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Defence spending and women in research: A cross-country comparison

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Abstract

This article explores whether greater levels of national defence spending effectively push women away from research careers in science and engineering due to the biases that defence spending can foster in research and development (R&D) institutions. Defence R&D spending shapes the orientation of R&D both through the direct subsidisation of R&D, as well as through procurement, which creates demand for military technologies. These biases created by defence spending potentially alter and shape career tracks in ways that may be more antithetical to feminine gender norms and job values than those of men, thus reducing women's participation in research careers and reducing gender diversity among developers of new technology. We evaluate this gender asymmetry empirically through a panel dataset of thirty-three nations. Our findings indicate that greater levels of defence spending are indeed associated with lower participation of women in research careers, particularly in government and higher education.

Key words: gender; defence spending; research and development; STEM; research policy

1. Introduction

Among nations vying for economic power on the international stage, much emphasis is placed on the importance of technology in maintaining international competitiveness. As nations look to increase their pool of individuals who can perform cutting edge research and development (R&D), they often focus on the relatively low percentages of females participating in this R&D. Despite substantial increases in past decades, many countries still report disproportionately low numbers of female researchers.[1] With increasing percentages of women now completing tertiary education, many fear that the inability of research-intensive fields to draw from this pool of talent could significantly limit the potential of new R&D. As a result, one straightforward yet important question has become critically important to longer-term national and international economic prospects: 'Why are relatively few women opting for research careers?'

A variety of answers to this question have already been suggested and extensively researched, including differences in preferences, discrimination against women (implicit and explicit), lack of female networks and mentors, and many others (Ceci et al. 2014; Charles and Bradley, 2002, 2009; Duch et al. 2012; National Academy of Sciences et al. 2006; Xie and Shauman 2003). Many have examined differences in the primary and secondary education of boys and girls for possible clues. However, while many researchers have paid attention to the issue of who is performing the research, so far there has been relatively little attention paid to where they get the support to actually do the research and how this could affect the nature of the research, as well as who does the research. More specifically, because many countries rely substantially on defence spending to support R&D, a bias toward reliance on defence spending will shape the nature of R&D institutions in many ways, including *what types* of R&D are they most likely to produce as well as *who* is most likely to perform the R&D in these potentially military-biased institutions. In their extensive study of women in science in the USA, Xie and Shauman (2003) concluded that differences in achievement, coursework, and familial influences could not address the likelihood that a high school student aspires to a research career. They did find, however, that individual 'choice' explained much of the gender differences, in that career 'choices' reflect the broad social structure, such as gender norms and occupational segregation based on gender.

The present study thus will focus on the roles played by military spending and gender norms: two institutions that each make up a key part of the broad social structure of culture, social classes, roles, groups, and institutions, in order to better explain low female representation in research. In existing research on the gender gap in STEM (Science, Technology, Engineering, and Math), there has been relatively little focus on the effects of government spending on research institutions. By recognizing the influence of (1) defence spending on research and (2) the influence of gender roles on occupational choice—as well as how these two interact with each other—we seek here to enhance our understanding of the relatively low international representation of women in research. Countries which focus a substantial amount of government spending on defence may be biasing their economies (as well as their societies, more broadly) in a number of ways, as a result of a relatively-biased focus on the development and procurement of military technologies. This article attempts to establish that one of the biases related to high defence spending is that the production of research is male biased.

1.1. Defence spending and research priorities

Public policies, which include the amounts and types of public spending, clearly play a significant role in shaping the social institutions of any country. When it comes to research institutions, public spending is likely to influence the directions in which research-defining science and technology fields progress via two key channels: the supply of R&D and the demand for R&D. The government typically fills a crucial gap in the *supply* of R&D funding left by the private sector, as private firms tend to underinvest in many types of R&D due to the high risk and high uncertainty associated with such long-term projects, which have questionable payoffs and generate relatively large positive externalities (Block 2008; Mazzucato 2013). With so much emphasis placed on short-term profits in the market, private industries are less likely to invest in technologies with large up-front costs and high downside risk, even though the potential future payoff could be extremely high. The government, on the other hand, is not subject to the same rules that govern the market, allowing for much longer-term, high-risk investment projects with potentially-transformative high-reward technologies, such as computers or nuclear fusion. In this way, the government plays a crucial role in guiding the paths of scientific and technological change by deciding which projects receive public funding (Block 2008; Lakoff 1977; Mazzucato 2014).

With respect to the *demand* for R&D, the government plays probably an even more significant role in guiding what R&D work is pursued through the procurement of goods and services. When the government purchases the end products of R&D work, these highly-public and large-scale choices also play a crucial role in determining which R&D projects are viable. Again, private markets see high risk and uncertainty for long-term investments, such as R&D. Having a relatively large and reliable purchaser in the form of the government can reduce the uncertainty and risk of such investments. While in this case, the government is not directly selecting which R&D projects receive funding, other investors will be more likely to invest in R&D projects related to the types of products which the government is likely to purchase. Sometimes the government can even serve as the 'purchaser of last resort' for new products that have difficulty finding enough buyers in the private market (Chomsky 2013). While procurement may have less of a direct effect on R&D than when the government pays explicitly for the R&D work itself, the amount of money spent by the government on the demand side is generally much greater than the amount spent by the government on the supply side, so both play a critical role in R&D signaling.

