DISSERTATION

# FEMALE PARTICIPATION IN RESEARCH AND DEVELOPMENT:

# THE ROLE OF GOVERNMENT AND DEFENSE SPENDING


Submitted by

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# ABSTRACT

## FEMALE PARTICIPATION IN RESEARCH AND DEVELOPMENT: THE ROLE OF GOVERNMENT AND DEFENSE SPENDING

This study analyzes how defense spending has biased research and development (R&D) institutions and the path of technological change in a specifically gendered way. Military considerations have long played a significant role in the development of science, technology, and industry. The large role played by military spending in shaping R&D has biased R&D institutions towards militaristic purposes, especially in the United States. Furthermore, this relatively militaristic organizational culture in science, technology, engineering, and mathematics (STEM) may affect men and women differently. Prior research indicates that women may be more likely than men to self-select out of STEM due to a greater aversion to militarism, and militaristic institutions may be more likely to discriminate against women and/or reinforce occupational segregation frameworks based on more traditional gender roles. Chapter 1 applies a difference-in-difference methodology to demonstrate how changes in Federal defense R&D spending in the U.S. can alter the gender composition of engineers in the U.S. Chapter 2 uses panel data from 46 different countries to assess the effects of defense spending on the differing gender compositions of research workers across countries. Using the institutional framework of ceremonial encapsulation of technology, Chapter 3 analyzes the broader institutional structures of STEM work and R&D, specifically the ways in which defense spending implicitly genders the institutional structures of STEM in the United States, and proposes avenues for future research on this topic.

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# INTRODUCTION

Disinterested, detached, autonomous, independent, indifferent, impartial, objective. These adjectives are often used to describe science and scientists, to convey the idea that science and scientists are ideally meant to be free of all values and biases that could potentially distort their pursuit of scientific truth. But there are serious limits to how much science can insulate itself from the biases and values of its social environment, particularly with modern science, done in modern society. Scientists have never truly been islands unto themselves, and many had been acknowledging debts to their predecessors long before Isaac Newton's well-known declaration to have stood on the shoulders of others in order to realize his great scientific accomplishments. Furthermore, the independent development of calculus by Gottfried Wilhelm Leibniz at roughly the same time as Newton is just one of many examples of multiple simultaneous scientific discoveries (the independent development of evolutionary theory through natural selection by both Charles Darwin and Alfred Russel Wallace is another well-known example). These indicate that the social context has always played a large role in explaining which scientific discoveries are made, when/where they are made, who they are made by, etc.

In the modern age of science, from the end of World War II up to the present day, the social context arguably plays an increasingly important role in guiding the path of scientific and technological change, especially the political and economic contexts. The Manhattan Project not only began the Atomic Age, but also the era of "big" science. "Big" science brought the promise of bigger results from new technological developments, but of course it also required bigger investments in resources: time, labor, money, etc. Amassing ever-increasing pools of resources means involving larger numbers of people and/or people with larger pools of wealth and resources.

As science and technology become bigger and bigger in order to surpass the improvements realized by preceding "big" science, science and technology must become increasingly social, political, and economic endeavors. While some claim that scientific institutions are value-free, comprising an autonomous "republic" unto themselves, it is more difficult to argue that social, political, and economic institutions are value-free. How likely is it then that science can remain free of the values of the institutions that provide the foundation upon which scientific work is done? Can we expect that these institutions, which function as patrons of science, don't expect their patronage to produce something that reflects their own particular values?

Even if it is true that the scientists and engineers themselves are free from the biases and values of the broader society, their work can still be guided in the directions most favored by their sponsors. The relationship between the sponsor of science and the sponsored scientist may perhaps be most effective under these circumstances, where individual researchers can still claim objectivity and freedom from bias, maintaining the myth of a value-free science, while in actuality the values of the sponsors are given preference. The myths of individual scientists' autonomy and value-free science serve to obscure the actual power and control exerted over scientific and technological progress by those who control large concentrations of wealth and resources. Another useful related myth, that economic markets are driven primarily by individual entrepreneurs, is also applied to the world of science and technology, where the scientist-entrepreneur draws attention away from the larger role played by government agencies and large corporations, who supply large investments for research and development (R&D). Scientists themselves often play into these myths which serve powerful public and private institutions. Scientists may argue against increasing public intervention in or social control of science, such as regulations that are seen as impositions on their intellectual freedom, while at the same time largely ignoring the role played by entrenched economic interests (Florig 1986). The reality is that the large political and economic institutions which have the wherewithal to fund truly "big" science, while perhaps unable to determine *precisely* what technologies are developed along the path of technological change, will be able to steer science and technology in a direction that satisfies their own goals. Malcolm Goggin (1986) explains some of the mechanisms through which elite institutions can shape technological progress:

> Through their sponsorship, patrons influence providers of new discoveries and applications; their choices of research questions, methods, and protocols; and when and through what channels they will communicate their results. Scientists and technologists, like most people, are self-interested individuals whose choices invariably reflect the interests and concerns of their patrons, whether these be the military, "study sections" in federal agencies, capitalists sponsoring research, or leaders in their own professional circles. These patrons are elites in the sense that they set the standards for what constitutes scientific progress. As David Noble describes the relationship between technologists and their patrons, "The power relations of society…define to a considerable extent what is technically possible."

Among the powerful and elite institutions which have a large influence on scientific and technological progress, my focus is on the military. The military is and has been an important shaper of science and technology, particularly in the United States, and primarily since the end of World War II. Military control and funding of R&D has had a profound impact on which technologies have been developed during the era of "big" science, as well as on the nature and structure of R&D institutions themselves. For one, researchers may be less likely to question the authority and the motives of the military. They are probably also less *able* to question the military's influence on R&D due to the wall of secrecy and classification behind which military R&D often takes place. Under such circumstances, the free flow of ideas that is so essential to science is severely restricted. Researchers are unable to share their results with many others who might find the information quite useful for their own work, or who might be able to assist with the military researchers' own work, hindering the overall progress of science all for the sake of secrecy.

Militaristic confidentiality doesn't just limit scientists' access to potentially useful scientific knowledge, but also serves to shield military R&D from the public scrutiny of taxpayers. With the Department of Defense (DoD) distributing the majority of U.S. Federal Government funds for technological development, this means that (1) using the national defense as a justification for a technology development project is the surest way to receive government funding for that project, and (2) if such funding is given by the DoD, that development project will also be relatively free from the scrutiny of the public (who are paying the taxes to fund it). This risks the creation of a democratic disconnect between the true patrons of the technology and the developers of the technology, if those patrons are unable to monitor, evaluate, or oversee the projects they are effectively funding. This increases the danger that such projects will serve primarily the interests of the DoD and those with close economic ties to the DoD. While it is certainly possible that these interests may overlap with the interests of the public tax base, and that technology developed for the DoD will fully serve the interests of the public, the lack of transparency in military R&D leaves open a greater risk that the public interest will not be served. And while military institutions are less apt to make their R&D projects open to the public, the public are also less likely to take interest in and to try to exert their influence on national security policy than social policy, ceding political authority to non-elected officials (Goggin 1986). Consequently, the public is more likely to be fearful of the end products of science produced without their consent, all in the name of national defense. Technophobia and anti-intellectualism could become increasingly common without democratic governance of R&D and the path of technological change.

Because science in the 21$^{st}$ century is an increasingly social endeavor, requiring substantial financial resources and interactions between large numbers of people, then it must be also seen as an essentially *political* endeavor. If researching science and developing new technologies are fundamentally political activities, then they should be governed democratically. Does this mean science should be a participatory democracy, a multi-tiered representative democracy, a revisionist democracy ruled by competing groups of elites, or one of many other permutations of "democracy"? I leave this question outside the scope of the present research project. For my purposes here, the main point is that the hierarchical, authoritarian, nontransparent, and exclusionary characteristics of the military and the R&D done by/for the military undermine the basic principles of democratic governance.[1] Many scientists and directors of science policy may prefer to restrict public participation in constructing scientific policies and institutions, arguing that scientific experts are the ones best qualified to make decisions regarding these policies and that too much democratic participation would only make scientific institutions less efficient, ultimately impeding scientific progress. But science is politically and economically interlinked with society, on one hand by the supply of crucial resources needed to conduct science, many of which are provided by taxpayers, and on the other hand through the profound changes in political and economic circumstances that science and technology can bring to the broad population. Science and technology's roles in society are too important to allow them to be controlled by an elite few who may not have the public's best interests in mind and who may be more easily coopted by vested interests if they need only to focus their influence on just those few who control science policy.

[1] Some argue that these characteristics also undermine the basic principles of good science (Merton 1968).

An essential part of this discussion of democratic governance of scientific institutions is the issue of who gets included in or excluded from the scientific process. Who gets a seat at the table? Who gets to decide the intended impacts and uses of science and technology? While this depends in part on the ways that science and technology are governed, it also depends on who is actually conducting scientific research and who is developing new technologies. Focusing the goals of R&D on the restrictive goals of the military is likely to exclude viewpoints that run counter to these goals, as well as those who hold such viewpoints. The following chapters argue that this is yet another way that the military biases science and technology: by exacerbating the exclusion of women from science and engineering. Whereas the goals of scientists and engineers typically must be adapted to the goals of their R&D patrons, to at least some extent, I argue that women are less apt then men to adapt to the militaristic goals of the DoD, and that women are also viewed by the DoD as less apt than men to be suitable for working toward such R&D goals.

Adopting a feminist institutional approach to addressing the question of why there are relatively few women in STEM (particularly in engineering), demonstrates how society is structured in such a way that, relative to societal norms of masculinity, societal norms of femininity are less compatible with the norms of engineering and the "hard" sciences. Alison Jaggar (2014) explains this approach:

> Unjust social structures create systematically unequal advantages or disadvantages for the members of different social groups…. They also structure the options that are socially available to individuals by assigning costs and benefits to various choices…. We ask whether institutions present systematically different options to people with varying gender, class, and racial-ethnic identities, and whether the social costs of selecting particular options are higher for some social groups than others. We are less interested in individual decisions than in the ways those decisions are shaped by structures that provide the menu of choices and set the social prices of various options.

In order to enhance participation in R&D institutions, to ensure that they are as just and fair as possible, understanding the systematic biases of R&D governance is key, especially where those biases may inhibit participation and economic justice. Rather than focusing just on individual women's choices, and how these can be adapted to better fit with existing R&D institutions, we can complement that approach by also focusing on institutional structures and how these might be adapted to be more diverse, inclusive, and therefore more democratic.

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# CHAPTER 1

## DEFENSE R&D SPENDING AND WOMEN'S PARTICIPATION IN ENGINEERING IN THE UNITED STATES

### Introduction

Much has been written about the occupational segregation of men and women in the labor force of the United States and other economically developed nations, and specific attention has been paid to the relatively low percentages of women working in STEM fields. While there is a need for greater female participation in STEM, on one hand to avoid labor shortfalls in growing high technology industries (Broecke et al 2016), others have also stressed the importance of increasing diversity in STEM, in terms of gender as well as many other measures of diversity, as key to improving scientific research and innovation (Harding 2015; Jaggar 2014). Significant progress has been made to increase opportunities for the inclusion and advancement of women in these fields, but some particular fields within STEM have seen more progress than others. For example, while nearly half the individuals working in life, physical, and social sciences are now female, still less than 20 percent of those in engineering occupations in the U.S. are female.[2] Not only does the persistent gender gap in engineering potentially reinforce gender stereotypes, limit women's job preferences and opportunities, and reduce the overall quality of engineering talent, it could also result in profound gender biases embedded within our technologies (Cockburn 1981, 1983).

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[2] Prior research by Maria Charles and Karen Bradley (2002, 2009) has shown that there is significant variation across countries when it comes to the level of gender segregation across STEM fields. Most countries in the OECD have relatively low representation of women in engineering, when compared to other STEM fields, but this is not the case for all OECD countries, and is even less common among non-OECD countries. A key finding from their 2009 study is that gender norms and the level of income per capita in each country will influence the level of gender parity in engineering within that country. This suggests a possibility that biases in government spending could also play a role in explaining the variation of female representation in engineering across countries. Hypothetically, countries that spend more on defense may have relatively low representation of women in R&D (all else equal). I address this question in the following chapter.

So far, many possible explanations have been offered as to why there are still such low numbers of women working as engineers, such as socialized or learned differences in preferences, discrimination against women (implicit and explicit), incompatibility of STEM work schedules with family responsibilities, lack of female networks and mentors, as well as many others (Alon et al 2015; Ceci et al 2014; Ecklund et al 2012; Hunt et al 2012; Hunt 2016; Xie & Shauman 2003). In addition to individual characteristics, recent literature has also stressed the important role played by the social/cultural workplace environment in the retention of female engineers (Ayre et al 2013; NAS 2006, 2007). In this chapter I will focus on the broader role that Federal Government R&D spending plays in engineering and the development of technology in the United States. I will be addressing the broad question of why more women don't work in engineering, but this study also attempts to provide evidence that the qualitative nature and purpose of U.S. Federal funding of R&D may bias engineering and technology in a gender-specific way. Because the U.S. Federal Government and the U.S. economy play major roles in the research and development of many of the world's major technologies, the existence of a gender bias in the development of these technologies could heavily influence the research and development of technology in many other countries around the globe. This could also put the United States at a competitive disadvantage, particularly with European countries paying greater attention to reducing gender biases in STEM/R&D through gender mainstreaming policies.

To begin this investigation, I will start by focusing on three basic facts about the U.S. economy: (1) engineering and the development of new technologies are heavily influenced by Federal Government spending on R&D, (2) U.S. Federal Government spending on R&D is in turn heavily influenced by the DoD, and (3) relative to men, women place more value on care labor and altruistic work and are more averse to militarism.

**Literature Review**

**(1)** In the United States, Federal Government subsidies for research and development have played a major role in the economy, particularly since the end of World War II. A variety of high technologies, including modern aircraft, semiconductors, lasers, solar panels, computers, etc., have greatly benefitted from these subsidies (Ruigrok & Van Tulder 1995; Tyson 1992). When comparing the many possible paths of technological change that *could* have been realized since the end of World War II to the path that technological change actually *did* follow, the role of the U.S. Federal Government cannot be ignored. Figure 1.1 shows the percentage of US national R&D that has been funded by the Federal Government and other sources over the past six decades.

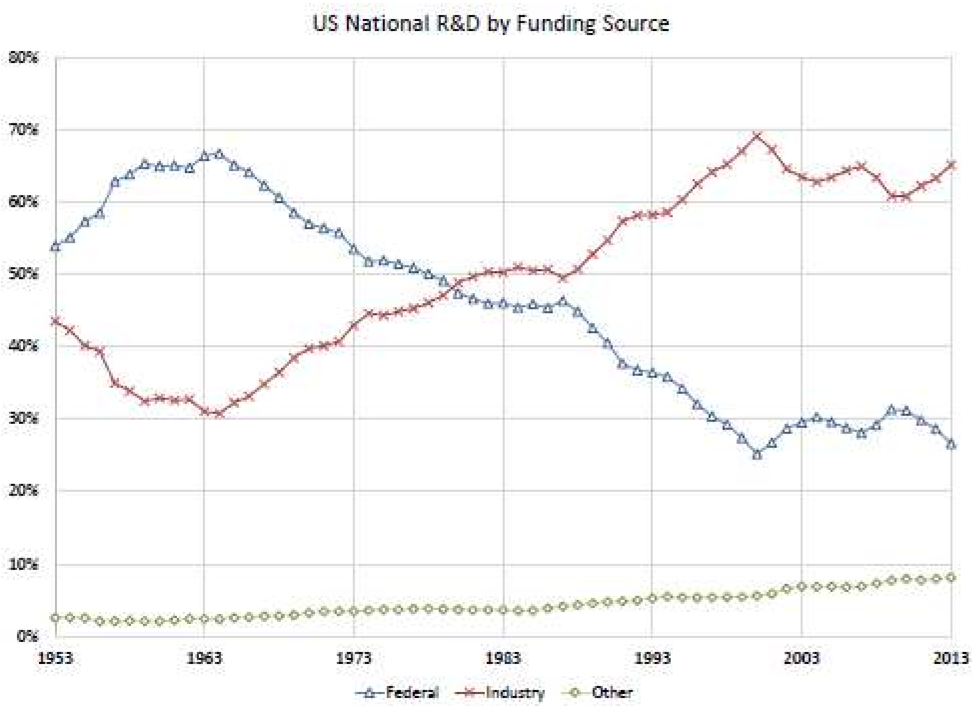



Figure 1.1
*Source*: American Academy for the Advancement of Science (National R&D By Funder, 1953-2013)

Although Federal Government spending on R&D has not accounted for quite as large a share of total R&D spending in recent decades, government R&D still plays a critical role in the research and development of new technologies. This is because the private economy still tends to underinvest in many types of R&D due to the high risk and high uncertainty associated with such long term projects that have questionable payoffs and relatively large positive externalities. The current realities of the market economy leave private industries hesitant to invest in many potentially lucrative technologies, but the government is much less beholden to the market and profit motives when making R&D investment decisions. This allows the government to engage in much more long term (high risk) investment projects with potentially transformative (high reward) technologies, such as computers or clean energy production (Block 2008; Mazzucato 2013). The National Science Board (2001) has argued that:

> even as the Federal share of funding has declined in national research & development, non-Federal sectors of the economy - industry, academe, state, and non-profit - have come to rely on the Federal Government to play a critical role in funding long-term investments in science and engineering discovery, education and innovation.

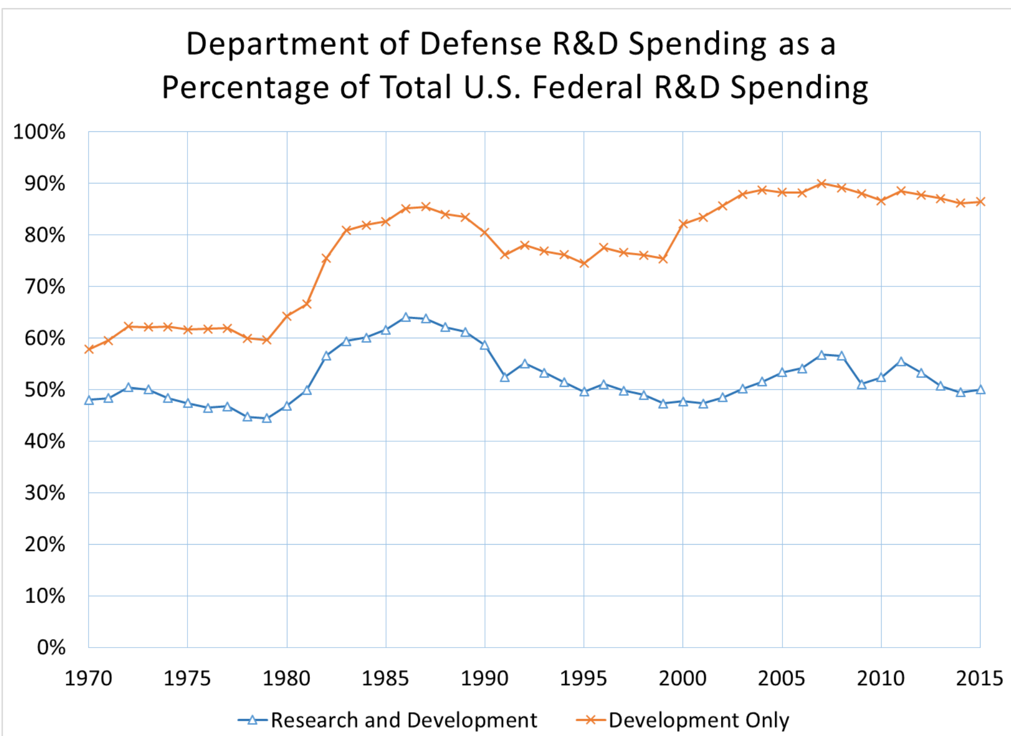



Figure 1.2

*Source:* National Science Foundation, Survey of Federal Funds for Research and Development, Detailed Statistical Tables. NSF 03-325. Detailed Historical Tables: Fiscal Years 1951–2002, Tables 7 and 46.

**(2)** Compared to most other industrialized nations, the United States spends a very large portion of its national budget on its military. The existence of this bias in overall Federal spending also translates into a bias in Federal spending on R&D. Figure 1.2 shows that since 1970 roughly half of all Federal expenditures on R&D have come from the Department of Defense. We can also focus on development, rather than research and development, since development is typically much more closely associated with engineering. By excluding research, we see in Figure 1.2 that development is even more closely tied to the DoD, with nearly ninety percent of federal funding for development coming from the DoD in recent years.[3] Daniel Sarewitz (2000) has written about the importance of this military bias in federally funded science and engineering:

> The role of the military in organizing the nation's current science and technology enterprise cannot be overstated. From the end of World War II until the launch of Sputnik by the Soviet Union in 1957, 80 percent or more of all federally funded research was justified in terms of national security needs. The creation of the American research university and the explosion of technology-intensive industries that lay at the core of the nation's economic growth were strongly and directly catalyzed by funding from the Department of Defense. Moreover, when Sputnik stimulated a highly politicized call for an increased national commitment to civilian research, the lion's share of resources during the subsequent decade went to the manned space program, which in many ways was simply a technological adjunct to the Cold War defense effort. For example, many of the information management, advanced materials, and navigation and control technologies necessary for space travel were also applicable to - or borrowed from - the nation's high technology defense system.

In the same article, Sarewitz further discusses the implications of this bias. For one, he argues, it led to a bias in favor of the physical sciences, and "Even in academia, many important fields, such as electrical engineering, computer science, and materials science, are today strongly supported by Defense Department funds…" Largely due to the effects of path dependence, this framework remains in place well after the end of the Cold War, despite many potential benefits

[3] Since WWII, the US Federal Government has typically spent more on development than basic or applied research. It spent more on development than basic and applied research *combined* (total research) almost every year during the second half of the twentieth century, but during the 1990s the amount spent on development was roughly equal to the amount spent on total research.

that could come from a greater emphasis on life sciences and social sciences in a twenty-first century faced with the issues of globalization, climate change, sustainable development, etc. It is also arguable that the militaristic approach associated with the Cold War required a top-down approach to science, in opposition to the ideology of autonomy and bottom-up arrangement now favored by many scientists (particularly with respect to basic research). Despite the efforts of other research agencies to support a bottom-up ideology, such as the National Science Foundation and the National Institutes of Health (NIH), the persistently large role played by the DoD in funding R&D continues to encourage the research and development of new technologies for military purposes (Sarewitz 2000). The influence of militarism in engineering is also evident further back in history, as the first engineering school in the U.S. was the United States Military Academy at West Point, New York, established in 1802, and even the use of the term "engineering" (which began in the fifteenth century) originally referred specifically to the design of devices used in warfare (Ambrose et al 1997).

Connecting these first two facts, that engineering is closely influenced by Federal R&D spending and U.S. Federal R&D spending is biased by the DoD, it follows that engineering in the U.S. is likely to exhibit some of this bias toward the DoD. How might the field of engineering have been different in another (less militaristic) historical context, and how might this have different implications for men versus for women?

**(3)** Much feminist economic literature has focused on differences in labor market outcomes, as well as differences in labor market preferences, of women relative to men. Some prior research has focused on why women tend to work in care labor fields at much higher rates than men, despite being paid less than if they worked in non-care fields requiring comparable levels of education and experience (Badgett & Folbre 1999; Folbre 2001). But money is certainly not the only important aspect of any job, and gender norms and socialization lead to different genders emphasizing different aspects of jobs as more valuable than others. For instance, while men are likely to place more importance than women on the money earned from a job, women are more likely to place more importance on the social and altruistic rewards of a job. In one study by Marini et al (1996), the authors found that it was significantly more important to women that their job was "helpful to others" and "worthwhile to society." This difference between the two genders has remained remarkably consistent over time, and the authors argue that this focus on altruistic rewards tends to limit women's job choices in ways that men's choices are not.

Although engineers are generally paid more than workers in other STEM fields, women tend to focus more on other aspects of these jobs besides money, instead focusing on the altruistic and social aspects (Diekman et al 2011; Marini et al 1996; Weisgram & Bigler 2006). Based on the evidence presented in these previous studies, a man would be more likely to focus on the pay acquired through engineering, while a woman would be more likely to focus on her ability to interact with and to help people through engineering. If the nature of engineering work is generally biased towards military purposes, then women may view these jobs as less appealing (despite the relatively high pay) if militarism is more likely to be at odds with their ideals of altruism and care.[4]

In addition, US public opinion surveys show a pervasive gender gap in opinions of military spending and the use of military force by the US – women are *less* in favor of both than men (Eichenberg 2002). Also of significance is the well-researched aversion of the military towards women and femininity, more broadly. This aversion can often manifest in the discrimination,

[4] Certainly, one could argue that the military epitomizes altruistic work, and it is partly based on the idea of providing a public good. However, other research has shown that this view is also heavily male-biased, and that women are much more likely than men to express altruism in a non-militaristic way (Kohn 1990). A case in point is that even among *civilians* (excluding servicemen and women), in 2006 35.9 percent of DoD employees were female, while 58.9 percent of employees in the Department of Veterans Affairs were female. (When including servicemen and women, the percentage of females in the DoD is much lower.)

sexual harassment, and bullying of women by members of the military (Koeszegi et al 2014; Silva 2008). Others have also found evidence 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 (Matthews et al 2009; Robinson Kurpius & Lucart 2000). The influence of military and defense institutions in R&D could transmit some of these biases from the DoD to STEM institutions. With women making up a minority of employees in the DoD, this may also reinforce the position of women as a minority in STEM fields, particularly engineering.[5] Prior research (Cockburn 1983; Enloe 1983; Hacker 1981, 1989; Weber 1997) has also acknowledged that the influence of militarism in science and technology may deter the participation of women. However, none of this research has examined in detail the political and economic mechanisms behind this phenomenon, and not much focus was given to measuring this impact of militarism in quantitative terms.

To summarize these three key facts, there appear to be two biases in the US economy: on the one hand, federal spending is biased in favor of military spending, and on the other hand, women are biased against militaristic work. These two biases interact with each other due to the influence that Federal Government spending has on technology and the type of work available to women. One aim of this study is to see if these two biases coincide or differ in any significant way, in order to determine if it is likely that the biased system of military spending by the federal government may be gender-biasing economic outcomes in engineering and technology development. Of the three key facts reviewed above, I will focus on fact (2) as the exogenous variable. The fact that the U.S. Federal Government biases so much of its R&D spending towards

[5] Coincidentally, in 2016 women made up 15.48 percent of active duty enlisted service members in the US military, and 14.2 percent of engineers in the US economy. Koeszegi et al (2014) describe instances of such low representation as exhibiting characteristics of tokenism: women tend to distance themselves from traditional femininity, assimilate to majority norms, and trivialize discrimination.

the military is the most circumstantial and arbitrary of these three facts, and therefore most easily modified. It is based on political decision-making, and although the military-industrial complex has been deeply imbedded in U.S. political decisions since World War II, levels of military spending may be more malleable than women's job preferences. This can be seen when comparing U.S. Federal R&D spending to that of other countries within the OECD, and even within NATO. The US spends a much higher percentage of its R&D on defense than any of these countries, except Israel. Many of these countries spend at or below one percent of federal R&D on defense, while the U.S. range is close to fifty percent. Yet practically all of these countries have significantly fewer women working in engineering/technology fields than in other STEM fields.[6] The international existence of institutions that reinforce gender norms and the socialization of women is more pervasive and resistant to change, though they are certainly not unchangeable.

Even within the U.S., the American Reinvestment and Recovery Act (ARRA) provides a telling example of the relative flexibility of government spending. This economic stimulus package included over $15B in funding for R&D (spent during 2009 and 2010), with less than two percent of that amount going to the DoD. The majority of the ARRA funding for R&D went to the Department of Health and Human Services, with large portions also received by the Department of Energy and the National Science Foundation, demonstrating substantial flexibility in the mix of U.S. federal R&D spending. While the ARRA represents a relatively small, short-term shock to the mixture of federal R&D spending, the U.S. has undergone some much larger,

[6] I am not arguing that military spending is the sole reason for the low numbers of women working in engineering fields, but simply that military spending plays a significant role in this disparity. For instance, in countries that have very low defense spending and also have low female representation in engineering, it would be difficult to argue that the low number of female engineers is caused solely by high defense spending. In the following chapter I address the question of whether female representation in engineering would be relatively lower if defense spending were relatively higher (all else equal).

longer-lasting shocks to Federal spending policies, due to essentially exogenous developments in international affairs, such as the end of the Cold War and the attacks of September 11, 2001.

For these reasons, the main independent (policy) variable in my analysis will be the relative levels of defense and non-defense R&D funding from the U.S. Federal Government, and the main dependent variable will be the percentage of women working and studying in engineering. The specific measures I will use for each of these variables will depend on which variant of my model I am testing in the empirical portion of this chapter.

**Data**

To measure changes in the independent variable, I will be using data from the American Association for the Advancement of Science and the National Science Foundation's Survey of Federal Funds for Research and Development. These sources provide information on the dollar amounts of federal R&D spending in any given year, based on agency, allowing for comparisons of defense and non-defense R&D spending over time.

To measure changes in the dependent variable, I will be using two separate datasets. The Current Population Survey (CPS) from the Bureau of Labor Statistics includes information on the number of employees in different fields and subfields of the U.S. economy each year, including specific numbers of males and females in each field. It has data for several subfields of engineering (such as aerospace engineering or chemical engineering), as well as engineering as a whole (the aggregate of these subfields). The data reported in the CPS include the percentage of female employees in each subfield, except for any subfield with fewer than 50,000 total employees in any given year, indicating less reliable figures for these smaller subfields. Because of this, I will focus only on the six largest subfields of engineering in the CPS dataset: aerospace, chemical, civil, electronic, industrial, and mechanical engineering, all of which have more than 50,000 employees during the entire time period tested. One limitation in this dataset is that the definitions of many occupational fields and subfields were redefined in 1983, 2003, and 2011, so that the longest string of continuous data is from 1983-2002. Trends in the data cannot be compared across these three breaks, so I will be focusing on 1983-2002 when using the CPS dataset.

The Survey of Graduate Students and Postdoctorates in Science and Engineering (SGS) includes figures on the numbers of graduate students in the U.S. each year in several fields of engineering, science, and health. It specifies the number of students in each field by gender, and unlike the CPS, the SGS maintains consistent definitions of subfields of engineering from 1975 to 2007, allowing for the use of a longer time period than the CPS dataset. Further, the SGS includes data for the same six fields used with respect to the CPS dataset, plus two additional fields of comparable size that can be included in the empirical analysis: biomedical and metallurgical/materials engineering.

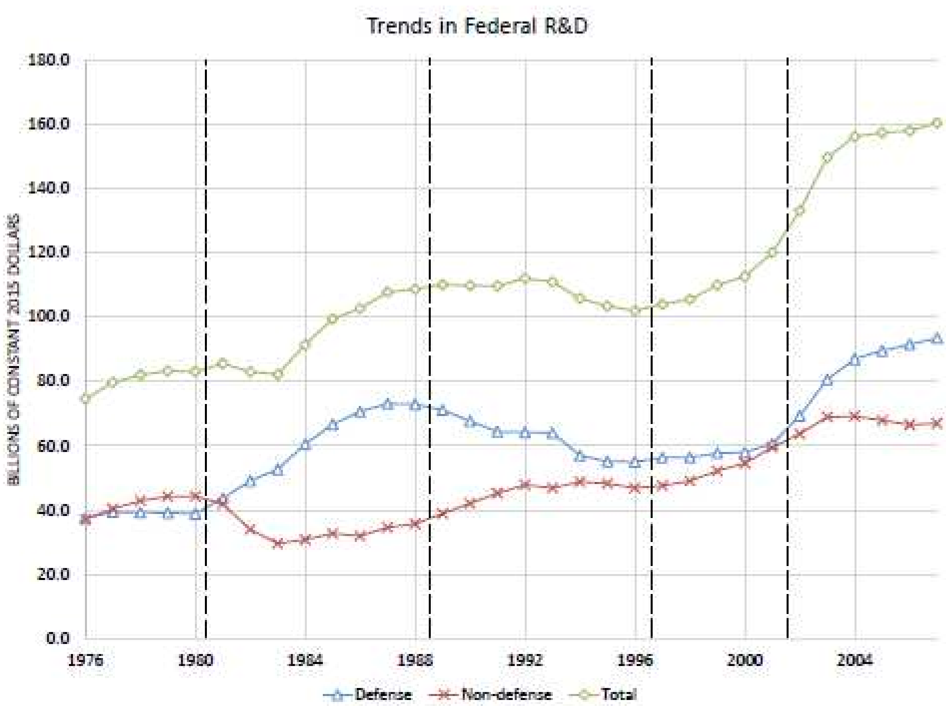



Figure 1.3

*Source*: American Academy for the Advancement of Science (Defense, Nondefense, and Total R&D, 1976-2016)

For both datasets, the basic methodological approach will be a quasi-natural experiment framework. The U.S. federal R&D spending environment underwent three major exogenous shifts near the beginning of the 1980s, the 1990s, and the 2000s: the major shift in economic policies instituted by the first Reagan administration beginning in 1981, the end of the Cold War near the end of the 1980s, and the beginning of the "War on Terror" shortly after the attacks of September 11, 2001. Figure 1.3 shows that these three events (represented by vertical dashed lines in the figure) coincide with major shifts in the mix of defense and non-defense R&D spending by the US federal government. An additional (fourth) dotted line in Figure 1.3 breaks the 1975-2007 period into five distinct periods, the basis of which may be easier to explain when looking at Figure 1.4, which shows in more detail how the five separate periods were delineated in relation to the events mentioned above.

In order to define each period of the experiment, I will focus on the year-to-year change in the mix of defense and non-defense R&D spending, since my dependent variable will also focus on year-to-year changes in the gender composition of engineering. This is represented by the X-marked line in Figure 1.4, where the triangle-marked line represents the difference between the percentage of total Federal R&D made up of defense R&D and the percentage of total Federal R&D made up of non-defense R&D in any given year. For example, in 1990 defense R&D made up 61.67 percent of total Federal R&D, and non-defense R&D made up 38.33 percent of the total, resulting in a difference between the two of 23.34 percent, as shown by the triangle-marked line. This difference of 23.34 percent is 6.02 percent lower than the difference in 1989, which was 29.36 percent. The X-marked line then displays a value of negative 6.02 as the independent variable for 1990. The first period of the late 1970s represents a post-Vietnam, pre-Reagan period that exhibited minimal changes in the mix of defense and non-defense R&D, with just a slight increase in non-defense R&D while defense R&D was roughly constant. Starting in 1981, Reagan's first year in office, defense R&D began to increase rather sharply, while non-defense R&D began to decrease. Defense R&D continued to increase more rapidly than non-defense R&D until about 1987, when the two increased at roughly the same rate for two years in a row. By 1989, the trend of the early 1980s had clearly reversed, represented by the large negative value of the X-marked line in Figure 1.4. This same rationale is then applied to the following two periods.

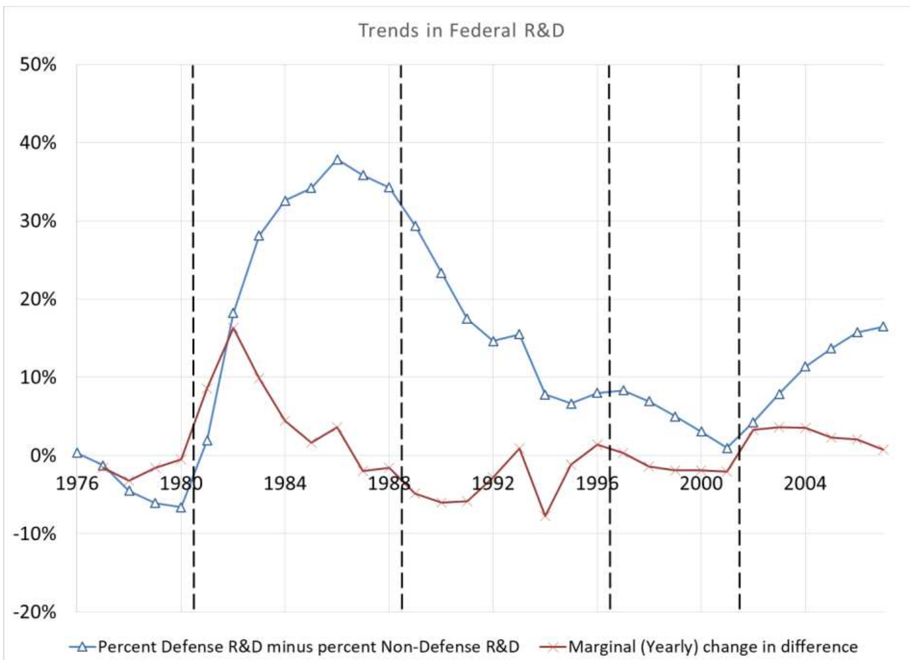
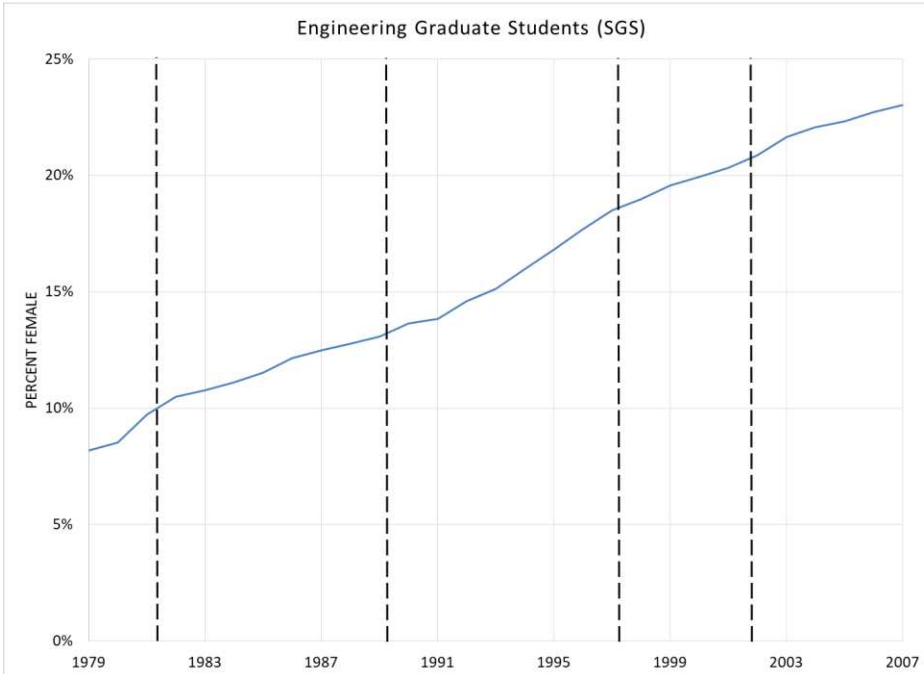



Figure 1.4
*Source*: American Academy for the Advancement of Science (Defense, Nondefense, and Total R&D, 1976-2016)

Based on the yearly change in the difference between defense and non-defense R&D spending, the five periods can be sorted into three categories. First, the post-Vietnam (75-80) and dotcom bubble (97-01) periods serve as the control periods, where there is little to no change in the mix of types of R&D spending. Next, the post-Cold War "peace dividend" (89-96) period serves as a positive treatment period (theoretically increasing women's likelihood of participating in engineering). Lastly, the Reagan years (81-88), and the post-9/11 years (02-07) serve as negative treatment periods.



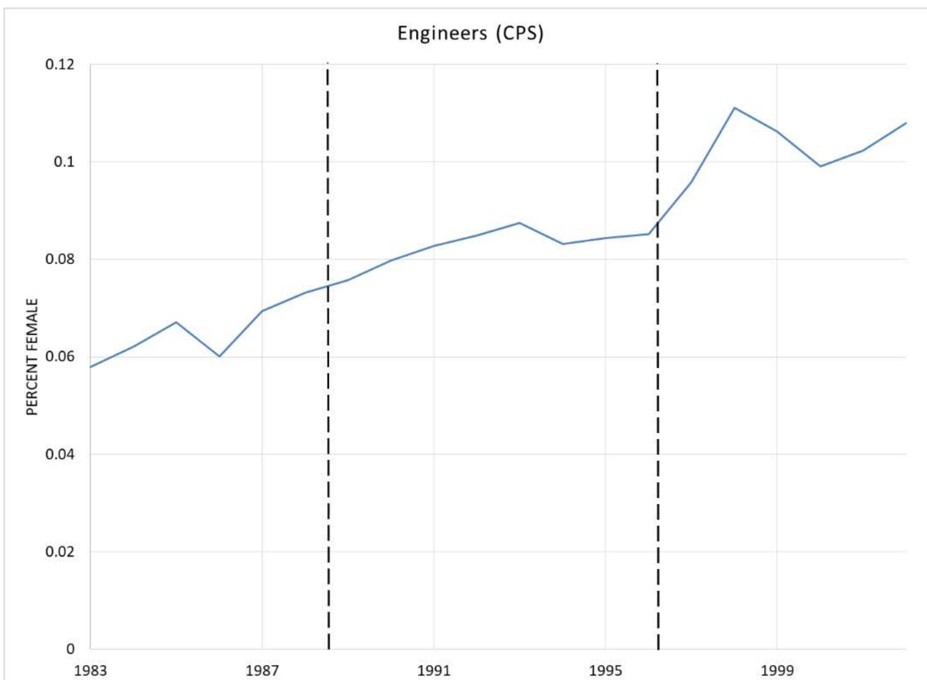




Figure 1.5

*Source*: Survey of Graduate Students and Postdoctorates in Science and Engineering (Table 1: Graduate students in science, engineering, and health in all institutions, by field: 1975–2013 and Table 4: Female graduate students in science, engineering, and health in all institutions, by field: 1977–2013); Current Population Survey Tables, Annual Averages (Table 11)

My general hypothesis is that a greater emphasis on defense R&D spending will cause fewer women to participate in engineering. Based on this, I would expect to see relatively rapid increases in the percent of female engineers during the peace dividend period and relatively slow increases, possibly even decreases, during the Reagan years and post-9/11 years.

The graphs from each dataset in Figure 1.5 show a general trend of increasing percentages of women in engineering across all periods. While the graduate student data does exhibit more rapid entrance by women during the 1990s (as suggested by my hypothesis), the CPS data show a pretty constant slope across all time periods. However, the CPS graph doesn't necessarily invalidate my hypothesis because there is no counterfactual example in this graph. It is possible that there actually was a positive effect of reducing defense R&D (and increasing non-defense R&D) during the peace dividend period, which increased the rate of women entering into engineering, and that without this positive effect on the trend, the graph would have actually exhibited less growth of the percent of women in the period after the Cold War due to some other effect deterring women from working in high tech fields during the early 1990s.[7] Figure 1.6 may help illustrate this point.

The first graph in Figure 1.6 shows the same data from the previous CPS graph for the engineering field, but now compares it to the math and computer science field. Whereas both

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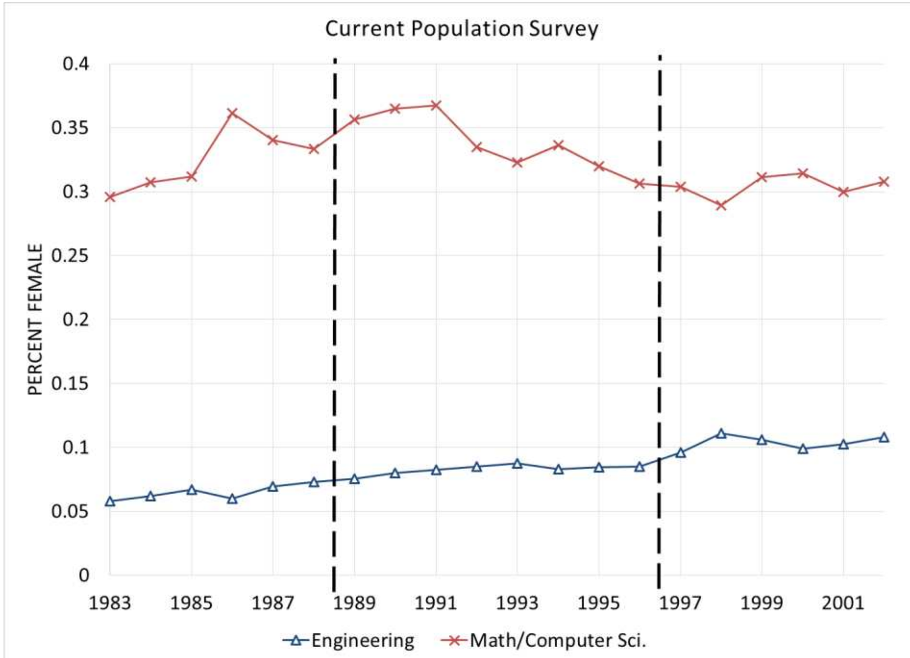
[7] One possible reason for such an effect in the U.S. economy during the early 1990s could be the transition to the "third wave" of feminism after the 1980s. Maria Charles and Karen Bradley (2009) have argued that:

> The segregative effect of gender-essentialist beliefs is intensified, moreover, by a strong Western cultural emphasis on individual self-expression and self-realization that has been diffusing worldwide wince World War II and is today most clearly evident in affluent late-modern societies. Because gender remains so central an axis of human identity, we argue that self-expressive value systems tend to encourage the development and enactment of culturally masculine or feminine affinities. Girls may, for example, be more likely to express an aversion to mathematics and avoid related programs where self-expression is a legitimate, and even normative, criterion for curricular choice.

Another possible explanation could come from rising economic inequality and the associated changes in U.S. class structure during these time periods.



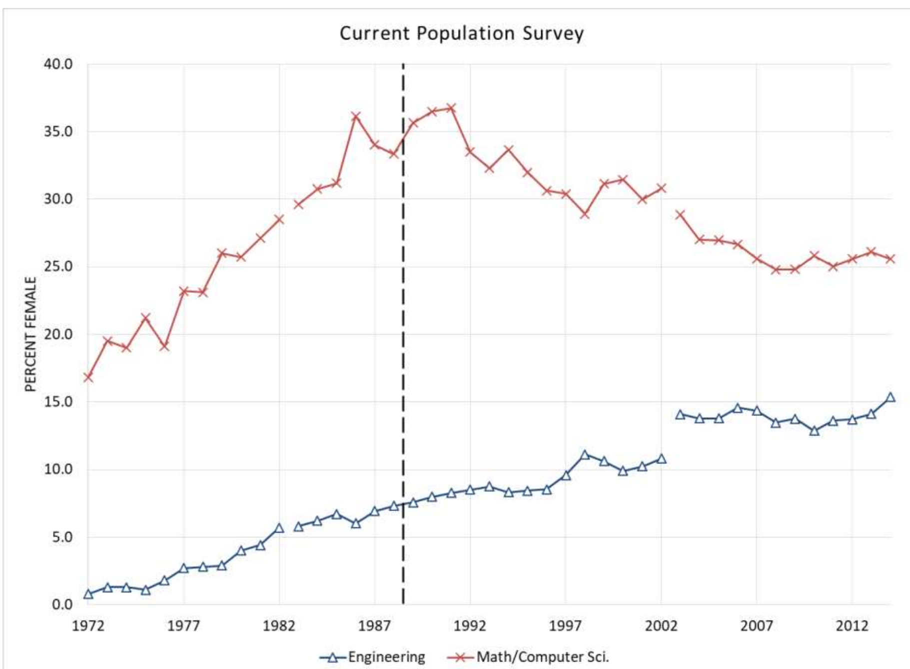




Figure 1.6

*Source*: Current Population Survey Tables, Annual Averages (Table 11)

fields show a slight upward trend during the 1980s, engineering continues this trend through the 1990s, while the trend for math and computer science becomes negative after the 1980s. The second graph in Figure 1.6 adds additional time periods to compare the time trends of engineering against math/computer science during the 1970s and 2000s, even though these periods cannot be directly compared to the trends of the 1980s and 1990s.

Despite using the math/computer science field to illustrate this last point, there are not enough occupational fields that are suitable for comparison to engineering, so I will focus on the *subfields* of engineering and compare across these subfields instead. When looking at these subfields (aerospace, chemical, etc.), the *trend* of percent female employees *within* any of these subfields does not exhibit any significant changes between time periods, relative to the other subfields.[8] What the data show is that some of the subfields have relatively high percentages of female employees (industrial and chemical engineering) while other groups have relatively low percentages of females (electrical, aerospace, and mechanical engineering), and that this division is consistent across time periods. This is apparent in the first graph of Figure 1.7, which shows a clear gap between the percentage of female graduate students in the bottom three subfields and the five subfields above, consistently across the time periods studied.[9] The second graph of Figure 1.7 does not show as clear of a delineation between the two groups, as there are greater variations of the percentage of women in these subfields of the workforce (as well as breaks in the data trend after 1982 and 2002). Using trendlines for each of these subfields makes the pattern more clear.[10]

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[8] As an alternative, the independent variables used in the models below were regressed *on the change in the percentage of female graduate students and employees* in subfields of engineering as the dependent variable (instead of growth of the size of the subfield). Regressions were done with subfields aggregated together, as well as dividing them into relatively male and female groups, and each subfield was regressed individually. No significant results were found with any of these models.

[9] England et al (2007) describe a similar long term trend in data for US doctoral degree recipients.

[10] The one possible exception is civil engineering, which seems to belong to the low female percentage group at the beginning of the 80s (in the CPS data, but not the SGS data), but this subfield exhibits a greater increase in its percentage of female employees

These figures indicate that changes in the mix of defense and non-defense R&D spending are not altering the percentages of women working within particular subfields, rather some subfields tend to be consistently more male-dominated across time periods, a kind of horizontal segregation effect. However, if the change in R&D spending alters the relative sizes of each of these subfields, for instance creating more jobs in industrial engineering (a less male-dominated field) and reducing jobs in aerospace engineering (a more male-dominated field), this could serve to increase the percent of female employees in the broader field of engineering at the aggregate level. My strategy will be to test if such a relationship exists by using the percentage yearly growth of grad students or employees in each subfield as my dependent variable.

Because of my choice of dependent variable, I'm not inferring that there is any significant change in the nature/appeal of each subfield of engineering due to the changes in defense spending. I am inferring that the changes in spending will bias engineering as a whole more towards some subfields (which may appeal more to women or men) and less towards other subfields. The number of men and women within each subfield shrinks (or grows) at roughly the same rate when the spending pattern changes, so the trend in the share stays roughly the same *within each subfield*. The share of men and women in the aggregate engineering field can change, however, depending on which subfields are shrinking or growing, the ones with higher shares of women or the ones with lower shares of women.

To clarify, the engineers are not self-sorting based on the spending, and subfields aren't becoming more or less gender-biased when spending changes, the engineers are mainly self-sorting based on which fields appeal most to them and which ones they can obtain a job or graduate

across time than any of the other 5 subfields, suggesting it may belong in the former category with industrial and chemical engineering as it has relatively higher percentages of females in periods closer to the present.

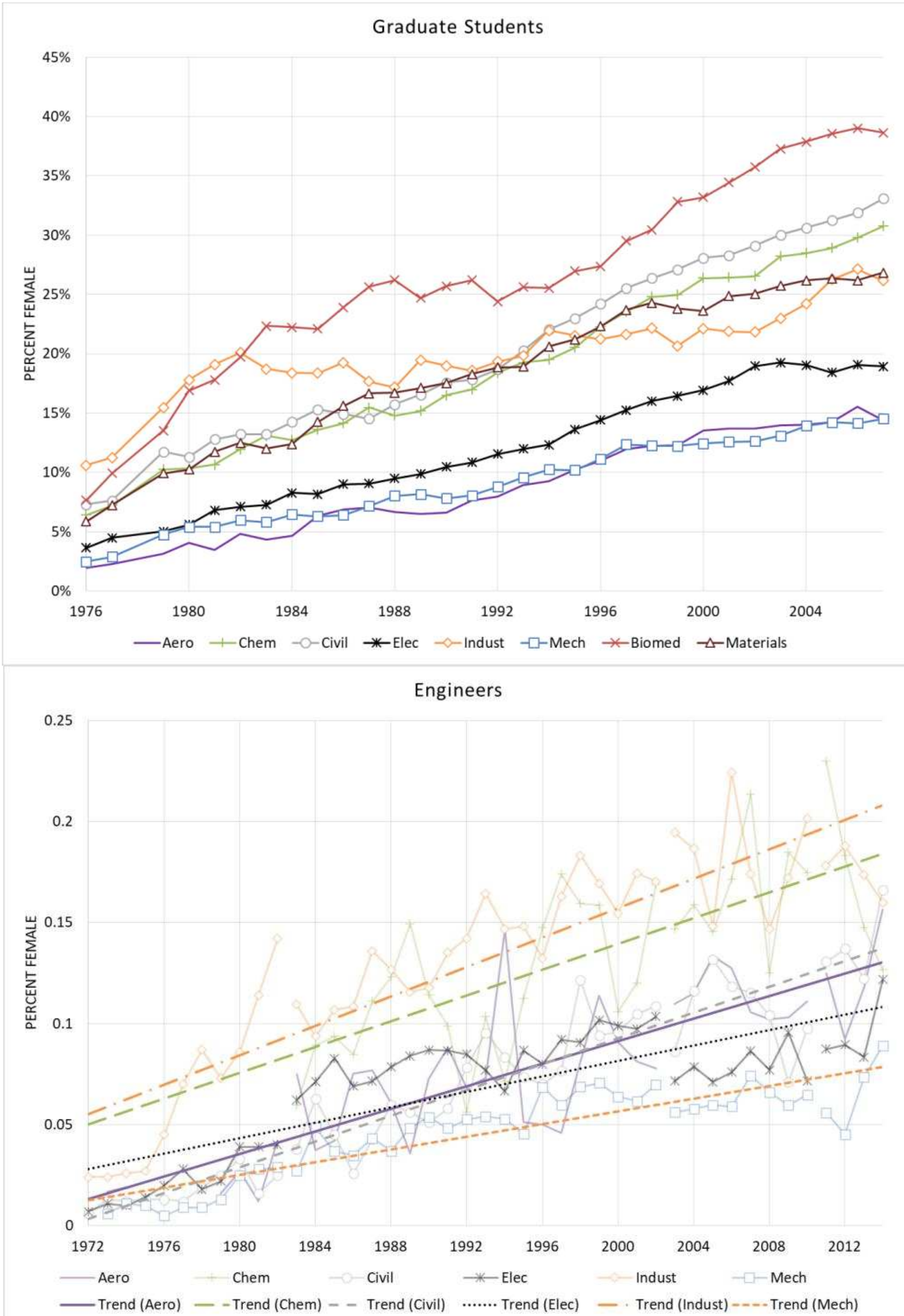


Figure 1.7

*Source*: Scientists and Engineers Statistical Data System (SESTAT Integrated Survey Data); Current Population Survey Tables, Annual Averages (Table 11) student position in. For example, a particular subfield might appeal more to a particular engineer because she perceives that it is aligned with her values, however it might be relatively difficult to get a job in or keep a job in, depending on government funding. She might look at other subfields which have more funding support from the government, but maybe the work in this subfield is less appealing to her, especially if the government funding supporting those jobs is not aligned with her values. Obviously the ideal situation for her job prospects would be if there was strong job growth in a subfield that most appealed to her values, but that job growth will depend to a significant extent on government funding, which can be quite variable. If there is a relative lack of engineering jobs available in an engineer's particular field, they will likely end up working in another industry, such as healthcare, education, business administration, or finance (Preston 2004).

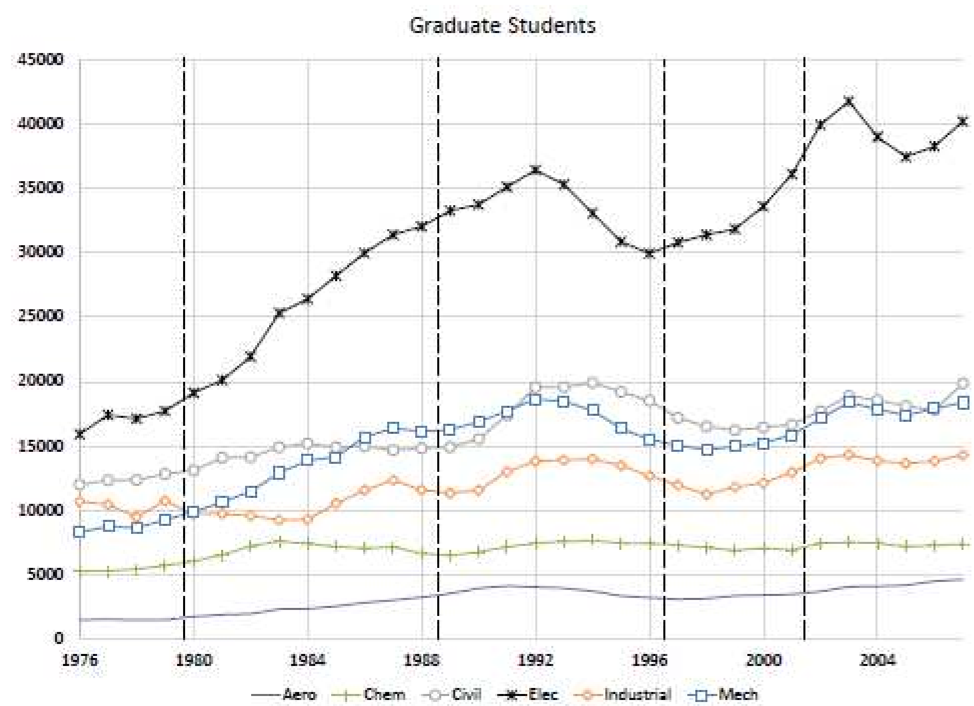

Figure 1.8
*Source*: Scientists and Engineers Statistical Data System (SESTAT Integrated Survey Data)

Figure 1.8 shows the trends in the number of graduate students in the U.S. for the same six subfields of engineering from 1975-2007. Electrical, mechanical, and aerospace engineering are the three fields most closely associated with the DoD and also have lower percentages of female employees than the other fields. Based on my hypothesis, this means that these three fields should see relatively high growth in the 80s and relatively low growth in the early 90s, when compared to other engineering subfields. In the figure we see aerospace, mechanical, and electrical engineering experiencing relatively rapid growth during the 80s (and the 00s to a lesser extent), while chemical, industrial, and civil[11] engineering grow relatively rapidly during the early 90s.

**Methods**

My hypothesis is that subfields of engineering with relatively more women will exhibit more growth during periods when federal R&D spending is more biased towards non-defense R&D and less growth during periods when federal R&D spending is more biased towards defense R&D. To test this hypothesis, I will first separate the different subfields of engineering, eight for the SGS dataset and six for the CPS dataset, into two groups. One group will be subfields that consistently have relatively high percentages of women in them, and the other group will be the subfields with relatively low percentages of women in them. Based on historical data from the SGS, aerospace, electrical, and mechanical engineering have consistently had lower percentages of female graduate students, by a margin of more than five percent. The CPS data shows a very similar division of subfields by gender, with civil engineering as the only exception. After dividing the subfields into these two groups, I will then look to see if the treatment of altering the mix in

[11] Among graduate students, civil engineering consistently has a significantly higher percentage of females than aerospace, electrical, and mechanical engineering.

defense and non-defense R&D spending affects each group differently by using a difference-in-difference framework.

My analysis will apply two similar models to each dataset. One model for each dataset will use a basic difference-in-difference model with a categorical variable to measure the effects of treatment during the natural experiment. I will also slightly modify this model for each dataset by incorporating the magnitude of the treatment administered during the natural experiment, and by also incorporating the extent to which each subfield is relatively biased towards men or women. Because the treatment and control periods are delineated by referring to the yearly change in the mix of defense and non-defense R&D spending, I will simply use the magnitude (in percentage) of this yearly change as my main independent variable, instead of using a categorical variable to indicate the treatment period. Similarly, because the treatment groups are delineated by the relative percentages of females in each group, in the second model I will use the actual amount by which the percentage of females in each subfield differs from the average percentage of females in all subfields combined.

The first model I will apply to the SGS dataset will take the following form:

$$y_{it} = \beta_0 + \beta_1 dTrtmt_t + \beta_2 dFem_i + \beta_3 (dTrtmt_t * dFem_i) + e_{it}$$

where $y_{it}$ is the percentage yearly growth in the number of graduate students in subfield $i$ in year $t$. $dTrtmt_t$ is a categorical variable that takes on a value of zero during the control periods (1975-80 and 1997-2001), a value of one during the positive treatment period (1989-96), and a value of negative one during the negative treatment periods (1981-88 and 2002-07). $dFem_i$ is a dummy variable that takes on a value of one if the subfield has a relatively high percentage of females (chemical, industrial, civil, metallurgical/materials, or biomedical) or a value of zero otherwise (aerospace, electrical, or mechanical). The coefficient of interest is $\beta_3$, which measures the difference-in-difference in growth between the two groups. Based on my hypothesis, I would expect this coefficient to be positive, indicating that growth of the subfields with more women would be higher than the other subfields during the peace dividend period and lower during the Reagan years and post-9/11 years.

The second model applied to the SGS data will be very similar to the first:

$$y_{it} = \beta_0 + \beta_1 Trtmt_t + \beta_2 Fem_{it} + \beta_3 (Trtmt_t * Fem_{it}) + e_{it}$$

Here $Trtmt_t$ represents the actual yearly change in the difference between the percent of total R&D spending going to defense and non-defense, rather than a categorical variable. $Trtmt_t$ varies from a minimum value of -16.30 percent in 1982 to a maximum of 7.72 percent in 1994, with an average of -0.52 percent. This allows for the incorporation of more detail in this model when compared to using just negative one, zero, and one. $Fem_{it}$ is generated by first calculating the difference between the percent female in a subfield in each year and the average percent female in all subfields combined in that same year. For example, if females made up 15 percent of all engineering graduate students in year *t*, and females made up only 10 percent of graduate students in mechanical engineering in that same year, mechanical engineering would receive a value of negative 5 for that year. Then the average of this value for years $t$ and $t-1$ for subfield $i$ gives $Fem_{it}$ (since the other independent variable and the dependent variable represent changes across years $t$ and $t-1$). Again, I expect a positive value for $\beta_3$, based on my hypothesis.

The models applied to the CPS data will be slightly different, due to the availability of additional data on all other non-STEM fields (which were not included with the SGS data). Incorporating non-engineering fields allows the model to control for economy-wide fluctuations, such as recessions, that are likely to affect engineering fields but are not unique to engineering. In addition, these economy-wide fluctuations may have somewhat different impacts on female fields versus male fields. By incorporating non-engineering occupational fields the model will then take the form of a difference-in-difference-in-difference model.

The first model applied to the CPS dataset will take the following form:

$$y_{it} = \beta_0 + \beta_1 dEngr_i + \beta_2 dTrtmt_t + \beta_3 dFem_i + \beta_4(dEngr_i * dTrtmt_t) + \beta_5(dTrtmt_t * dFem_i)$$

$$+ \beta_6(dEngr_i * dFem_i) + \beta_7(dEngr_i * dTrtmt_t * dFem_i) + e_{it}$$

where $y_{it}$ is the percentage yearly growth in the number of employees in subfield $i$ in year *t*. $dTrtmt_t$ is a categorical variable that takes on a value of zero during the control period (1997-2001), a value of one during the positive treatment period (1989-96), and a value of negative one during the negative treatment period (1983-88).[12] $dFem_i$ is a dummy variable that takes on a value of one if the subfield has a relatively high percentage of females or a value of zero otherwise.[13] $dEngr_i$ is also included here to differentiate between engineering and non-engineering occupational fields because engineering fields are assumed to be much more closely tied to federal R&D spending than non-STEM fields. $dEngr_i$ takes on a value of one for engineering subfields or zero otherwise. The coefficient of interest is now $\beta_7$, which measures the difference-in-difference-in-difference between the two groups of engineering subfields. Based on my hypothesis, I also expect the estimate of this coefficient to be positive, indicating that the female-biased engineering subfields will grow more rapidly than the male-biased subfields during the

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[12] I excluded the year 2002 from this dataset because it began a new trend in R&D spending, and the CPS data did not use comparable engineering subfield categories after this year.

[13] For the engineering subfields, the values of *dFem*$_i$ used with respect to the CPS data were very similar to those used with respect to the SGS data. For greater detail on determining the *dFem*$_i$ values for engineering subfields and non-engineering fields, see Appendix A.

peace dividend period, and the female-biased subfields will grow more slowly during the Reagan years.

The difference between this last model and the second model applied to the CPS dataset is analogous to the difference between the two models applied to the SGS dataset; that is, I will simply replace the $dTrtmt_t$ and $dFem_i$ variables with $Trtmt_t$ and $Fem_{it}$ variables in order to capture the effects of the more detailed changes in these variables.

**Results**

Table 1.1 displays the results of pooled OLS regressions of the SGS data. The top half of the table shows the results from applying the first model to all eight engineering subfields, with four different sets of estimates depending on whether year effects and/or biomedical engineering are included or excluded. The difference-in-difference estimates are shown in the third row of the table as the estimate of the coefficient corresponding to the interaction term $dTrtmt_t * dFem_i$. The first model estimates the difference-in-difference between the two groups of engineering subfields as 0.0207, which is statistically significant at the five percent level.[14] This estimate indicates that the subfields with higher percentages of female grad students grew roughly 2 percent faster, on average, than the other subfields during the peace dividend period and roughly 2 percent slower than the other subfields during the Reagan and post-9/11 years, in support of my hypothesis.

[14] Because the difference-in-difference-in-difference models used here have multiple years within each treatment period, there is a possibility that serial correlation of the standard errors could be biasing the standard errors downwards, which would lead to an overstatement of the statistical significance of the coefficient estimates. Further, using clustered robust standard errors is also problematic because clustering at the subfield level results in only 8 clusters, whereas having at least 50 clusters is ideal for making inferences using clustered robust standard errors. Given the realities of the data available for the study in this chapter, it seems that there is no ideal way to handle the standard errors. Angrist and Pischke (2008) suggest multiple possible ways to address serial correlation, such as bias-reduced linearization, but they also suggest using standard errors clustered at the subfield level, even when the number of clusters is quite low. In general, they suggest using the maximum of both conventional and clustered robust standard errors as a best practice. In all tables of results in the present chapter, the maximum of the conventional and clustered robust standard errors is reported to maintain conservative estimates of statistical significance by subjecting the coefficient estimates to multiple different tests. The results of the robustness test reported in Table 1.3 also help to guard against the potential for overstatement of statistical significance due to serial correlation.

The bottom half of Table 1.1 shows the results from applying the second model to this dataset. The difference-in-difference estimate for this model is 2.498, statistically significant at the

**Table 1.1: Survey of Graduate Students**

| Variables | Model 1 Results | | | |
|---|---|---|---|---|
| *dFem* | -0.00121 | -0.00121 | -0.0112 | -0.0112** |
| | (0.00721) | (0.00589) | (0.00703) | (0.00532) |
| *dTrtmt* | -0.0282*** | -0.0308 | -0.0282*** | -0.0188 |
| | (0.00677) | (0.0223) | (0.00630) | (0.0205) |
| ***dFem*** x ***dTrtmt*** | **0.0207*** | **0.0207***** | **0.0236***** | **0.0236***** |
| | (0.00857) | (0.00700) | (0.00834) | (0.00632) |
| Observations | 248 | 248 | 217 | 217 |
| Adj. R-Squared | 0.0643 | 0.3761 | 0.0965 | 0.4811 |
| Year Effects | No | Yes | No | Yes |
| Biomedical Included | Yes | Yes | No | No |
| **Variables** | **Model 2 Results** | | | |
| *Fem* | 0.0895 | 0.0933 | -0.139** | -0.133** |
| | (0.0575) | (0.155) | (0.0683) | (0.0514) |
| *Trtmt* | -0.212*** | -0.738 | -0.170** | -0.126 |
| | (0.0718) | (0.936) | (0.0728) | (0.864) |
| ***Fem*** x ***Trtmt*** | **2.498*** | **2.500*** | **3.672**** | **3.827***** |
| | (1.279) | (1.218) | (1.470) | (1.105) |
| Observations | 248 | 248 | 217 | 217 |
| Adj. R-Squared | 0.0415 | 0.3732 | 0.0764 | 0.4792 |
| Year Effects | No | Yes | No | Yes |
| Biomedical Included | Yes | Yes | No | No |

Standard errors in parentheses

*** $p$<0.01, ** p<0.05, * p<0.1

ten percent level. The interpretation of this coefficient is slightly different because of the elimination in this model of the dummy and categorical variables. The estimate is roughly two orders of magnitude higher than in the previous model because in this model $Trtmt_t$ and $Fem_{it}$

are measured as a fraction between 0 and 1. However, the interpretation is roughly the same, with the positive estimate indicating that the fields with higher percentages of females experienced relatively higher (lower) growth when government spending shifted more towards non-defense (defense) R&D. For example, in this case a subfield where the percentage of women is 10 percent higher than another subfield could expect to grow roughly 2.5 percent faster than that other subfield when the difference between shares of non-defense and defense R&D increases by 10 percent.

The third and fourth columns repeat the analyses of the first and second columns, respectively, after having omitted the biomedical subfield, reducing the total number of subfields to seven.[15] Partly because biomedical engineering was not very well established prior to the mid-1970s, compared to the other subfields, it consistently experienced much more rapid growth than any other engineering subfield over practically all the time periods in this study.[16] Columns three and four show that omitting biomedical engineering results in larger difference-in-difference estimates with greater statistical significance.

Table 1.2 shows the results for both models using the Current Population Survey dataset. The estimates of the difference-in-difference-in-difference are shown in the third row of coefficient estimates. The magnitudes of the coefficients have the same interpretation as with the SGS dataset, except that the data of interest are number of employees, rather than graduate students. Again, the results support my hypothesis that the female subfields of engineering see

[15] The biomedical engineering subfield may be an outlier in this dataset because of its relatively small size at the beginning of the time period in the mid-1970s. In 1975, there were only 883 graduate students in this subfield, barely more than half the total in the next smallest subfield used in my sample, aerospace engineering (1,670). However, I decided to include it in part of the analysis here because by the end of the time period under review, it had grown to 6,904 graduate students, considerably larger than aerospace (4,616) and metallurgical/materials engineering (5,314) at that point in time.

[16] Not surprisingly, the increase in the size of the biomedical subfield follows rather closely the large increase in federal R&D spending by the National Institutes of Health during this same time period. The NIH has arguably been the only agency to pose any challenge to the dominance of the DoD in the area of federal R&D since NASA did during the Apollo missions of the 1960s. While the DoD still continues to account for nearly half of all federal R&D spending, the NIH has accounted for just over 20% of federal R&D since 2000, far more than any other non-defense agency.

**Table 1.2: Current Population Survey**

| Variables | Model 1 Results | | | |
|---|---|---|---|---|
| *dTrtmt* | -0.00629 | -0.0207 | -0.00629 | -0.0207 |
| | (0.00402) | (0.0181) | (0.00402) | (0.0181) |
| *dTrtmt* x *dEngr* | -0.0218 | -0.0218 | -0.0143 | -0.0143 |
| | (0.0153) | (0.0157) | (0.0136) | (0.0139) |
| ***dTrtmt* x *dEngr* x *dFem*** | **0.0431**** | **0.0431**** | **0.0420**** | **0.0420**** |
| | (0.0180) | (0.0185) | (0.0178) | (0.0183) |
| Observations | 306 | 306 | 306 | 306 |
| Adj. R-Squared | 0.0294 | 0.047 | 0.0241 | 0.0414 |
| Year Effects | No | Yes | No | Yes |
| Civil Engineering | Female | Female | Male | Male |
| **Variables** | **Model 2 Results** | | | |
| *Trtmt* | -0.129 | -0.369 | | |
| | (0.0757) | (0.257) | | |
| *Trtmt* x *dEngr* | 0.136 | 0.136 | | |
| | (0.231) | (0.238) | | |
| ***Trtmt* x *dEngr* x *Fem*** | **10.662** | **10.662*** | | |
| | (6.222) | (5.917) | | |
| Observations | 306 | 306 | | |
| Adj. R-Squared | -0.0072 | 0.0164 | | |
| Year Effects | No | Yes | | |

Standard errors in parentheses
*** $p$<0.01, ** p<0.05, * p<0.1

relatively higher growth rates than male fields during the peace dividend period, and relatively lower growth rates during the Reagan years. Model 1 was applied to the data with civil engineering categorized as either a male or female subfield, due to the ambiguity of this subfield's category mentioned above.[17] The results are fairly robust to the categorization of this subfield as the

[17] The new specification of the $Fem_{it}$ variable in the second model eliminates the need to categorize subfields into either the male or female group.

estimates changed only slightly when civil engineering is switched from the male group to a female group. By supporting my hypothesis, the results here indicate that patterns of federal R&D spending have influenced women's participation in engineering, and that increasing non-defense R&D spending and/or decreasing defense R&D spending could lead to higher percentages of female engineers.

**Table 1.3: Aggregated Time Periods**

| Variables | SGS (Model 1) | | Variables | CPS (Model 1) | |
|---|---|---|---|---|---|
| *dFem* | 0.000191 | -0.00966 | *dTrtmt* | -0.0109* | -0.0106* |
| | (0.00931) | (0.00564) | | (0.00566) | (0.00587) |
| *dTrtmt* | -0.0287*** | -0.0287*** | *dTrtmt* x *dEngr* | -0.0175* | -0.00945 |
| | (0.00901) | (0.00522) | | (0.00925) | (0.00880) |
| ***dFem* x *dTrtmt*** | **0.0227*** | **0.0253***** | ***dT* x *dE* x *dF*** | **0.0391***** | **0.0358**** |
| | (0.0114) | (0.00691) | | (0.0129) | (0.0139) |
| Observations | 24 | 21 | | 51 | 51 |
| Adj. R-Squared | 0.255 | 0.606 | | 0.300 | 0.248 |
| Biomedical Included | Yes | No | Civil Engineering | Female | Male |

Standard errors in parentheses
*** $p$<0.01, ** p<0.05, * p<0.1

As an additional robustness check against the possibility of serial correlation across years overstating the statistical significance of the above estimates, I analyzed each of these models against a modified version of both datasets. In these modified versions, instead of using individual observations for the growth of each subfield in each year (which could plausibly exhibit some serial correlation), I used the average yearly growth across the years of each time period. This means that there was only one observation for each subfield in each time period, eliminating the possibility of serially correlated observations of growth across years within the same time period.

The results of this new specification applied to Model 1 are shown in Table 1.3 and are comparable to the previous estimates, albeit slightly smaller in magnitude.[18]

I also address two potential shortcomings of the above models. First, the models all focus only on the changes in the pools of engineering graduate students and employees that occur in the same year as a change in R&D spending patterns. It is likely that the change in R&D spending will produce a lagged effect on engineers in following years. This first issue is addressed in Appendix B. Another potential shortcoming of the base models is that they are structured in a way that assumes that an increase in defense spending relative to non-defense spending will have the same magnitude effect as an increase in non-defense spending relative to defense spending, only the effects are expected to have opposite signs. Although these models produced statistically significant results, it is possible that these results may be driven largely by increases in defense spending relative to non-defense spending, while increases in non-defense spending have little to no effect, or vice versa.

To test for this possibility, the base models will be modified by splitting the $dTrtmt_t$ and $Trtmt_t$ variables. With respect to Model 1, in place of $dTrtmt_t$ there will be two new independent variables: $dDef_t$ and $dNondef_t$. Whereas $dTrtmt_t$ took on a value of zero during the control periods (1975-80 and 1997-2001), a value of one during the positive treatment period (1989-96), and a value of negative one during the negative treatment periods (1981-88 and 2002-07), $dDef_t$ will take on a value of one during the periods of high defense R&D spending (1981-88 and 2002-07) and a value of zero in all other periods, and $dNondef_t$ will take on a value of one during the periods of low defense R&D spending (1989-96) and a value of zero in all other periods.

[18] This robustness check was also applied to Model 2, producing similar results as shown above, which have been omitted for space.

**Table 1.4: Split Spending Variables (SGS)**

| Variables | Model 1 Results | | | |
|---|---|---|---|---|
| *dDef* | 0.0231* | 0.0172 | 0.0231* | 0.00822 |
| | (0.0132) | (0.0233) | (0.0123) | (0.0213) |
| *dNondef* | -0.0343** | -0.0885*** | -0.0343** | -0.100*** |
| | (0.0150) | (0.0238) | (0.0140) | (0.0216) |
| ***dDef* x *dFem*** | **0.00116** | **0.00116** | **-0.00517** | **-0.00517** |
| | (0.0166) | (0.0136) | (0.0163) | (0.0123) |
| ***dNondef* x *dFem*** | **0.0465**** | **0.0465***** | **0.0454**** | **0.0454***** |
| | (0.0189) | (0.0154) | (0.0185) | (0.0139) |
| Observations | 248 | 248 | 217 | 217 |
| Adj. R-Squared | 0.0714 | 0.3833 | 0.098 | 0.4869 |
| Year Effects | No | Yes | No | Yes |
| Biomed. Included | Yes | Yes | No | No |
| **Variables** | **Model 2 Results** | | | |
| *Def* | 0.278*** | -2.280 | 0.230*** | -2.219 |
| | (0.0545) | (2.469) | (0.0562) | (2.608) |
| *Nondef* | 0.0706 | 0.641 | 0.0642 | 0.795 |
| | (0.0543) | (0.777) | (0.0558) | (0.823) |
| ***Def* x *Fem*** | **-0.230** | **-0.269** | **-1.737** | **-1.888**** |
| | (0.876) | (1.061) | (1.057) | (0.816) |
| ***Nondef* x *Fem*** | **2.221**** | **2.158**** | **1.694** | **1.757**** |
| | (0.933) | (0.767) | (1.094) | (0.844) |
| Observations | 248 | 248 | 217 | 217 |
| Adj. R-Squared | 0.1042 | 0.3771 | 0.1156 | 0.4749 |
| Year Effects | No | Yes | No | Yes |
| Biomed. Included | Yes | Yes | No | No |

Standard errors in parentheses

*** $p$<0.01, ** p<0.05, * p<0.1

When applied to Model 1 for the SGS, the new split model equation will then look like this:

$$y_{it} = \beta_0 + \beta_1 dDef_t + \beta_2 dNondef_t + \beta_3 dFem_i + \beta_4(dDef_t * dFem_i) + \beta_5(dNondef_t * dFem_i) + e_{it}$$

and the equation for Model 2 looks like this:

$$y_{it} = \beta_0 + \beta_1 Def_t + \beta_2 Nondef_t + \beta_3 Fem_{it} + \beta_4 (Def_t * Fem_{it}) + \beta_5 (Nondef_t * Fem_{it}) + e_{it}$$

For Model 2, the treatment variables $Def_t$ and $Nondef_t$ are no longer measured relative to each other, as percentages of total Federal R&D, $Def_t$ is measured as the yearly percentage growth rate of defense spending, and $Nondef_t$ is measured as the yearly percentage growth rate of non-defense spending. This measures the effects of the magnitudes of defense and non-defense government spending, which is complementary to the focus on the mixture of the types of spending in the previous models.

This change in model specification is applied to all regressions of the SGS and all regressions of the CPS. The results for the SGS are shown in Table 1.4, and the results for the CPS are shown in Table 1.5. The first thing to note is that the expected sign of the difference-in-difference estimates for periods of high defense R&D spending is now negative (because the sign of the independent variable has been flipped for high defense spending periods in this version of the model), while the expected sign during high non-defense periods is still positive. The results in Tables 1.4 and 1.5 show that (except for one regression) defense spending typically does not have a significantly different effect on the growth of relatively female versus relatively male subfields. However, while the results here are not quite as uniform as with the base models, the SGS results indicate that there is a significant difference in growth between male and female engineering subfields during periods of relatively high non-defense R&D spending. The CPS results are somewhat mixed, with the Model 1 regressions producing similar results to those from the SGS dataset, and the Model 2 results producing no statistically significant results.

**Table 1.5: Split Spending Variables (CPS)**

| Variables | Model 1 Results | | | |
|---|---|---|---|---|
| *dDef* | 0.00982** | 0.0173 | 0.00982** | 0.0173 |
| | (0.00444) | (0.0198) | (0.00444) | (0.0198) |
| *dNondef* | -0.00320 | 0.0227 | -0.00320 | 0.0227 |
| | (0.00649) | (0.0146) | (0.00649) | (0.0146) |
| ***dDef*** x ***dEngr*** x ***dFem*** | **-0.0307** | **-0.0307** | **0.00576** | **0.00576** |
| | (0.0232) | (0.0238) | (0.0213) | (0.0218) |
| ***dNondef*** x ***dEngr*** x ***dFem*** | **0.0540** | **0.0540** | **0.0838**** | **0.0838**** |
| | (0.0391) | (0.0402) | (0.0340) | (0.0349) |
| Observations | 306 | 306 | 306 | 306 |
| Adj. R-Squared | 0.0205 | 0.0385 | 0.0245 | 0.0427 |
| Year Effects | No | Yes | No | Yes |
| Civil Engineering | Female | Female | Male | Male |

| Variables | Model 2 Results | |
|---|---|---|
| *Def* | 0.0757 | 0.0292 |
| | (0.0436) | (0.0996) |
| *Nondef* | -0.0343 | -0.435 |
| | (0.0393) | (0.361) |
| ***Def*** x ***dEngr*** x ***Fem*** | **-7.174** | **-7.174** |
| | (4.621) | (4.282) |
| ***Nondef*** x ***dEngr*** x ***Fem*** | **1.895** | **1.895** |
| | (2.598) | (2.618) |
| Observations | 306 | 306 |
| Adj. R-Squared | -0.0085 | 0.0169 |
| Year Effects | No | Yes |

Standard errors in parentheses

*** $p$<0.01, ** p<0.05, * p<0.1

**Discussion**

This study has presented an empirical example of how patterns in federal R&D spending may contribute to low female participation in engineering by using data on the numbers of engineering graduate students and employees in the United States, allowing us to quantify some of the more concrete impacts of the militaristic biases in our technology and related R&D spending policies. By separating engineering subfields into two groups, one with relatively high percentages of women and one with relatively low percentages of women, subfields with high percentages of women have tended to grow more during times of relatively low DoD-funded spending, while subfields with low percentages of women have tended to grow more during times of relatively high DoD-funded spending. More specifically, increasing federal R&D spending from non-defense agencies (which may or may not necessitate a reduction DoD R&D spending) might contribute to an increase in female participation in engineering overall.

This analysis of the changes in trends within the engineering field caused by changes in the type of federal R&D spending further indicates that the qualitative biases inherent in defense R&D spending may contribute to a gender bias in engineering as a whole. This is partly because acquiring and maintaining financial support are critical to technology development and engineering work, whether in graduate school or in the labor force. Because women are likely to be more concerned with the qualitative and intrinsic characteristics of their work, they are also more likely to be concerned with the nature and meaning of the R&D they are doing in STEM fields, which will inevitably depend on their funding sources. Coupled with women's relatively greater aversion to militarism than men, the military bias in federal R&D funding is likely to deter more women than men from studying or working in engineering, particularly those subfields most dependent on DoD for their funding. The effects of this spending bias on the gender composition of engineering appear to be particularly strong in the periods just before and just after the end of the Cold War, but are also present in the 1970s and 2000s in graduate schools.

While my analysis in this chapter focused specifically on the numbers of women working in engineering in the U.S., either as a graduate student or an employee, the potential implications of this gender bias in federal R&D spending are could be broader than this. For instance, a gender bias could extend beyond just the gender of the employees and graduate students in engineering to the types of technologies developed and even the nature of the engineering work itself. The relatively large size of the U.S. economy and the U.S. Federal Government mean that these trends in the U.S. could also influence the types of engineering and technology development done in many countries outside of the U.S., as well. For instance, these findings could help inform gender mainstreaming efforts in the European Union, by identifying additional institutional barriers to increasing women's representation in STEM/R&D work. Rather than taking the culture in STEM as a given, and then trying to simply provide equal treatment to both genders in STEM fields, recognizing ways in which R&D spending policies may be gender-biased may help accomplish the gender mainstreaming goal of fully accounting for how certain policies' implementation may have different effects on men and women (Pollack & Hafner-Burton 2000).[19]

While some have already argued that much of our current technology exhibits a male bias, others have also asserted that science itself has been male-biased in the way that it has been conceptualized and performed since the Enlightenment (Harding 1991, 2015). This bias may have been reinforced by the influence of the Cold War and the military-industrial complex, as Sarewitz (2000) has pointed out, and the results of my study here provide some quantitative evidence that supports these arguments. Future research may seek to address whether there are other types of biases, such as racial, environmental, authoritarian, etc., inherent in science and technology as a result of the influence of the DoD.

[19] More specifically, a better understanding of the gender biases of spending patterns could help policy makers to avoid what Rounaq Jahan (1995) calls an "integrationist" approach, where a gender perspective is introduced into existing policy processes without challenging the ends/goals of the broader policy paradigm. Instead, policy makers could incorporate gender in the ends/goals, in what Jahan calls an "agenda-setting" approach, by focusing on how different types of R&D spending could embed gender biases within STEM.

In terms of reducing this gender bias in R&D in the United States, one straightforward recommendation could be to diversify the Federal Government's R&D portfolio by having non-defense agencies contribute a larger share of the total. The results in Table 1.5 suggest that increasing non-defense R&D funding may be more effective in achieving this goal than simply cutting defense R&D spending. Significant ground has already been covered along these lines with large amounts of funding now coming from the NIH. However, it should come as no surprise that the NIH began significantly increasing its share of federal R&D during the 1990s, in the peace dividend era. After all, the National Science Board (2001) has declared that:

> The most important historical event affecting the national post-World War II consensus on Federal participation in science and technology is the end of the Cold War. Until that time, the rationale for Federal investments in research relied heavily on the contributions of science and technology to a strong national defense.

Compared to other industrialized nations, though, the U.S. Federal R&D investment portfolio is still quite lopsided in favor of defense. The U.S. is rather unique in this sense, with most other nations funding a much lower percentage of R&D for defense purposes (often well below one percent of all R&D). However, because the U.S. government is much larger than most other nations' governments, the absolute amount of money spent on R&D in the U.S. can significantly bias *global* totals of R&D spending towards defense purposes in a way that may foster gender biases in engineering and technology throughout the world

**CHAPTER 2**

DEFENSE SPENDING AND WOMEN IN RESEARCH: A CROSS-COUNTRY COMPARISON

## 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 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. With increasing percentages of women now completing tertiary education, many fear 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 & Bradley 2009; Duch et al 2012; National Academy of Sciences et al 2006; Xie & Shauman 2003). Many have examined differences in the primary and secondary education of boys and girls for possible clues. However, in their extensive study of women in science in the United States, Xie & 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*** [emphasis added] and as such reinforce the current gender segregation of occupation.”

The present study thus will focus on the roles played by two specific institutions that each make up a key part of the “broad social structure” in order to better explain low female representation in research. By recognizing the influence of (1) defense spending on research, and (2) the influence of gender roles on occupational choice – alongside how these two interact with each other – we seek to enhance our understanding of the relatively low international representation of women in research.

**Defense Spending and Research Priorities**

Public policies, which include both the amounts and types of public spending, clearly have a significant impact on the social structure of any country. When it comes to research careers, public spending is likely to influence the directions in which research-defining fields of science and technology 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. 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 2013).

With respect to the *demand* for R&D, the government plays a 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 defense. In many countries, public spending on defense has had a major impact on the advancement of science[20] and technology, and the potential military advantages

[20] This argument applies not only to the natural sciences, but also to the social sciences. Examples from the United States where defense spending has directly influenced the social sciences include Project Camelot of the 1960s, as well as the more recent Minerva Research Initiative (Robin 2008).

gained through technological superiority on the battlefield have motivated R&D since ancient times (Brodie & Brodie 1973; Chomsky 2002; Melman 1985; Ruigrock & Van Tulder 2013; Sapolsky 1977). Because one of the main roles fulfilled by the modern government is national defense, and subsidizing 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 commonly orienting towards the defense 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 defense R&D (Bellais & 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 countless other possibilities that could have been unlocked, had a different general direction – such as healthcare, education, or the environment – been explored. If government funding of R&D is biased towards defense spending, how then might this bias influence the gender of those performing the R&D?

**Gender Roles and Occupational Choice**

Gender roles influence the career choices of men and women. Fields that exhibit certain characteristics associated with gender roles for either women or men will have more acceptable career choices for each gender. With respect to female gender roles, many of the norms associated with women's labor come from the historical and cultural assignment of care for others: children, husbands, and the elderly (Badgett & 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 towards this kind of work (Diekman et al 2010, 2011). To quote Cynthia Cockburn (1999a), "[i]t seems as though for women more than for men the social purpose of work is important."[21] These values may help explain why women researchers in fact collaborate more than their male counterparts (Bozeman & 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 could significantly reduce the perceived communal and altruistic value of the R&D, particularly in the eyes of women. Richard Eichenberg's (2007) 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." In a more recent study, he also finds that "[t]he largest and most cross-nationally consistent gender difference occurs on issues of defense spending, spending on 'power,' the acceptability of war, and the use of military force." (Eichenberg 2012) Charles & 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 GDP per capita) in a country plays a significant

[21] The argument in this section is not based on an essentialist view of gender differences. Rather, the argument is that men and women have long been *socialized* to internalize different values, based on laws, gender norms, discrimination, etc. "It is important to emphasize here that this tradition is *culturally* rather than *biologically* maternal or womanly, for women's *social* location in science and society has been the primary factor in its creation." (Des Jardins 2010)

role in reinforcing sex segregation among researchers, arguing that asymmetries in career ideologies may intensify gender typing of curricular choice, especially in wealthier countries.

If women are more concerned with the communal and altruistic values inherent in their work, and they are more averse to militarism and defense spending, then a bias towards defense-related projects could be a greater deterrent to female researchers and potential researchers than to males. Further, 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, and sexual assault 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 & Lucart 2000). Where military institutions have significant influence on R&D, some of these biases could be transmitted to the R&D institutions. Taking these biases into account, we should expect to see lower percentages of female researchers in countries where defense spending is higher. This proposition is our underlying hypothesis of inquiry.

**Data**

Data from 46 nations (24 in Europe, 10 in Latin America, 9 in Asia[22], and 3 in Africa) are used in this study. The 4 dependent variables draw from UNESCO's data on human resources in research and development; these variables are summarized in Table 2.1. Table 2.1 shows that the percentages of female researchers[23] in higher education and government research jobs tend to be

[22] Turkey, Azerbaijan, and Georgia are counted as Asian countries here.

[23] 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 percent of researchers worked in natural sciences and engineering, roughly 15 to 20 percent worked in social sciences, and roughly 10 percent worked in humanities and arts, with the remainder classified as "other." Appendix C explores the question of gender segregation by field of inquiry, reinforcing the intuition that defense spending primarily affects science and engineering.

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.

**Table 2.1: Summary Statistics - Dependent Variables**

| Variables | | Mean | Std Dev | Min | Max | Observations | | |
|---|---|---|---|---|---|---|---|---|
| *% of* ***total*** *researchers that are female* | overall | 37.30 | 9.97 | 9.67 | 55.62 | N | = | 143 |
| | between | | 9.70 | 12.85 | 52.68 | n | = | 46 |
| | within | | 2.11 | 28.89 | 45.26 | T-bar | = | 3.11 |
| *% of researchers in* ***business enterprise*** *that are female* | overall | 28.43 | 12.67 | 6.18 | 74.60 | N | = | 112 |
| | between | | 13.08 | 7.21 | 67.66 | n | = | 38 |
| | within | | 3.19 | 13.00 | 36.66 | T-bar | = | 2.95 |
| *% of researchers in* ***government*** *that are female* | overall | 39.26 | 8.71 | 14.30 | 57.96 | N | = | 119 |
| | between | | 7.71 | 20.26 | 56.85 | n | = | 43 |
| | within | | 2.92 | 32.47 | 46.47 | T-bar | = | 2.77 |
| *% of researchers in* ***higher ed.*** *that are female* | overall | 41.09 | 11.35 | 8.41 | 65.27 | N | = | 117 |
| | between | | 10.68 | 13.62 | 65.27 | n | = | 43 |
| | within | | 3.69 | 24.71 | 57.48 | T-bar | = | 2.72 |

The key independent variable in this study is defense spending within each country, which will be measured as the percentage of total government spending that consists of defense spending. Data for this variable are obtained from the Stockholm International Peace Research Institute (SIPRI). The difference in average math test scores of girls minus the average math test of boys in each country also serves as an important variable to control for socio-cultural variation across countries (Charles & Bradley 2009). Data for this variable are drawn from the Trends in International Mathematics and Science Study (TIMSS) dataset. TIMSS data exist only for 1999, 2003, 2007, 2011, so the data for all other variables were collected for these same four years as well. The (unbalanced) panel of data used in this study includes 46 countries, with at most 4 observations per country.[24] The other independent variables shown in Table 2.2 come from World Bank data.

**Table 2.2: Summary Statistics - Independent Variables**

| Variables | | Mean | Std Dev | Min | Max | Observations | | |
|---|---|---|---|---|---|---|---|---|
| *% of govt. spending on defense* | overall | 5.48 | 4.01 | 0.00 | 32.22 | N | = | 182 |
| | between | | 3.46 | 0.00 | 13.60 | n | = | 46 |
| | within | | 2.04 | -3.57 | 24.10 | T-bar | = | 3.96 |
| *% of tertiary STEM grads that are female* | overall | 34.96 | 7.30 | 17.89 | 56.24 | N | = | 112 |
| | between | | 7.33 | 17.89 | 49.49 | n | = | 43 |
| | within | | 3.46 | 15.39 | 52.69 | T-bar | = | 2.60 |
| *% of seats in parliament held by women* | overall | 18.35 | 10.14 | 0.60 | 42.50 | N | = | 177 |
| | between | | 9.10 | 7.23 | 39.63 | n | = | 46 |
| | within | | 4.72 | 4.37 | 34.45 | T-bar | = | 3.85 |
| $\frac{\textit{Female LF participation}}{\textit{Male LF participation}}$ | overall | 69.86 | 13.58 | 33.96 | 97.82 | N | = | 184 |
| | between | | 13.40 | 35.42 | 96.74 | n | = | 46 |
| | within | | 2.78 | 61.63 | 81.02 | T | = | 4 |
| *Log GDP per capita* | overall | 9.57 | 0.89 | 6.98 | 10.84 | N | = | 184 |
| | between | | 0.88 | 7.18 | 10.70 | n | = | 46 |
| | within | | 0.18 | 8.84 | 10.20 | T | = | 4 |
| *Fertility rate* | overall | 2.09 | 1.05 | 1.13 | 6.90 | N | = | 184 |
| | between | | 1.04 | 1.27 | 6.53 | n | = | 46 |
| | within | | 0.19 | 1.35 | 2.89 | T | = | 4 |
| *Days of paid maternity leave* | overall | 126.60 | 51.64 | 60.00 | 410.00 | N | = | 184 |
| | between | | 48.91 | 60.00 | 273.00 | n | = | 46 |
| | within | | 17.70 | 57.85 | 332.85 | T | = | 4 |
| *TIMSS math test (avg. female score minus avg. male score)* | overall | -1.59 | 9.20 | -31.75 | 18.54 | N | = | 68 |
| | between | | 9.72 | -31.75 | 14.03 | n | = | 25 |
| | within | | 4.36 | -11.14 | 8.55 | T-bar | = | 2.72 |

[24] 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 an effect on a year-to-year basis, but more likely over a somewhat longer period.

**Methods**

This study will use three different empirical strategies to test the gender-defense spending 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 defense 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 choices after graduation from tertiary education. This distinction has been of particular concern in various prior studies. Many countries have seen increasing gender equality in education, while still facing difficulties translating this trend into greater gender equality in the labor force more generally (NAS 2006; Xie & Shauman 2003; Xu 2016). The other independent variables shown in Table 2.2 are included to help control for other factors that could significantly impact female representation in STEM. TIMSS math test scores and GDP per capita are both included because Charles & Bradley (2009) found that these had the most significant impact on horizontal 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.[25] In addition, the

[25] 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.

pooled model does not leverage the cross-country nature of the panel data set. 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 defense 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,[26] and the fact that there is much more variation *between* countries than there is *within* countries (as shown in Tables 2.1 and 2.2), a cross-country latitudinal analysis could be more fruitful for understanding the relationship between defense spending and women in research.[27]

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:

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

$\bar{X}_i$ is a vector of the country means of all the independent variables from Table 2.2, pertaining to country $i$, and $\bar{f_i}$ 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 defense spending in a particular country on that country's percentage of female researchers, this between-effects model estimates how much the variations in defense spending between countries can explain cross-country variations in female representation in research, when controlling for other relevant socioeconomic and institutional variables.

[26] At best, there is about 15 years of (non-TIMSS) data per country available, but most countries have much less than this, often with data missing between individual years.
[27] Fixed effects regressions of the panel data consistently produced non-significant 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.

The inherent difficulties of a limited time-series across cross-sectional units with little variation across time indicates 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 broad socio-cultural and 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 defense spending, to see how these variables relate to the country-specific fixed effects.[28]

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 ($\lambda_t$), and control variables ($C_{it}$).

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

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: defense spending, based on the

[28] The methodology used for this third model is based on Weiler (2001).

arguments presented in this paper: maternity leave; fertility rate, due to the high time commitment of research work and the greater responsibility for childcare typically placed on women; TIMSS math scores, and GDP per capita, both based on the findings of Charles & 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 defense 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 ordinary least squares on the means of the institutional variables for each country ($\bar{Z}_i$).

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

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.[29] 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 each of three different sectors of the economy: business enterprise (private sector), government, and higher education.

**Results**

Results from the pooled OLS model are shown in Tables 2.3 and 2.4.[30] Table 2.3 shows the results of the pooled OLS model estimated without including the TIMSS scores variable, while

[29] 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 7 reflect standard errors from bootstrapping with 10,000 replications.

[30] Default standard errors, rather than clustered robust standard errors, are reported in Tables 2.3 and 2.4 due to the relatively low number of clusters (countries) and the unbalanced nature of the panel data.

Table 2.4 shows the pooled OLS results when TIMSS scores are included. TIMSS scores are excluded in Table 2.3 partly as an initial robustness check. Because relatively few countries participated in the TIMSS program, including this variable cuts the number of observations roughly by half, as can be seen in Table 2.4. The left-most column of each table displays the coefficient estimates of the independent variables when the percentage of *all* researchers who are female is used as the dependent variable.

**Table 2.3: Pooled OLS**

| Variables | % of researchers who are female | | | |
|---|---|---|---|---|
| | % of Total | % in Bus. Enterprise | % in Higher Ed. | % in Government |
| ***% of govt. spending to defense*** | **-0.736**** **(0.247)** | **-0.601** **(0.373)** | **-1.159***** **(0.239)** | **-1.324***** **(0.312)** |
| *% female STEM grads* | 0.455*** (0.118) | 0.554** (0.180) | 0.407*** (0.117) | 0.630*** (0.156) |
| *% women in parliament* | 0.117 (0.084) | 0.194 (0.124) | 0.070 (0.076) | -0.001 (0.101) |
| *FLFP/MLFP* | 0.142* (0.060) | 0.213* (0.099) | 0.039 (0.058) | 0.334*** (0.076) |
| *Log GDP per capita* | -8.101*** (1.495) | -14.710*** (2.275) | -3.686* (1.453) | -8.361*** (1.883) |
| *Fertility rate* | -4.174** (1.306) | -5.749† (3.097) | -3.166† (1.633) | -5.076* (2.123) |
| *Days of paid mat. leave* | 0.016 (0.014) | 0.016 (0.019) | 0.009 (0.012) | -0.007 (0.015) |
| Year dummy variables | Yes | Yes | Yes | Yes |
| N | 93 | 78 | 80 | 80 |
| n | 42 | 33 | 36 | 35 |
| Adjusted R-Squared | 0.5068 | 0.5256 | 0.5048 | 0.5485 |

*** $p<0.001$, ** $p<0.01$, * $p<0.05$, † $p<0.10$

The results in both tables 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. Not surprisingly, the coefficients on the TIMSS variable in

Table 2.4 indicates a positive correlation between females outperforming males on math tests and greater female participation in research. Most importantly, both tables show a significant negative relationship between defense spending and the percentage of women in research, with a stronger negative relationship predicted in Table 2.4, where TIMSS scores are included. The coefficient estimate of -2.047 in Table 2.4 indicates that, *ceteris paribus*, a country whose defense spending as a proportion of total government spending is one percent higher than another country could expect to have a proportion of female researchers that is roughly two percent lower than its counterpart.

**Table 2.4: Pooled OLS with TIMSS math scores**

| | % of researchers who are female | | | |
|---|---|---|---|---|
| **Variables** | % of Total | % in Bus. Enterprise | % in Higher Ed. | % in Government |
| ***% of govt. spending to defense*** | **-2.047*** (0.263)** | **-1.030* (0.438)** | **-1.809*** (0.286)** | **-2.371*** (0.336)** |
| *% female STEM grads* | 0.351** (0.112) | 0.350† (0.203) | 0.129 (0.129) | 0.654*** (0.155) |
| *% women in parliament* | 0.251* (0.105) | 0.170 (0.181) | 0.285* (0.107) | 0.355* (0.139) |
| *FLFP/MLFP* | -0.086 (0.080) | 0.057 (0.136) | -0.100 (0.089) | 0.078 (0.104) |
| *Log GDP per capita* | -13.646*** (1.921) | -20.549*** (3.624) | -7.694** (2.290) | -5.717† (2.778) |
| *Fertility rate* | -7.789* (3.476) | -6.634 (6.432) | -5.951 (3.983) | -9.907† (4.931) |
| *Days of paid mat. leave* | -0.027 .0186072 | 0.012 (0.035) | -0.021 (0.023) | -0.021 (0.026) |
| *Difference in TIMSS scores (female - male)* | 0.536*** (0.090) | 0.372* (0.149) | 0.472*** (0.096) | 0.467*** (0.114) |
| Year dummy variables | Yes | Yes | Yes | Yes |
| N | 40 | 37 | 38 | 37 |
| n | 18 | 17 | 18 | 17 |
| Adjusted R-Squared | 0.8625 | 0.7264 | 0.7946 | 0.8307 |

*** p<0.001, ** p<0.01, * p<0.05, † p<0.10

**Table 2.5: Between Regression (Regression on Group Means)**

| Variables | % of researchers who are female: % of Total | % in Bus. Enterprise | % in Higher Ed. | % in Government |
|---|---|---|---|---|
| ***% of govt. spending to defense*** | **-0.059**<br>**(0.344)** | **-0.219**<br>**(0.544)** | **-0.694**$^{\dagger}$<br>**(0.346)** | **-0.685**<br>**(0.416)** |
| *% female STEM grads* | 0.489**<br>(0.166) | 0.667*<br>(0.278) | 0.654***<br>(0.165) | 0.675**<br>(0.214) |
| *% women in parliament* | 0.235$^{\dagger}$<br>(0.137) | 0.132<br>(0.187) | 0.168<br>(0.111) | 0.019<br>(0.136) |
| *FLFP/MLFP* | 0.132<br>(0.084) | 0.191<br>(0.150) | 0.035<br>(0.085) | 0.377***<br>(0.102) |
| *Log GDP per capita* | -6.601**<br>(2.337) | -13.058***<br>(3.498) | -1.399<br>(2.225) | -7.621**<br>(2.675) |
| *Fertility rate* | -4.124*<br>(1.840) | -4.593<br>(4.612) | -1.127<br>(2.261) | -3.523<br>(2.732) |
| *Days of paid mat. leave* | 0.013<br>(0.025) | 0.038<br>(0.032) | 0.015<br>(0.021) | -0.011<br>(0.025) |
| N | 93 | 78 | 80 | 80 |
| n | 42 | 33 | 36 | 35 |
| Adjusted R-Squared | 0.4675 | 0.5491 | 0.4135 | 0.5285 |

*** $p<0.001$, ** $p<0.01$, * $p<0.05$, $^{\dagger}$ $p<0.10$

Comparing the results in the other three columns is also revealing. In both Tables 2.3 and 2.4, defense 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 defense 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 2.4 indicate that there is a significant negative relationship between defense spending and female representation in private-sector research, Tables 2.3 and 2.4

indicate that 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. While the coefficients for the defense spending variable are generally higher than those in Table 2.3, they still exhibit roughly the same pattern.

**Table 2.6: Between Regression with TIMSS scores**

| **Variables** | **% of researchers who are female** | | | |
|---|---|---|---|---|
| | % of Total | % in Bus. Enterprise | % in Higher Ed. | % in Government |
| ***% of govt. spending to defense*** | **-2.096***** **(0.346)** | **-1.093** **(0.901)** | **-1.961**** **(0.527)** | **-2.611***** **(0.421)** |
| *% female STEM grads* | 0.379* (0.122) | 0.269 (0.375) | 0.289 (0.206) | 0.943*** (0.175) |
| *% women in parliament* | 0.093 (0.120) | 0.073 (0.279) | 0.211 (0.152) | 0.216 (0.130) |
| *FLFP/MLFP* | -0.077 (0.080) | 0.069 (0.194) | -0.117 (0.114) | 0.013 (0.091) |
| *Log GDP per capita* | -12.750*** (2.005) | -22.496** (5.470) | -5.660 (3.197) | -4.471 (2.555) |
| *Fertility rate* | -4.945 (3.002) | -1.573 (7.403) | -2.699 (4.323) | -11.020* (3.458) |
| *Days of paid mat. leave* | -0.014 (0.018) | 0.049 (0.049) | -0.002 (0.028) | -0.010 (0.023) |
| *Difference in TIMSS scores (female - male)* | 0.697*** (0.093) | 0.587* (0.239) | 0.665** (0.140) | 0.576*** (0.112) |
| N | 40 | 37 | 38 | 37 |
| n | 18 | 17 | 18 | 17 |
| Adjusted R-Squared | 0.8759 | 0.7830 | 0.7822 | 0.8579 |

*** p<0.001, ** p<0.01, * p<0.05, † p<0.10

The results for the Between-effects model are displayed in Tables 2.5 and 2.6. Table 2.5 shows the higher-observation results without TIMSS scores, while Table 2.6 willingly abandons some observations to show the results with TIMSS scores included. With respect to the effects of defense spending, the estimates obtained without using TIMSS scores are not quite as strong or significant as the pooled OLS estimates, though the pattern is similar. When TIMSS scores are included, however, the Between-effects results reflect the same pattern as the results from the original pooled OLS model.

**Table 2.7: OLS with Country Fixed Effects as Dependent Variables**

| | % of researchers who are female | | | |
|---|---|---|---|---|
| Variables | % of Total | % in BE | % in HE | % in Govt |
| ***% of govt. spending to defense*** | **-0.346**<br>**(0.309)** | **-0.280**<br>**(0.446)** | **-0.832***<br>**(0.371)** | **-0.574**<br>**(0.493)** |
| *Log GDP per capita* | -7.498***<br>(1.314) | -17.211***<br>(3.119) | -3.996**<br>(1.538) | -11.690***<br>(2.375) |
| *Fertility rate* | -4.855**<br>(1.610) | -0.137<br>(4.065) | -1.780<br>(1.843) | -4.709<br>(3.000) |
| *Days of paid mat. leave* | 0.012<br>(0.017) | 0.023<br>(0.033) | 0.034*<br>(0.014) | 0.002<br>(0.022) |
| Year dummy variables (in initial FE model) | Yes | Yes | Yes | Yes |
| N | 42 | 33 | 36 | 35 |
| Adjusted R-Squared | 0.1602 | 0.4025 | 0.1024 | 0.2989 |

*** $p<0.001$, ** $p<0.01$, * $p<0.05$, † $p<0.10$

Lastly, the results of the two-stage model are shown in Table 2.7. These results are similar to the Between-effects results (without TIMSS), indicating that defense 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.[31]

**Implications, Limitations, and Future Research**

Coming full circle, the intuitive sequence of empirical models provide a broader robustness test for our fundamental hypothesis, namely that countries where the government spends more of

[31] When using TIMSS scores, the coefficient estimates in the two-stage model were similar to those from the Between-effects model, but these results are excluded from this paper due to the difficulty of determining their statistical significance due to the relatively low number of observations in the TIMSS-inclusive data set.

its money on defense have significantly lower percentages of female researchers, particularly among government researchers. This result implies that decreasing defense spending and/or increasing non-defense spending may encourage more women to pursue research. Many other factors are obviously also relevant. 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 chapter's cross-country empirical result that higher levels of defense spending may tend to reduce 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.

In particular, these results shed new light on ways in which R&D may itself be seen not only as biased, but gendered towards a specific form of militaristic masculinity. 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 may experience pressure to adopt male characteristics and values, or may be perceived as having done so if they have successfully established themselves in this type of work. "There is a sense that in order to succeed in these fields, women must deny their true selves to think like men." (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 don't 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 a more diverse group of researchers.

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, potentially hindering 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 in research is also key 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, some have argued that all groups should have an equal say and an equal role in determining the use, impact, and control of the research itself (Harding 2016; Nelkin 1977).

Defense spending is not likely to decrease in wealthier countries in the foreseeable future, though, making policy prescriptions especially difficult. In this sense, recognizing and addressing these gender asymmetries may best be undertaken at the non-governmental 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 particular gender asymmetry problem (Kuo, 2017). Federal spending priorities should also recognize that optimal R&D outcomes would benefit from greater participation by women, and thus try to better balance defense-related spending with investment in broader types of basic science.

Prescriptions are also 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 defense spending, or whether current high-defense-spending countries are somehow different in that respect than present low-defense-spending nations. Appendix C hints at the possibilities of further segregation by field of inquiry; 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 non-governmental institutions identifying further ways to maximize the potential of global R&D by balancing the gender asymmetry in research.

# CHAPTER 3

## THE SCIENTIFIC-MILITARY-INDUSTRIAL COMPLEX: R&D IN A MALE-DOMINATED POLITICAL ECONOMY

> "I look at the future from the standpoint of probabilities. It's like a branching stream of probabilities, and there are actions that we can take that affect those probabilities, or that accelerate one thing, or slow down another thing." – Elon Musk

### Introduction

This chapter is partly intended to address some of the areas lacking in the prior chapters, while extending the analysis of the prior chapters to other potential research questions and data. By framing the analysis of the prior chapters within the institutionalist framework of the Veblenian dichotomy, this chapter explains in greater detail the mechanisms through which R&D funding is channeled can actually shape the organizational structure, culture, and purpose R&D institutions. Thereby, this also has a significant influence on the demographic makeup of who is choosing to work in these institutions, acknowledging the ways that such choices may be limited by one's gender, in particular. While this chapter intends to answer many questions that have been left open by the previous chapters, other new questions are inevitably raised, as well. As a result, several opportunities for future research projects that could naturally grow out of the current project are proposed at the conclusion of this chapter.

Prior work from the sociology of science offers a useful starting point to begin this examination of the influence that the social, cultural, and economic contexts can have on the R&D work done in STEM institutions. Contrary to the persistent myth that science and technology are primarily advanced by individual "great men" of science (Newton, Edison, Einstein, Jobs, etc.), the science and technology of the 21$^{st}$ century is increasingly dependent on large communities to provide the necessary labor and capital needed to drive further progress (Merton 1968). And while the rate of technological change is clearly dependent on the level of economic resources devoted to generating new knowledge and developing applications of that knowledge, more specifically, what *types* of technologies are developed will also depend upon what *types* of technologies receive the most economic support. This means that not only the rate but also the *direction* of technological change depends heavily on the context within which technology develops. Scientific researchers are always faced with the issues of what questions they should be asking, what methodologies they should use to generate data, and how they should interpret data. Developers of technology must also decide the best ways of applying knowledge from the existing pool. To put it simply: where do they focus their interest? But before scientists and engineers can pursue any of these questions, they must figure out how to obtain the resources necessary to pursue them in the first place. The needs for collaboration, evaluation, verification, and perhaps most of all, funding, are why the economic, political, and cultural contexts play such an important role in steering the direction of technological change (Longino 1990; Merton 1968). This means that despite claims that science and technology develop in an isolated community, free from subjectivity and bias, in actuality science and technology are likely to acquire some of the biases that exist in the broader society.

The primary argument of this paper is that there is a male bias in the direction of technological change, due largely to the male biases in the economic and political institutions that are propelling technological change forward along its particular path. Examining science and technology from this perspective can provide insight into the much-researched question of why there are relatively few women in science, technology, engineering and mathematics (STEM). To explain the low numbers of women in STEM, many researchers have emphasized the importance of gender discrimination, exclusionary practices, and unequal treatment of women in STEM. More recently, however, some fields within STEM have achieved gender parity, while others remain male-dominated, as shown in Figure 3.1. Furthermore, Maria Charles and Karen Bradley (2002, 2009) have found that in more gender-egalitarian societies where women have greater economic freedom, there actually tends to be *more* horizontal segregation across fields of study by gender. This suggests that the issue does not depend as much on the historical prevalence of men in STEM fields or differences between men and women in their preferences for doing math and/or science (though these may still have significant effects). Rather, the lack of women which persists in particular STEM fields, specifically engineering and computer science, may depend more on biases in the deeper cultures and values of these fields. Male-dominated political and economic institutions may have led some STEM fields to adopt values and foci of interest that are more congruent with men's values than women's, deterring greater numbers of women from entering these fields or from remaining long after they enter them.

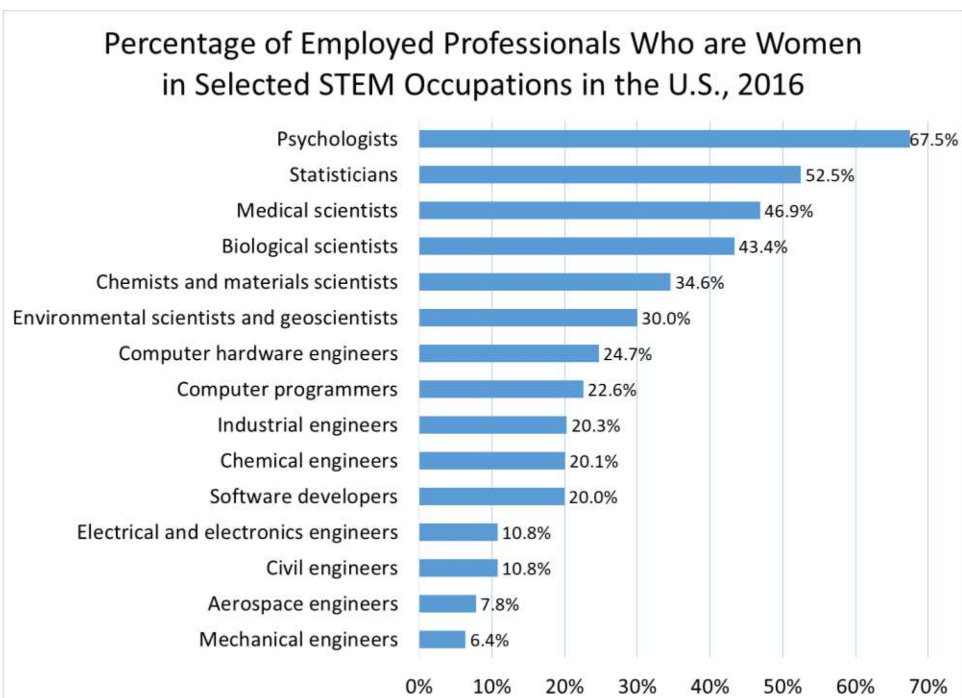


Figure 3.1

*Source:* U.S. Department of Labor, Bureau of Labor Statistics, 2016, Current Population Survey, Table 11.

**Ceremonial Encapsulation of Science and Technology**

The Veblenian dichotomy of ceremonialism and instrumentalism is a useful conceptual tool for demonstrating how science and technology can become *encapsulated* by the broader economic and political institutions, adopting many of the biases exhibited by the encapsulating ceremonial institutions. Instrumentalism is characterized by institutions that promote flexibility, democracy, accessibility, and participation. