IS THERE A LAND OF EQUALITY FOR PHYSICISTS? RESULTS FROM THE GLOBAL SURVEY OF PHYSICISTS

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SUMMARY

A country-level analysis of the Global Survey of Physicists shows sex differences in the distribution of career-advancing resources and opportunities and in the relationship between family and careers.

Significant efforts to improve the situation of women in physics have been made in many countries [1]. Everything from improving undergraduate education to funding university-level initiatives has been attempted in various countries. In spite of all the programmatic efforts, there are little to no international data documenting the specific areas in which efforts should be made. In this paper, we argue that one area of focus should be on the allocation of resources, such as funding and lab space, that are needed to contribute to the scientific body of knowledge. Another area of focus should be on the distribution of opportunities to present one's work and be acknowledged as a scientific colleague. Are scientific resources and opportunities distributed equally between women and men? Previous research suggests that they are not [2]. In this paper, we look country-by-country to see where the inequalities lie.

Across the world, women are generally expected to take most of the responsibility for family and childrearing [3–5]. Our previous research suggests that these expectations have negative effects on women's careers in physics, but that there are few effects on men's careers [6]. Will we see these effects on women's careers in all countries?

To answer these questions, we use data from the Global Survey of Physicists (GSP), a multi-national collaborative effort arising from a series of international conferences of women in physics. These conferences were sponsored by the Working Group for Women in Physics of the International Union of Pure and Applied Physics (IUPAP).

HISTORY OF THE GLOBAL SURVEY OF PHYSICISTS

The first and second IUPAP International Conferences of Women in Physics sponsored surveys that were designed to document the situation of women in physics. The first two global surveys of physicists were based on the notion that the situations of women in physics should be documented. The goal was to describe common problems that women in physics across the world face in their work and studies. The first two global surveys, therefore, were sent exclusively to women. More than 1,000 women from more than 50 countries responded to each of the two surveys [6,7].

For the third International Conference of Women in Physics, held in Seoul, South Korea, in 2008, the IUPAP Working Group for Women in Physics decided to expand the scope of the surveys. First, men were included in the third survey to allow for comparisons between men's and women's experiences. In addition, the IUPAP working group decided to expand the languages of the survey; the first two surveys had been conducted in English only. With support from the Henry Luce Foundation, the survey was translated into seven languages other than English. These included all the UN languages (Russian, Arabic, Spanish, Chinese, and French), and Japanese and German. The Statistical Research Center of the American Institute of Physics, which had conducted the first two surveys, again undertook this project. We worked collaboratively with women's working group team leaders from the IUPAP countries to create the third survey, now called the Global Survey of Physicists (GSP).

Once the surveys were ready to be distributed, most of the team leaders distributed the web-based survey among their contacts. At the end of the survey form, respondents were encouraged to pass the survey on to other physicists, especially women, whom they knew. This created a snowball distribution. In some countries, physical societies distributed the survey to their members. The American and the German Physical Societies distributed the survey to random samples of their members, and the Japanese Physical Society distributed the survey to all its members.

The survey was available to respondents for one year, from October 2009 to October 2010. At the close of the survey, 14,932 physicists from 130 countries had responded, a dramatic increase from the 1,000+ who had responded to past surveys. Part of the reason for the huge increase in respondents was the addition of men. But the

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distribution by physical societies, the addition of seven languages, and the participation of the team leaders no doubt contributed to the increase as well. In the end, 22% of the respondents were women, representing approximately 3,000 women, a significant increase over the number answering the first two women-only surveys. The analyses in this paper are limited to respondents who are not students and who have had a job that uses their knowledge of or skills in physics.

IMPORTANCE OF RESOURCES, OPPORTUNITIES, AND FAMILY RESPONSIBILITIES

There are many types of resources needed to advance a career in science, ranging from access to graduate students or employees to assist with research, to clerical support, research funding, and travel money. One study of social science faculty members in the U.S. found that mothers are less likely than fathers and childless professors to have access to resources, but this difference was entirely explained by mothers being more likely to work outside of research-intensive universities [8]. Professional opportunities also are essential to career advancement for scientists. These include invitations to speak, serving on committees, and conducting research abroad. Results from the GSP have already shown that even controlling for sector of employment and age, women physicists have access to fewer career-advancing resources and opportunities than men. In turn, lack of opportunities and resources can mean that careers in physics advance more slowly [2].

The effects of cultural expectations requiring women to take most of the child care and household responsibilities cannot be overlooked. These effects have been documented in the U.S. for academic women's career outcomes. One of the most cited studies found, among many other things, that mothers in the U.S. are 29% less likely to enter tenure-track positions than women without children. Furthermore, women who are full professors are much less likely to be married with children than men who are full professors [9].