Because of the impact of government spending on R&D, any trends in government spending are also likely to shape the fields in which R&D operates, which are predominantly science and engineering. One particularly notable pattern in government spending is the large proportion spent on defence. In many countries, public spending on defence has had a major impact on the advancement of science[2] and technology, and the potential military advantages gained through technological superiority on the battlefield have motivated R&D for centuries (Brodie and Brodie 1973; Chomsky 2002; Melman 1985; Ruigrock and Van Tulder 2013; Sapolsky 1977). Because one of the main roles fulfilled by the modern government is national defence, and subsidising and otherwise shaping R&D work is another major role fulfilled by the modern government, these two roles often become closely intertwined, with R&D inevitably orienting toward the defence goals of the government.

Many of the most significant scientific and technological developments in history have been largely the result of R&D carried out specifically for military purposes, such as nuclear fission, computers, and the Internet, to name just a few. While many of these technologies serve various functions beyond their originally-intended (military) purposes, sometimes referred to as 'spin-offs' or 'dual-use' technologies, they still reflect the bias of the original purposes of defence R&D (Bellais and Guichard 2006; Sapolsky 1977). Whatever general direction of investigation is explored, many new possibilities may be unlocked, but they still reflect a bias due to the opportunity cost of other possibilities—such as healthcare, education, or the environment—that are foregone as a result of this focus on defence spending. How then might this bias influence the gender of those performing the R&D?

1.2. Gender roles and occupational norms

The socialization of men and women into binary gender roles influences their career paths. Rather than arguing that women and men have different biological propensities toward certain types of careers, or that women and men are naturally drawn toward different kinds of work, we argue that institutionalized gender constraints, such as laws, discrimination, and binary gender norms, substantially alter the availability and attainability of career options, depending on one's gender. Fields that exhibit certain characteristics associated with gender roles for either women or men will have more apparently acceptable careers available for each gender. In addition, organizational structures and relationships may also have built-in gender biases, particularly in STEM research occupations, where careers have traditionally been structured around a model largely incompatible with devoting significant amounts of time to care work, and rigid hierarchical structures may impede women's participation and influence as well (Smith-Doerr and Croissant 2011). Relatively militaristic societies may arguably exhibit relatively rigid gender norms and barriers to gender equality, as indicated by Caprioli (2000), due to the large influence that militarism has historically had on both male and female gender roles (Goldstein 2001). These gender biases may then manifest directly in R&D institutions themselves, but militarism can also influence gender biases in other areas of society, such as in schools, family structure, and care work responsibilities in the home, which may also indirectly influence women's ability to pursue relatively competitive and time-intensive careers in research.

Many of the norms associated with women's labor also come from the historical and cultural assignment of care for others: children, husbands, and the elderly (Badgett and Folbre 1999). The requirements of this type of work have encouraged women to internalize communal and altruistic values, such as working with and for others, while male gender norms have encouraged men to internalize more agentic and individualistic values, such as pay and status (Mooney Marini et al. 1996). Perceptions of whether research careers fulfill mainly agentic values or communal values can influence women's preferences toward this kind of work (Diekman et al. 2010, 2011). To quote Cockburn (1983: 18), '[i]t seems as though for women more than for men the social purpose of work is important,' but perceptions of the values inherent to certain types of careers also influence the amount of pushback and exclusionary practices women face in these careers, particularly those that have been historically male-dominated (Faulkner, 2001; Wajcman, 2010). When pursuing careers in fields that historically have been filled primarily by men, and also have been heavily associated with masculine gender norms, women are more likely to face gender harassment, a variety of exclusionary practices intended to make women's gender more visible and to characterize femininity as a weakness that does not belong in such career fields (Miller 1997). These values may help explain why women researchers in fact collaborate more than their male counterparts (Bozeman and Gaughan 2011).

Different types of R&D will allow researchers to express differing levels of agentic and communal values based on the nature and purpose of that R&D. R&D specifically focused on militaristic purposes that could significantly reduce the perceived communal and altruistic value of the R&D, particularly in the eyes of women who are typically more averse to militarism than men are (Brooks and Valentino, 2011; Eichenberg, 2012; Wilcox et al. 1996). Eichenberg's (2007: 7) research on cross-national gender differences in policy preferences shows that '[t]here are many commonalities in the views of men and women, but the direction of gender differences is always and everywhere that women are less supportive of using military force than men.' Militaristic R&D will also give less value to employees who are particularly focused in pursuing relatively-altruistic work, neglecting their work in favor of those perceived as more agentic and individualistic. Charles and Bradley (2009) have explicitly focused on the importance of social context in understanding sex segregation among researchers in different countries. They find that the level of economic development (measured as gross domestic product per capita) in a country plays a significant role in reinforcing sex segregation among researchers, arguing that asymmetries in career ideologies may intensify gender typing of curricular fields, especially in wealthier countries.

If social norms prescribe communal and altruistic values as inherently feminine, and these values are perceived as antithetical to militarism and defence spending, then a bias toward defence-related projects could implicitly bias research against norms of femininity. Under a regime of relatively-militarized research, female researchers will be perceived as less suitable for this type of work, relative to men who may be perceived by supervisors, peers, and society at large as better-suited for militaristic work associated with masculine norms. While women may be biased against militarism and military institutions, military institutions may also be biased against women. In addition to the bullying, sexual harassment, sexual assault, and other forms of gender harassment experienced by many women in military institutions, prior research also indicates that members of military institutions may hold more traditional views of gender roles and feel it is less appropriate for women to work in a variety of military positions (Koeszegi et al. 2014; Robinson Kurpius and Lucart 2000). Given the requirements of R&D and the relative scarcity of funding available to support R&D activities, competition over these resources often requires building relationships with government institutions to maintain a reliable stream of funding. When such funding streams are militarized, the masculine biases of the military may give male researchers an implicit advantage in obtaining funding, making it easier for either funding agencies or research peers to exclude female researchers competing for scarce R&D subsidies. Where military institutions significantly influence R&D, by awarding grants, hiring personnel, determining the direction of research, etc., R&D institutions would be more likely to reflect some of the biases held by the military. Taking these biases into account, we should expect to see lower percentages of female researchers in countries where defence spending is higher. This proposition is our underlying hypothesis of inquiry.

Because of the hypermasculine nature of the military, we would expect to see fewer women in research fields that are more closely tied to and influenced by the military. The data in Fig. 1 and Table 1 support this hypothesis, in the specific case of the USA. Figure 1 and Table 1 show that the STEM fields that receive the largest percentage of their Federal research subsidies from the US Department of Defense (DoD) also have the lowest percentages of women working in them. The bottom row of Table 1 shows that there is a substantial negative correlation between the per cent of Federal research received that is DoD-funded and the per cent of researchers in a field who are female, based on the most recent data available from the US Current Population Survey (CPS), the Survey of Doctorate Recipients (SDR), and the Survey of Graduate Students and Postdoctorates in Science and Engineering (SGS). In this study, we extend this analysis beyond the US economy, comparing across thirty-three different countries, to determine if the prevalence of military spending in national economies is significantly correlated with the prevalence of female participation in research in those national economies.

2. Data

Data from thirty-three nations (twenty-two in Europe, five in Latin America, and six in Asia)[3] are used in this study. The four dependent variables draw from United Nations Educational, Scientific, and Cultural Organization (UNESCO) data on human resources in R&D; these variables are summarized in Table 2. Table 2 shows that the percentages of female researchers[4] in higher education and government research jobs tend to be fairly close to each other, while percentages of female researchers in business enterprise (private sector) tend to be substantially lower. Looking at the maximum measures of these variables shows that some countries did have more female than male researchers in the years observed; however, the average across countries is still significantly below gender parity, even among researchers working in higher education and government. Each country's percentage of tertiary education graduates that are female in STEM fields is also drawn from UNESCO's education data, and will serve as one of the main control variables.

The key independent variable in this study is defence spending within each country, which will be measured as the percentage of total government spending that consists of defence spending. Data for this variable are obtained from the Stockholm International Peace Research Institute. The (unbalanced) panel of data used in this study includes thirty-three countries, with at most four observations per country.[5] The remaining independent variables shown in Table 3 are obtained from World Bank data. Drawing on Caprioli's (2000) previous cross-country study on the relationship between gender and militarism, three important control variables are included: the percentage of females in parliament, fertility rate, and female labor force participation (LFP). Caprioli was able to show that these measures of women's rights are correlated with the level of militarism in a particular country (the higher the level of women's rights, the less militaristic a country typically is). Our study builds off of Caprioli's work by not only including these control variables but showing that the militarism embedded in defence spending also negatively correlates with women's likelihood of establishing and maintaining a presence in research work that is equal to that of men.

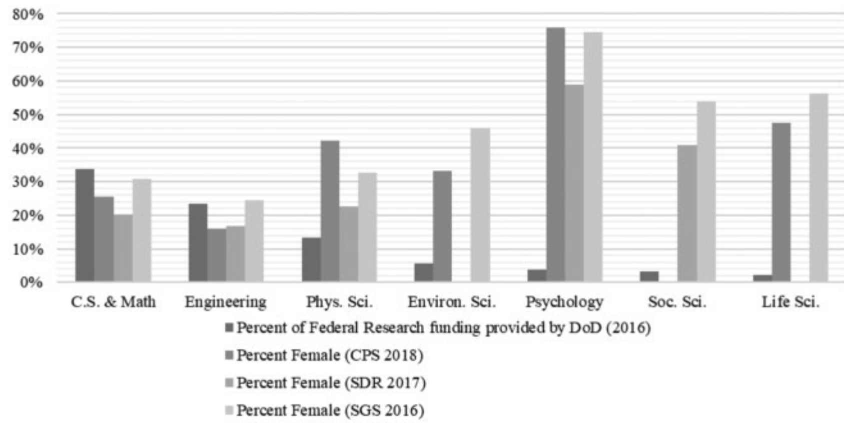

Figure 1. US DoD funding and female participation in STEM fields.

Table 1. US DoD funding and female participation in STEM fields.

	Percentage of Federal Research funding provided by DoD (2016)	Percentage of female (CPS 2018)	Percentage of female (SDR 2017)	Percentage of female (SGS 2016)
All fields	10.72	25.66	35.24	45.16
Computer science and Math	33.72	25.6	20.32	30.75
Engineering	23.30	15.9	16.67	24.55
Physical sciences	13.46	42.1	22.73	32.68
Environmental sciences	5.56	33.1	–	46.06
Psychology	3.75	75.9	58.90	74.55
Social sciences	3.26	–	40.77	53.97
Life sciences	2.31	47.5	41.59[a]	56.22
Correlation with DOD funding	1.00	−0.69	−0.80	−0.78

[a]Percentage female in biological, agricultural, and environmental life sciences.

Table 2. Summary statistics: Dependent variables.

Variables		Mean	SD	Min	Max	Observations
Percentage of *total* researchers that are female	Overall	37.57	9.92	9.67	55.62	*N* = 76
	Between		9.29	13.32	52.82	*n* = 33
	Within		1.70	33.34	41.59	*T*-bar = 2.30
Percentage of researchers in *business enterprise* that are female	Overall	29.31	12.80	6.18	74.60	*N* = 76
	Between		12.32	9.71	67.66	*n* = 33
	Within		3.32	13.88	37.54	*T*-bar = 2.30
Percentage of researchers in *higher ed.* that are female	Overall	39.38	8.24	14.30	56.17	*N* = 76
	Between		7.34	20.26	56.17	*n* = 33
	Within		3.04	32.17	46.47	*T*-bar = 2.30
Percentage of researchers in *government* that are female	Overall	42.31	11.05	8.41	60.77	*N* = 76
	Between		9.61	14.58	57.62	*n* = 33
	Within		3.93	25.93	58.70	*T*-bar = 2.30

3. Methods

This study will use three different empirical strategies to test the gender-defence hypothesis, the first being a pooled ordinary least squares (OLS). With the percentage of female researchers in each country representing the dependent variable, it is necessary to control as much as possible for the different social, cultural, and economic factors in each country that could be expected to influence female representation in research, in addition to defence spending. One way to effectively capture much of these cross-country differences is by including the percentage of female graduates from STEM tertiary education as a principal control variable. This variable should reflect many of the same cross-country institutional differences that are reflected in the dependent variables. This approach implies, however, that this study is focusing mainly on what explains the *differences* between female representation in STEM tertiary education and research career paths after graduation from tertiary education. This distinction has been of particular concern in various prior studies. Many countries have seen increasing gender equality

Table 3. Summary statistics: Independent variables.

Variables		Mean	SD	Min	Max	Observations		
% of govt. spending on defence	Overall	4.93	3.01	1.56	14.53	*N*	=	76
	Between		3.24	1.56	14.00	*n*	=	33
	Within		0.76	2.86	7.36	*T*-bar	=	2.30
% of tertiary STEM grads. that are female	Overall	34.42	6.11	22.77	47.94	*N*	=	76
	Between		6.19	23.62	47.42	*n*	=	33
	Within		2.23	27.93	39.13	*T*-bar	=	2.30
% of seats in parliament held by women	Overall	19.27	9.48	3.70	42.50	*N*	=	76
	Between		9.48	5.25	42.50	*n*	=	33
	Within		3.72	10.20	35.37	*T*-bar	=	2.30
Female LFP as a percentage of male LFP	Overall	72.62	11.16	33.96	91.34	*N*	=	76
	Between		11.48	37.45	91.34	*n*	=	33
	Within		2.19	64.39	82.38	*T*-bar	=	2.30
Log GDP per capita	Overall	9.93	0.58	7.86	10.75	*N*	=	76
	Between		0.60	7.92	10.72	*n*	=	33
	Within		0.15	9.51	10.25	*T*-bar	=	2.30
Fertility rate	Overall	1.61	0.42	1.13	3.10	*N*	=	76
	Between		0.44	1.26	2.90	*n*	=	33
	Within		0.10	1.41	1.83	*T*-bar	=	2.30
Days of paid maternity leave	Overall	142.13	57.14	60.00	410.00	*N*	=	76
	Between		52.39	60.00	273.00	*n*	=	33
	Within		18.52	73.38	348.38	*T*-bar	=	2.30

in education, while still facing difficulties translating this trend into greater gender equality in the labor force more generally (National Academy of Sciences et al. 2006; Xie and Shauman 2003; Xu 2016). The other independent variables shown in Table 3 are included to help control for other factors that could significantly impact female representation in STEM. GDP per capita is included because Charles and Bradley (2009) found that this had the most significant impact on horizontal[6] gender segregation in STEM.

