, differences in mean values of barriers to international research collaboration among groups in three regions. Chi square tests assess whether the distribution (counts) for a categorical variable differs between two or more groups; for example, whether the distribution of frequency of international research collaboration differs for respondents in three regions. Particular significance levels appear in the findings (without a single cut-off [e.g., .05] across tests). When the data are partitioned, the size of the groups/samples differ. Powers of tests relate to size of samples, as widely documented (see, for example, Henkel 1976; Tokunaga 2015). For these reasons, we forego a single cut-off point in reporting, and provide as much information as available in significance levels attained.

3 Findings

3.1 Frequency of international research collaboration

Among professionals (for cases complete on the variables = 423), the largest group (44.4 %) have one or two prior international collaborations; followed by 26.2 % with none; and 14.7 % with three or four, and 10.6 % with five or more[4] (Fig. 1).

[3] The form of this question varied somewhat between the three waves of application, but for each wave, the responses to the questions were checked and coded so that students were coded as "students" and those who were "not students" as professionals (types of ranks/positions).

[4] In Fig. 1, the residual bar is for self-reported responses that are not classifiable into the numeric categories of prior international research collaboration, represented by "at least one" (3.1 %) or "other" (0.9 %) with responses, for examples, of "discussed a project, some follow-up," "will teach an international course," and "did undergraduate education and thesis in Europe."

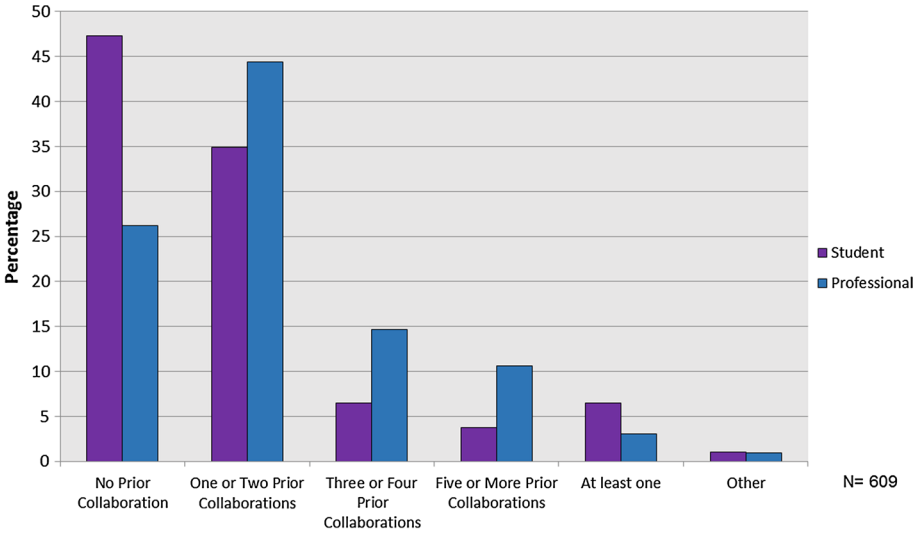

Fig. 1 Prior international research collaboration for students and professionals

Among students (for cases complete = 186), the largest group (47.3 %) report no prior international research collaboration, as we might expect. This is followed by 35 % with one or two, and 6.5 % with three or four and 3.8 % with five or more.

Experience with international research collaboration varies in interesting and significant ways with the geographic regions of the women engineers ($p < .000$). First, among professionals, women engineers in the US are more likely to report *no* international research collaboration than respondents in other regions. Close to 30 % (29.3 %) of the US women engineering professionals report none. This contrasts with 13.6 % of the professionals in Europe, and 15.9 % of those in nations outside US and Europe (Fig. 2).

Second, one or two prior research collaborations represent the most common pattern among the women engineering professionals in US and among those outside of US and Europe—with 44.8 % in US and 59.1 % outside US and Europe, respectively, reporting one or two. Higher frequencies of international research collaboration, on the other hand, are most prevalent among the women engineering professionals in Europe—with 20.5 % reporting three to four, and 34.1 %, five or more. In contrast, only 13.7 and 8.7 % of the US women engineering professionals report as many as three to four, or five or more, collaborations. Among those outside the US and Europe, only 15.9 and 2.3 % report these frequencies (Fig. 2).

Third, among students as well, frequency of prior international research collaboration varies by region ($p < .000$). The contrast, by regions, is most notable among students with none, compared to some, prior experience. The 51.4 % majority of the US student respondents and 80.0 % of the student respondents outside the US and Europe report *no* prior international research collaboration; while only 14.8 % of the European students report none (Fig. 2). Thus, among both students and professionals, international research collaboration is most prevalent in Europe. This may reflect the geographic proximity of European nations, the resulting ease of collaboration that is international within the European continent, and scientific research policies, as discussed in the conclusions.