Previous results from the GSP focused on differences between respondents from very highly developed countries (as defined by the United Nations) and less developed countries. These results show the importance of resources and opportunities for advancing all careers in physics. The results also show the dampening effect of having children on women's—but not men's—careers. The results held true for respondents across the world, regardless of their age, employment sector, and their country's level of economic development [2]. However, among countries with similar levels of economic development, there may be cultural differences that could affect the distribution of resources and opportunities within that county's scientific community. In addition, the effect of children on people's careers could be different in different countries. The purpose of this paper is to determine whether resources, opportunities, and children affect people's careers in physics differently at a country-by-country level.

ANALYSIS AND RESULTS

Although respondents from more than 130 countries answered the GSP, we conducted country-level analyses only for countries with at least thirty women respondents who were no longer students: Argentina, Canada, China, France, Germany, Italy, Japan, Spain, and the U.S. Recall that we drew random samples of the American and German Physical Societies, and that the survey was sent to the entire membership of the Japanese Physical Society. In all other countries, the respondents were asked to pass along the survey to colleagues, so the results are not necessarily representative of the entire population of physicists in those countries. However, the differences we found are statistically significant and merit further discussion.

In our results, statistical significance is indicated by the *p*-values shown in the tables. A *p*-value is a measure of the weight of the data against a specified (null) hypothesis. In our tests, the null hypothesis is that there is no difference between men and women. A *p*-value ranges between 0 and 1, and a smaller *p*-value indicates stronger evidence to reject the hypothesis. We set our cutoff for statistical significance to $p\text{-value} < 0.10$.

Limited Resources and Opportunities

To measure access to resources, we asked respondents whether they had enough of the following items to do their research: funding, office space, lab space, equipment, travel money, clerical support, and employees or students. To measure opportunities, we asked respondents whether they had done eleven different things such as given a talk as an invited speaker or served on various committees. (For a complete list of opportunities, see Table 2 in [2].)

We measured the accumulation of resources and opportunities by summing the number of resources and then the number of opportunities that each respondent reported. Scores for the number of resources could range from 0 to 7, and opportunities from 0 to 11.

A simple approach to examine sex differences in the accumulation of resources and opportunities would be to look at the mean number of each for men versus that for women. However, we believe additional factors beyond the respondent's sex could affect his or her accumulation of resources and opportunities [8]. For example,

- respondents with a longer work experience would be expected to have had more resources and opportutnities by nature of having been in the workforce longer, and
- respondents working in different job sectors (government, post-secondary education, etc.) would be expected to have different resources and opportunities.

To account for these differences, we used ordinal regression models that included the respondent's age and employment

sector to test for differences in the accumulation of resources and opportunities. In these models, the value of the coefficient for sex (a 0 – 1 variable) can be interpreted as the difference between men and women. If it is statistically significant, there is evidence to suggest a difference between men and women. Our statistical tests were one-tailed tests because our alternative to the null hypothesis was that women would have fewer resources and opportunities than men.

While our data are not necessarily representative, the *p*-values are small enough to suggest that women accumulate fewer resources than men in Canada, China, Italy, Spain, and the U.S. In addition, our models show that women accumulate fewer opportunities than men in Argentina, China, France, Italy, Japan, and Spain (Table 1).

Relationship between Career and Family

In much of the world, women hold primary responsibility for taking care of the home and children [3–5]. The first two IUPAP surveys of women physicists consistently document the effects of children on women's careers [6,7]. In this section, we examine whether the relationship between career and family holds on a country-by-country basis.

The variable of interest in these models is binary (yes/no), so we used logistic regression models. Using the results of these models, we calculated the difference in likelihood for men and women. Our alternative hypothesis was that women would be more likely to be affected by the demands of balancing work and family, so our tests were again one-tailed tests.

We asked respondents whether their career had changed their personal life, such as decisions about marriage or children. For example, people may delay or avoid marriage or child rearing in order to focus on a career. In five countries—France, Germany, Japan, Spain, and the U.S.—women were significantly more likely than men to say that their career had affected their personal life. Because of the low *p*-values, we see that the evidence is the strongest in the U.S. and France (Table 2). Women in France, for example, are about three times as likely to say that their career had affected their personal life than are men – after accounting for age and employment sector. The differences were not statistically significant in Argentina, Canada, China, or Italy.

While focusing on a career may affect marriage and family decisions, the reverse could also be true. Becoming a parent, for example, may affect progress in a career, and this effect may be different for women and men. We asked respondents the degree to which they agreed or disagreed with the following statements:

- My work or career did not change significantly [after I had children].
- My career or rate of promotion slowed significantly [after I had children].