One of the main flaws with the pooled OLS model is that the panel of data used is unbalanced, meaning that some countries have more observations than others.[7] In addition, the pooled model does not leverage the cross-country nature of the panel dataset. To address these weaknesses, two additional models are used to complement the pooled OLS model. A fixed-effects model could potentially be useful in measuring the longitudinal effects of defence spending on female representation in research, but the available data make this approach difficult. Given the relatively small time-window for which data are available,[8] and the fact that there is much more variation *between* countries than there is *within* countries (as shown in Tables 2 and 3), a cross-country latitudinal analysis could be more fruitful for understanding the relationship between defence spending and women in research.[9] The authors stress here that due to these data limitations, we are unable to provide evidence for a causal effect of changes in defence spending on female participation in research in this particular study. Therefore, the primary aim of this study is to explore the correlations in cross-country variations of these two main variables, to see if this evidence supports our hypothesis concerning the relationship between defence spending and female participation in research.[10]

The most straightforward way to focus on the differences between countries is by using a Between-effects regression, where the country means of the dependent variables are regressed on the country means of each independent variable:

$$\overline{f}_i = k_i + \overline{X}_i\beta + \overline{\mu}_c \qquad (1)$$

$\overline{X}_i$ is a vector of the country means of all the independent variables from Table 3, pertaining to country i, and $\overline{f}_i$ is the average percentage of female researchers in country i across all years used. This particular model mitigates any variation *within* countries in order to focus specifically on the variations *between* countries. Rather than estimating the effects of changes in defence spending in a particular country on that country's percentage of female researchers, this Between-effects model estimates how much the variations in defence spending between countries can explain cross-country variations in female representation in research, when controlling for other relevant socioeconomic and institutional variables.[11]

The inherent difficulties of a limited time-series across cross-sectional units with little variation across time indicate the need for an additional empirical approach. A third model is thus used to analyze these cross-country differences from a slightly different angle. Although there is relatively little variation within countries, fixed-effects regressions are still useful for analyzing cross-country differences, particularly from a structural and institutional perspective, since fixed-effects regressions estimate an individual constant term for each country over all time periods controlling for key gender characteristics. These fixed-effect constants thus reflect the broader structural/institutional differences that affect the specific level of female representation in research for each country. Because the constant term for each country applies to that country *over all time periods*, the estimated constant terms can then be regressed on the average structural/institutional factors for each country, including defence spending, to see how these variables relate to the country-specific fixed effects.[12]

This third model has two stages. In the first stage, the percentage of female researchers (f_{it}) is regressed on country-specific constants (k_i), year-specific constants (λ_t), and control variables (C_{it}).

$$f_{it} = k_i + \lambda_t + C_{it}\gamma + \varepsilon_{it} \qquad (2)$$

The variables categorized as control variables—only used in the first stage—are those that more broadly represent women's economic and political status in each country: percentage of tertiary STEM graduates that are female, percentage of seats in parliament held by women, and female/male labor force participation ratio. The variables categorized as institutional variables—used in the second stage—are those that are expected to specifically influence women's representation in science-and-technology-dominated research: defence spending, based on the arguments presented in this article; maternity leave; fertility rate, based on the relatively high time commitment of research work and the greater responsibility for childcare typically placed on women; and GDP per capita, based on the findings of Charles and Bradley (2009).

Having been cleansed of cross-country effects of the control variables by the fixed-effects regression in the first stage, the country-specific constant term estimates produced in the first stage ($\hat{k}_i$) now represent the idiosyncratic aspects of female representation in research for each different country. To see if defence spending has a significant effect on these country-specific idiosyncrasies, the second stage of this estimation process uses the country-specific constant estimates as dependent variables, and regresses them by OLS on the means of the institutional variables for each country ($\overline{Z}_i$).

$$\hat{k}_i = \alpha + \overline{Z}_i\beta + \mu_i \quad (3)$$

This regression estimates the longer-term relationships between the institutional variables and women's representation in research, as variations over time have now effectively been eliminated in the second stage.[13] All three models will estimate the effects of the independent variables on four separate dependent variables: the percentage of *all* researchers in each country that are female, as well as the percentage of researchers in each country that are female in business enterprise, government, and higher education.

4. Results

Results from the pooled OLS model are shown in Table 4.[14] Table 4 shows the results of the pooled OLS model. The left-most column of this table displays the coefficient estimates of the independent variables when the percentage of *all* researchers who are female is used as the dependent variable.

The results in Table 4 indicate that the percentage of female STEM graduates is positively correlated with the percentage of female researchers, while the fertility rate and log GDP per capita are negatively correlated. Most importantly, Table 4 shows a significant negative relationship between defence spending and the percentage of women in research. The coefficient estimate of −1.185 in Table 4 indicates that, *ceteris paribus*, a country whose defence spending as a proportion of total government spending is 1 per cent higher than another country could expect to have a proportion of female researchers that is roughly 1.2 per cent lower than its counterpart.

Comparing the results in the other three columns is also revealing. Defence spending appears to have the least impact on female representation in business research, while having the greatest impact on government research. This result indicates that government researchers are those most affected by the impacts of government defence spending, which converges with the intuition that government researchers would likely be the ones most directly affected by government spending patterns. While the results in Table 4 indicate that there is a (not significant) negative relationship between defence spending and female representation in private sector research, these results also indicate there is perhaps a more striking negative relationship between GDP per capita and women researchers in the private sector, suggesting that higher-income economies systematically deter private sector female researchers further, even after controlling for other influencing factors.

The results for the Between-effects model are displayed in Table 5. With respect to the effects of defence spending, the estimates obtained are not quite as strong or significant as the pooled OLS estimates, and the Between-effects results may indicate a stronger relationship between defence spending and women researchers in higher education than in government. Both researchers in higher education and in government still appear to have a stronger relationship with defence spending than those in the private sector, similar to the results of the pooled OLS model.

Lastly, the results of the two-stage model are shown in Table 6. These results are similar to the Between-effects results, albeit with slightly larger magnitudes for the coefficients on government spending, indicating that defence spending only has a significant impact on female representation among researchers in higher education, where perhaps women researchers have the greatest flexibility in terms of occupational choice. In this two-stage model, per capita GDP appears to have the strongest, most significant impact on the dependent variable, although smallest precisely in the higher education researcher regression.

5. Discussion

Coming full circle, the intuitive sequence of empirical models provide a broader robustness test for our fundamental hypothesis,

Table 4. Pooled OLS.

Variables	Percentage of researchers who are female			
	Percentage of total	Percentage in business enterprise	Percentage in higher ed.	Percentage in government
Percentage of govt. spending to defence	−1.185† (0.599)	−0.624 (0.506)	−1.264** (0.361)	−1.468* (0.690)
Percentage of female STEM grads	0.628*** (0.153)	0.554** (0.183)	0.373* (0.152)	0.679** (0.216)
Percentage of women in parliament	0.053 (0.094)	0.196 (0.177)	0.084 (0.099)	0.122 (0.097)
Female Labor Force Participation/Male Labor Force Participation	0.112 (0.118)	0.204 (0.144)	0.036 (0.103)	0.196* (0.084)
Log GDP per capita	−8.874** (2.497)	−14.733*** (3.567)	−4.404† (2.361)	−9.036*** (1.932)
Fertility rate	−4.223 (2.914)	−5.669 (4.073)	−2.542 (2.923)	−9.370*** (2.408)
Days of paid mat. leave	0.008 (0.017)	0.015 (0.031)	0.008 (0.016)	−0.011 (0.013)
Year dummy variables	Yes	Yes	Yes	Yes
N	76	76	76	76
n	33	33	33	33
R-squared	0.6327	0.5871	0.5683	0.6454

Significance levels: ***P < 0.001; **P < 0.01; *P < 0.05; †P < 0.10.

Table 5. Between regression (regression on group means).

Variables	Percentage of researchers who are female: Percentage of total	Percentage in business enterprise	Percentage in higher ed.	Percentage in government
Percentage of govt. spending to defence	−0.454 (0.404)	−0.237 (0.543)	−0.749† (0.375)	−0.640 (0.407)
Percentage of female STEM grads	0.856*** (0.213)	0.672* (0.287)	0.554** (0.198)	0.803*** (0.215)
Percentage of women in parliament	0.096 (0.139)	0.132 (0.187)	0.186 (0.129)	0.146 (0.140)
FLFP/MLFP	0.121 (0.111)	0.183 (0.150)	0.053 (0.103)	0.236* (0.102)
Log GDP per capita	−6.104* (2.632)	−13.037** (3.545)	−1.964 (2.447)	−7.315* (2.654)
Fertility rate	−2.637 (3.385)	−4.557 (4.558)	−0.179 (3.147)	−8.427* (3.413)
Days of paid mat. leave	0.016 (0.024)	0.037 (0.032)	0.015 (0.022)	−0.015 (0.024)
N	76	76	76	76
n	33	33	33	33
R-squared	0.5424	0.5485	0.4203	0.5334

Significance levels: ***P < 0.001; **P < 0.01; *P < 0.05; †P < 0.10.

Table 6. OLS with country fixed effects as dependent variables.

Variables	Percentage of researchers who are female: Percentage of total	Percentage in business enterprise	Percentage in higher ed.	Percentage in government
Percentage of govt. spending to defence	−0.674 (0.489)	−0.340 (0.475)	−1.034* (0.426)	−0.836 (0.571)
Log GDP per capita	−10.476*** (1.670)	−17.361*** (3.257)	−4.308** (1.618)	−12.599*** (2.720)
Fertility rate	−1.964 (2.333)	0.540 (4.272)	−1.831 (2.544)	−7.585* (3.386)
Days of paid mat. leave	0.026 (0.014)	0.023 (0.035)	0.030* (0.013)	0.004 (0.020)
Year dummy variables (in initial FE model)	Yes	Yes	Yes	Yes
N	33	33	33	33
Adjusted *R*-squared	0.2516	0.4021	0.1200	0.2814

Significance levels: ***P < 0.001; **P < 0.01; *P < 0.05; †P < 0.10.

namely that countries where the government spends more of its money on defence have significantly lower percentages of female researchers, particularly among government researchers. This result implies that decreasing defence spending and/or increasing non-defence spending may encourage more women to pursue research. Many other factors are obviously also relevant, and increasing the mix of defence and non-defence spending will not provide a cure-all solution to eliminate gender inequality in STEM. Education, networks, mentors, gender norms, among other features, all remain vitally important, based on previous work (Ceci et al. 2015; National Academy of Sciences et al. 2006, 2007). However, this article's strong cross-country empirical result that higher levels of defence spending are clearly associated with less women's participation in research careers significantly deepens our understanding of the consistent bifurcation of gender research roles—and may offer fresh avenues to help bridge this divide. By indicating how high defence spending may create and deepen additional biases in the global economy, the present study may provide further motivation and support for peace-making initiatives and efforts to reduce defence spending and the proliferation of military technologies.

Additionally, these results may shed new light on ways in which R&D is itself not only biased, but gendered in specifically masculine ways. If the dominant share of R&D work is seen as embodying typically male characteristics and values, those women who still engage in this type of work are often either obligated to adopt male characteristics and values, or they are perceived as having done so if they have successfully established themselves in this type of work (Des Jardins 2010).

In terms of policy implications, when it comes to improving the roles of women in research careers, the 'add women and stir' strategy is at best severely limited (National Academy of Sciences et al. 2006, 2007; Yoder 1991; Zimmer 1988). While equal opportunities are certainly important, women may continue to opt out and leave research careers if these career pathways continue to exhibit the biases of male-dominated government institutions. Those women who do not opt out may just be forced to conform to the imperatives of biased institutions, and society would continue to miss out on the potential benefits of a larger pool of talent, as well as the new ideas and critical perspectives that can come from greater diversity in research personnel.

Furthermore, gender biases can also become embedded within research fields themselves. The quality of research could thus itself be flawed due to biases held by dominant groups and institutions, which can hinder the level of objectivity for such inquiry. Objectivity in science is greatly enhanced by including multiple different views and perspectives. In this sense, science can be viewed as a social endeavor, where the values of whichever groups participate in creating 'science' will inevitably be reflected in the science and ensuing technology that they create (Harding 1991; Longino 1990).

Diversity is key in research not just because it is created and refined by social processes, but also because research serves much broader social purposes (Longino 1990). The ways in which gender-biased technologies are used may serve to further perpetuate gender inequalities throughout society as technology plays an increasingly prominent role in the structures of social institutions and our everyday lives. If research is to serve all groups in society equally, then all groups should have an equal say and an equal role in determining the use, impact, and control of the research itself (Harding 2015; Nelkin 1977).

In addressing the gender inequality that exists in STEM, emphasizing gender-neutral patterns of spending and research subsidies should make up just one part of a multifaceted approach to this persistent injustice. Recognizing and addressing these gender asymmetries may also be undertaken at the nongovernmental institutional and disciplinary level, such as at universities where foundational training is occurring as well as through professional associations. These structures can emphasize the broader nature of inquiry and application in science and technology fields to all potential audiences, making clear that a range of ideals can match the possibilities of frontier research. In recognition of the arguably related issue of sexual harassment in the sciences, professional associations have been taking a lead in highlighting and tackling this particularly noxious gender asymmetry problem (Kuo 2017). Government spending priorities should also recognize that optimal R&D outcomes would benefit from greater participation by women, and thus try to better balance defence-related spending with investment in broader types of basic science.

Prescriptions are necessarily constrained by this study's own limitations, which pave a productive trajectory for future research. In particular, both the time-series and cross-sectional data hamper more clearly-defined conclusions. The range of countries is relatively small, especially for a complete set of structural and control variables. Time-series availability is relatively truncated, sporadic, and not well-aligned, making potentially invaluable within-country variation over time virtually impossible to define. This constraint makes it difficult to understand whether countries in fact repel female researchers as they increase their own levels of defence spending, or whether current high-defence-spending countries are somehow different in that respect than present low-defence-spending nations. Consistent data on relative participation by research subfield would allow considerably more insights into which disciplines need special attention. Coordinating and analyzing better-aligned, deeper, and longer international datasets could be tremendously useful to decision-makers across academic, governmental, and nongovernmental institutions identifying further ways to maximize the potential of global R&D by balancing the gender asymmetry in research.

Notes

1. According to UNESCO data on human resources in R&D, on average, women made up approximately 35.8 per cent of all researchers in seventy-six countries for which data was available in 2005. Women made up an average of 39.4 per cent of all researchers in eighty-three countries for which data was available in 2015. In 2015, the average percentage of female graduates from tertiary education in STEM was 34.8 per cent, while females made up 63.4 per cent of non-STEM graduates and 56.5 per cent of all graduates from tertiary education.
2. This argument applies not only to the natural sciences, but also to the social sciences. Examples from the USA where defence spending has directly influenced the social sciences including Project Camelot of the 1960s, as well as the more recent Minerva Research Initiative (Robin 2008).
3. The complete list of countries used: Argentina, Austria, Azerbaijan, Belgium, Bulgaria, Chile, Colombia, Croatia, Czech Republic, Denmark, El Salvador, Estonia, Finland, France, Greece, Hungary, Ireland, Italy, Kyrgyzstan, Latvia, Lithuania, Macedonia, Malaysia, Mexico, Mongolia, Poland, Romania, Slovak Republic, Slovenia, South Korea, Spain, Turkey, and the UK. Turkey and Azerbaijan are counted as Asian countries in the above categorization. This sample of countries was chosen based on the availability of data.
4. UNESCO defines 'researchers' as 'Professionals engaged in the conception or creation of new knowledge, products, processes, methods and systems, as well as in the management of these projects.' The particular measure used here is the headcount of both part-time and full-time researchers. According to UNESCO data, the vast majority of researchers in most countries work within the science and engineering fields. Averaging across countries during the time period used in this study, roughly 70 per cent of researchers worked in natural sciences and engineering, roughly 15–20 per cent worked in social sciences, and roughly 10 per cent worked in humanities and arts, with the remainder classified as 'other.'
5. Because of the broad cultural and institutional nature of this analysis, it is not likely that changes in the independent variables will have much of a significant effect from on a year-to-year basis, but more likely over a somewhat longer period.
6. Charles and Bradley briefly explain the difference between horizontal and vertical sex segregation: 'Horizontal segregation refers to distributional inequalities that are not explicitly hierarchical, while vertical segregation refers to inequalities in rank or prestige' (2009: 930). As in their 2009 study, the present study focuses on horizontal segregation.
7. This could, however, also be seen as a potential strength of the Pooled OLS model. The countries that have more complete statistical records are often those that have more substantial STEM institutions, meaning that the Pooled OLS results would give more weight to countries whose STEM institutions play a larger role on the international stage, which may be worth emphasizing in this analysis.
8. At best, there are about 15 years of data per country available, but most countries have much less than this, often with data missing between individual years.
9. Fixed-effects regressions of the panel data consistently produced nonsignificant estimates, likely due to the lack of within-country over-time variation of variables alongside the inclusion of time trends. These regressions, which emphasized the explanatory power of Between versus Within estimations, are available from the authors upon request.
10. A separate forthcoming work by one of the co-authors attempts to establish a stronger causal relationship by examining time-series data in the USA, covering a span of roughly 30 years.
11. Because the panel data is unbalanced, we used a weighted least squares Between-effects regression as an additional robustness check. The results of this model (included in Appendix) are very similar to the results of the pooled OLS model.
12. The methodology used for this third model is based on Weiler (2001).
13. Because the estimated value $\hat{k}_i$ is used as the dependent variable in the second stage of this model, both regressions of the two-stage process must be bootstrapped in order to obtain the standard errors of the coefficient estimates in the second stage. All second stage results reported in Table 6 reflect standard errors from bootstrapping with 10,000 replications.
14. All standard errors reported in Tables 5 and 6 are robust standard errors clustered by country.

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Appendix

Table A.1. Between-effects regression (weighted least squares).

Variables	Percentage of researchers who are female			
	Percentage of total	Percentage in business enterprise	Percentage in higher ed.	Percentage in government
Percentage of govt. spending to defence	−1.178* (0.450)	−0.744 (0.564)	−1.219** (0.424)	−1.478** (0.426)
Percentage of female STEM grads	0.769** (0.240)	0.694* (0.300)	0.445† (0.226)	0.869*** (0.227)
Percentage of women in parliament	0.080 (0.155)	0.230 (0.194)	0.113 (0.146)	0.143 (0.147)
FLFP/MLFP	0.104 (0.119)	0.159 (0.149)	0.044 (0.112)	0.191 (0.113)
Log GDP per capita	−8.703** (2.845)	−15.210*** (3.566)	−4.350 (2.682)	−8.876** (2.698)
Fertility rate	−3.264 (3.625)	−5.960 (4.544)	−0.681 (3.417)	−8.604* (3.437)
Days of paid mat. leave	0.009 (0.025)	0.012 (0.031)	0.011 (0.024)	−0.017 (0.024)
N	76	76	76	76
n	33	33	33	33
R-squared	0.5782	0.5608	0.4312	0.5719

Significance levels: ***P < 0.001; **P < 0.01; *P < 0.05; †P < 0.10.