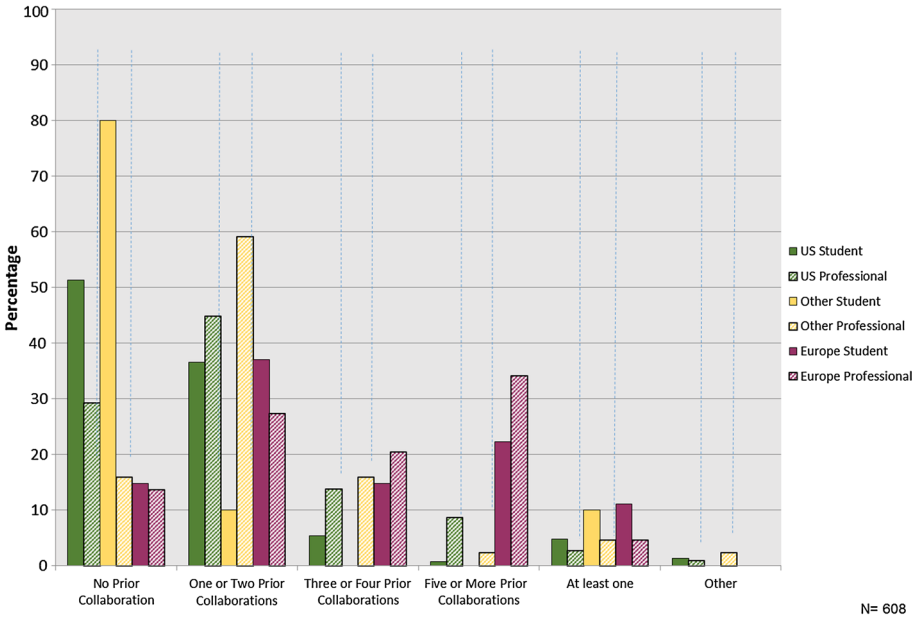

Fig. 2 Prior international research collaboration for students and professionals, by region

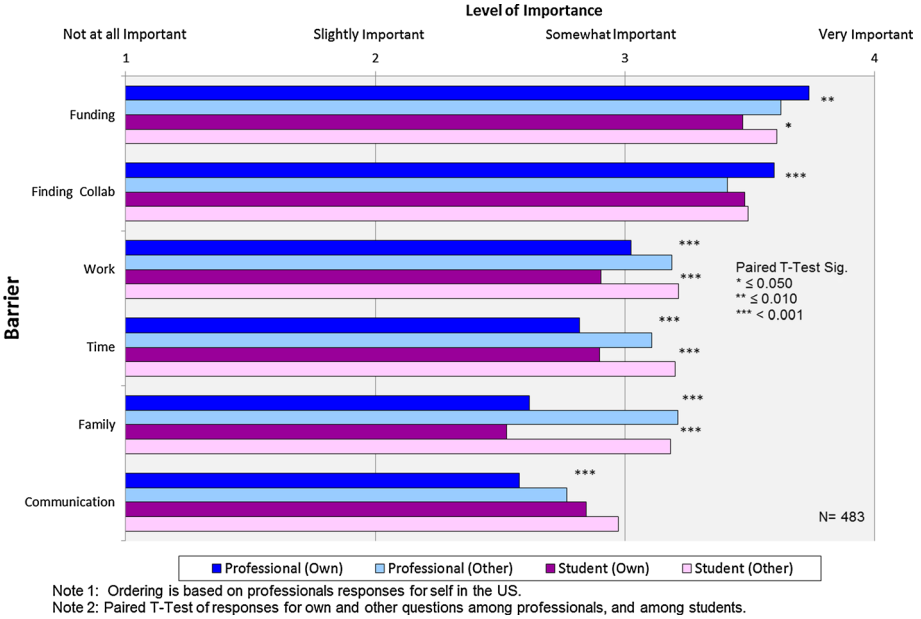

Fig. 3 Mean importance of barriers to international research collaboration, US

3.2 Reported barriers to international research collaboration

Given these patterns, what are the reported barriers to international research collaboration? Do the barriers that are reported/perceived vary by regions among these women engineers? Further, do the barriers reported for self differ from those perceived for other women in the respondents' home institution? More specifically, do these differences for self compared to others vary with the type of barrier and the region as well as status (professionals, students) within regions?

The average levels of importance that respondents in the regions report appear in Figs. 3–5. First, we see that among the women professionals in the US, two barriers stand out as the most important impediments to their own international research collaboration: (1) identifying and obtaining funding (mean = 3.74) and (2) finding collaborators (mean = 3.6; Fig. 3). These two barriers may be considered as relatively "external" to the respondents and less subjective than the other barriers.

On the other hand, the least important barriers for self among these US women professionals are (1) managing personal/family commitments (childcare, elder care, household responsibilities; mean = 2.62), and (2) and logistics in communicating with collaborators (mean = 2.58). These two barriers may be considered more "internal" to the respondent and more subjective than are funding and finding collaborators. In mid-range of importance are managing work commitments (mean = 3.02) and time commitments involved in initiating and conducting international research collaboration (mean = 2.82; Fig. 3).

Among the women engineering professionals in Europe and in countries outside Europe and US, the *order* of the importance of barriers (based on reports for self) follows closely the pattern found among those in the US. The highest ranking barriers are funding and finding collaborators, followed by work and time commitments, with family and communications as lowest ranking in importance (Figs. 4, 5). However, the *levels* of importance (mean values) vary by region, particularly for funding and finding collaborators; and they are lower than those reported for US women engineering professionals (Figs. 4, 5 compared to Fig. 3). An analysis of variance test shows difference between the three regions in mean levels of importance of these two leading barriers, funding ($p = .003$) and finding collaborators ($p = .04$). Further, the Tukey post hoc test points to significant difference in means ($p = .05$ or less) for importance of funding between US and European respondents, specifically, as well as between US respondents and those in regions outside Europe and US. This pattern repeats for the importance of finding collaborators.

Thus, across regions, respondents report that the two external barriers are the leading barriers to international research collaboration; however, the levels of importance are higher in the US than other nations. For students, likewise, the order of importance of the six barriers corresponds to that for professionals, except that communication is a more important barrier than family for students in US (Fig. 1) and in regions outside of US and Europe (Fig. 5). In addition, the two most important—and external—barriers of funding and finding collaborators are notably more important among students outside of US and Europe (Fig. 5). Finally, time commitments are reported to be a more important barrier (in level of importance) among US students (Fig. 3), compared to students in other regions (Figs. 4, 5). Communication is a relatively low barrier in Europe (Fig. 4); and family commitments are a particularly low barrier among students in nations outside of US and Europe (Fig. 5).

Second, these women engineers perceive barriers to international research collaboration differently for themselves compared to other women in their home institution. This is especially the case among the women engineering professionals in the US for whom the

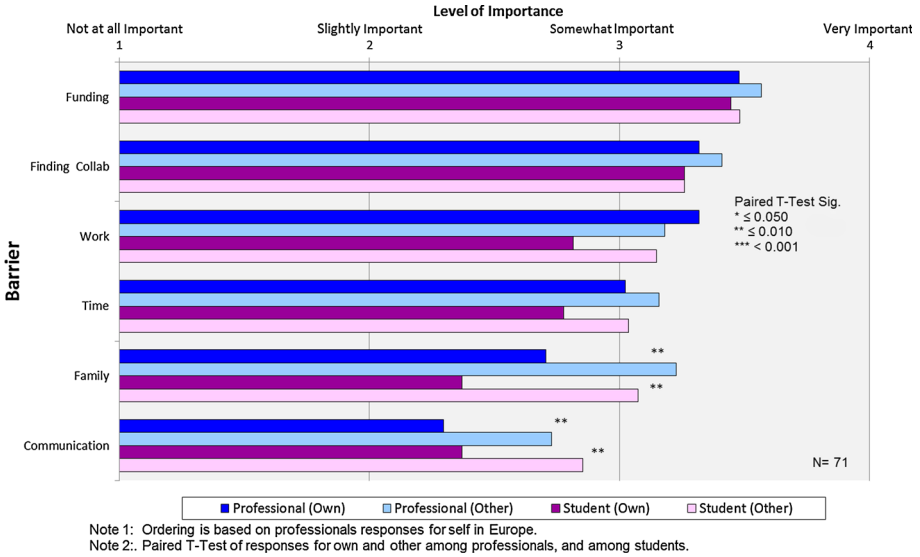

Fig. 4 Mean importance of barriers to international research collaboration, Europe

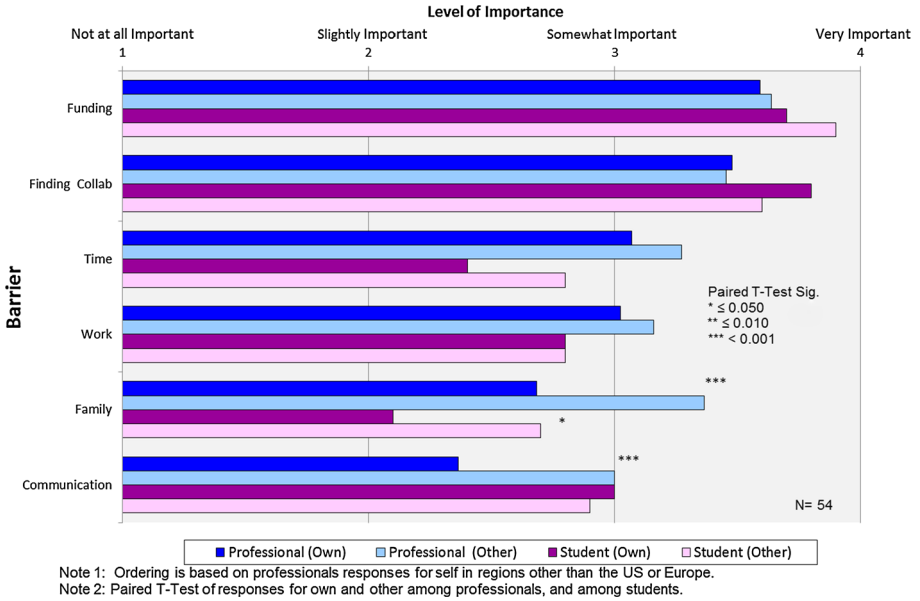

Fig. 5 Mean importance of barriers to international research collaboration, outside US and Europe

difference for self-other is significant ($p < .01$) for *each* of the six barriers (Fig. 3). For the majority—four out of six—of the barriers, the US women engineering professionals report that these barriers to international research collaboration are *more important* for other women in their home institution that for themselves. This is the case for work commitments, time commitments, family/personal concerns, and communication. The greatest

difference reported for self-other is for the personal/family concerns. On the other hand, for the more external barriers, namely funding and finding collaborators, the US women engineers report these to be *less* important for others than for themselves (Fig. 3).

Among the women engineering professionals in Europe, in contrast, significant differences in importance for self and others appear for only two of the barriers: namely, family/personal concerns and communication ($p < .01$; Fig. 4). For those outside of both US and Europe, likewise, highly significant differences (self-other) appear only for barriers of family/personal concerns and communication ($p < .001$) and to a lesser extent, for time commitments ($p < .10$; Fig. 5). The women engineering professionals in both of these regions report these barriers to be less important for self than others.

For students, the patterns for importance of barriers for self-other tend to be those that professionals within their regions report. Specifically, for US students, the significant patterns in reported importance for self-other are similar to those for the US professionals—except that for students the self-other difference is absent in finding collaborators and not significant for communication (Fig. 3). Among European respondents, the significant patterns for self-other that we see for professionals repeat for the students (Fig. 4). Among students outside US and Europe, the significant pattern of difference for self-other in importance of personal/family concerns occurs for students, as it does for professionals (but the self-other pattern for communication does not; Fig. 5).

4 Summary and conclusions

What do the findings reveal about frequency of, and barriers to, international research collaboration among these women engineers? First, the frequency of international research collaboration clearly varies by region, with revealing patterns. Women engineers in the US are more likely to report *no* prior international research collaboration: 30 % of the professionals in US, compared to 13.6 % of those in Europe and 15.9 % of those outside US and Europe, report none. Across regions, one or two prior collaborations are the most commonly reported frequency. The higher frequencies (three or four or five or more) of international research collaborations are most prevalent among women engineering professionals in Europe. Student engineers in Europe are also more likely to have prior international research collaboration than are students in other regions.

The experience with prior international research collaboration among women engineers in Europe may reflect, in part, the proximity between European nations and thus geographic feasibility for collaboration between nations. But it may also reflect overt science policies. The European Commission (2007, 2009) emphasizes explicitly the importance of trans-European research activities and programs, including the flow of researchers between institutions, fields, and countries, as well as global research collaborations. These science policies are ingredients in Europe's promotion of increasingly competitive, knowledge-based economies, with international research collaboration as a means to key resources (including skills, experience, and expertise), intended to support the scope and quality of scientific research and innovation (European Commission 2009). This does not mean that European nations have a single policy; rather, an amalgamation of policies exist that shape strategies of international collaboration in research (European Commission 2009).

For example, the European Science Foundation supports the European Collaborative Research Programme (EUROCORES) providing funding for research projects, based on collaborations of investigators in different fields and nations, including those in regions

beyond Europe. The procedures involve joint (cross-national) handling of calls for proposals, peer review, and decision making, and the funded projects include workshops, conferences, courses, and short-term visits toward effective international research collaboration. The European Commission's Marie Curie Research Program encourages transnational and interdisciplinary mobility. It does this through support of research networking, fellowships, and co-funding of programs of training and career development that expand into international dimensions—addressing international research collaborations.

Policies in nations outside of Europe and US also treat science and technology as integral to economic growth and development and international research collaboration as a means toward these ends (National Science Board 2012). But efforts outside Europe and US are more likely to transpire nation-by-nation rather than across continents in some coordinated way. Further, collaboration among scientists in developing nations may also depend on the flow of information and informal ties for both women and men (Ynalvez and Shrum 2011). In addition, although US science policies speak to policies for strengthened "ties between scientists and their institutions throughout the world" (Peters 2006: 236) and to "the role of international research collaboration in advancing knowledge" (National Science Board 2012: O-3), in actual patterns of collaboration, US scientists are less likely to collaborate internationally than those in other parts of the world (Finkelstein et al. 2009). Although the US is a major producer of numbers of internationally, authored publications (reflecting its large number of publications, overall), it ranks 27th in nations in its *proportion of total articles* with international authors (Gazni et al. 2012). Leading in the proportion of total articles with international authors are Switzerland, Belgium, Denmark, and Austria—each a European nation (Gazni et al. 2012).

Second, international research collaboration "does not occur automatically" (Engels and Ruschenburg 2008: 348)–and is subject to barriers that policies can address, a focal issue of this study. We find that, across regions, the women engineers point to two, relatively external, barriers as the highest ranking impediments to international collaboration: funding and finding collaborators. Women engineers in the US rate the level of importance of these barriers as significantly higher than do women engineers in Europe and nations outside of US and Europe. To the extent that these external factors of funding and finding collaborators are, in fact, the major barriers to international research collaboration for women engineers (that is, that these perceptions of barriers are in-line with what actually impedes the collaboration), science policies can address the external factors more easily than other barriers. External factors of funding and finding collaborators are subject to policies of material and human resources for international research collaboration (Bozeman et al. 2013; Lee and Bozeman 2005); while factors such as personal/family concerns and time commitments (which are lower ranked) are far more difficult to address with policy.[5] International research collaboration could be supported, for example, through stronger international components (such as international travel) in research awards, and lower institutional obstacles in arranging research grants with international partners (research investigators), reflecting the importance of institutional arrangements for women (and men) in science (Fox 2008; Gaughan 2006; Rossiter 2012).

Third and notably, women engineers tend to regard barriers to international research collaboration as more important for other women in their home institutions than for themselves. This is especially pronounced (1) for women engineering professionals in the

[5] As the Method points out, marriage and children do not appear to be impediments to applying for the summit. Thus, the lower reported importance of family conditions as a barrier to international research collaboration is not an artifact of the group applying.

US and (2) and across regions, for the barrier of personal/family concerns. Within the US, the women engineering respondents may be assessing differently the importance of barriers for self and others because the vast majority of these women have academic positions; and in the US, especially, academic institutions are highly decentralized with opportunities and rewards that vary for faculty not only between institutions and units with them, but also for persons within given units (Bastedo and Gumport 2003; Clark 1997). This can support perceptions that barriers may be different for self compared to others. In addition, the women engineers may be considering "other women in their home institutions" to be those outside of engineering (and sciences) and in turn, to be less "exceptional" than selves in having overcome obstacles to participate in their fields.

Fourth and revealing, across regions, women engineers regard personal/family concerns as a significantly less important barrier for themselves than for others. This may occur because the women engineers see themselves as having created family circumstances to support their participation in non-traditional fields for their gender (see Fox 2005). Further, research (Brown 1986) indicates, generally, that the greatest differences in assessments for self compared to others occur in assessments of more subjective factors (such as family concerns) compared to less subjective factors (such as funding).

The present study is unusual in addressing international research collaboration among women engineers, with findings not previously available. This study also provides bases for continuing research. The understandings presented here may be developed in ways that include these. The number of respondents in countries outside of US and Europe may be widened, if possible. Understandings of international research collaboration, generally, will be enhanced by geographic diversification of the groups studied, encompassing groups in Africa, Asia, Australia, Central and South America. The referent for barriers for "others" appearing as "other women in one's home institution," can be specified to indicate particular fields or areas of "others." A sample of men would help determine the ways that the patterns operate for women compared to men. Further, distinctions between international collaborations that occur among women engineers, compared to collaborations among women and men engineers, would point to patterns that may vary with gender compositions of international research collaborators (see Bozeman and Corley 2004). These developments will enrich the understandings provided here of women and international research collaboration, and in turn, the prospects for science policies to broaden participation in the increasing important global arena.

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