For the first question, we had enough respondents to analyze the data in eight of the nine countries analyzed above. (France is the exception.) In all eight countries, men were significantly more likely to say that their career did not change significantly after

TABLE 1
Sex Differences in the Allocation of Resources and Opportunities

	Resources			Opportunities		
Country	Average (Both Sexes)‡	On average men have __ more*	*p*-value	Average (Both Sexes)‡	On average men have __ more*	*p*-value
Argentina	2.83	—	ns◈	6.22	0.49	0.066
Canada	5.08	0.54	0.066	6.63	—	ns◈
China	4.52	0.51	0.068	5.66	0.69	0.023
France	4.58	—	ns◈	7.10	1.04	0.003
Germany	5.19	—	ns◈	4.82	—	ns◈
Italy	4.05	0.91	0.010	7.05	0.45	0.039
Japan	4.03	—	ns◈	6.43	0.59	0.005
Spain	3.98	0.45	0.052	7.23	0.41	0.023
United States	4.96	0.41	0.010	6.21	—	ns◈

‡ Averages should not be compared across countries since the data are not necessarily representative. Furthermore, each country has a different mix of men and women in a variety of employment sectors, and each employment sector offers different resources and opportunities.
* These differences account for respondent's age and employment sector.
◈ There is no statistically significant difference.

TABLE 2
Sex Differences in the Relationship between Work and Family

Country	Women more likely to say their career affects personal decisions		Men more likely to say their career NOT changed after having children		Women more likely to say rate of promotion slowed after having children	
	__ times more likely than men*	*p*-value	__ times more likely than women*	*p*-value	__ times more likely than men*	*p*-value
Argentina+	—	ns◇	5.57	0.002	2.79	0.031
Canada	—	ns◇	3.16	0.001	3.21	0.001
China	—	ns◇	2.05	0.024	5.18	0.000
France	2.98	0.005	Not enough respondents to perform tests			
Germany	1.53	0.012	7.85	0.000	Not enough respondents to perform test	
Italy+	—	ns◇	4.30	0.000	3.71	0.001
Japan	1.53	0.042	14.44	0.000	33.62	0.000
Spain	1.42	0.056	4.32	0.000	3.99	0.000
United States	2.07	0.000	2.24	0.000	2.14	0.001

* These differences account for respondent's age and employment sector.
+ Because some employment sectors included either all men or all women respondents, the regressions for Argentina and Italy do not include every employment sector.
◇ There is no statistically significant difference.

having children. The evidence is very strong that having children is more likely to change a woman's career than a man's in every country with enough respondents to test (Table 2). At a minimum, men were twice as likely as women to say their career had not changed after having children. In Japan – which was one of the countries where the survey was distributed through the national physical society – men were more than 14 times more likely than women to make that statement.

For the second question, about the rate of promotion, we had enough respondents to test the data in seven countries. In each—Argentina, Canada, China, Italy, Japan, Spain, and the U.S.—women were much more likely than men to say their career or rate of promotion slowed significantly after having children. France and Germany had too few women respondents with children to conduct the analysis. In all other countries, women are at least twice as likely to state that their rate of promotion had slowed after having children; in Japan, women are more than 33 times more likely to state that (Table 2).

Discussion

The GSP included nine countries with at least thirty women respondents who were no longer students. The nine countries included in these analyses are Argentina, Canada, China, France, Germany, Italy, Japan, Spain, and the U.S. For each of these nine countries, we examined sex differences in the accumulation of career-advancing resources and opportunities while controlling for possible effects of age and sector of employment. With the exception of Germany, we found that in each country, women had either fewer resources, fewer opportunties, or both than men did. China, Spain, and Italy are the three countries where women physicists had both fewer resources and fewer opportunities than men. There were no countries in which women had more resources and opportunities than men.

In addition, we examined sex differences in the relationship between career and family, again controlling for age and sector of employment. In most countries, we found that women were more likely than men to say that their careeers as physicists had affected their decisions about marriage and family. In every country in which there were enough women respondents with children, we found that, at a minimum, women were twice as likely as men to say that having children had slowed their rates of promotion. Similarly, in every country with enough respondents to test, we found that men were, at a minimum, twice as likely as women to say that having children had not significantly affected their careers at all. In some countries, these ratios were much higher than two times.

The question of why these relationships hold in some countries but not in others is beyond the scope of this paper. The reader should keep in mind that in only three countries (Japan,

Germany, and the U.S.) are the results representative of the memberships of the physics societies. Each of the countries in this paper has a unique culture, history, and economy that affect the distribution of resources and opportunities. These unique circumstances also affect the relationship between career and family. We welcome further research into the causes of the differences documented here.

IMPLICATIONS

One of the main problems with unequal distribution of scientific resources and opportunities is that it creates disadvantage for the groups or people with limited access. These disadvantages can have a cumulative effect [10]. For example, a scientist with limited resources may not receive the recognition or opportunities that a scientist with more resources receives. Because of the limited recogntition, the scientist who started out with limited resources may not be eligible for as many resources in the future. Lack of resources and opportunities can have long-term effects on people's careers.

In addition, constraints are placed on women's careers in science by the demands of parenting. These contraints also have cumulative effects. If a mother's rate of promotion slows, she may have access to fewer resources and opportunties in the future, so that the effects of parenting become cumulative over her career.

In the authors' opinion, resources and opportunites should not be allocated based on characteristics beyond one's control, such as sex. Science places importance on equity and taking an unbiased approach to its problems. Where possible, the values of fairness and objectivity should be applied to level the playing field for women in physics.

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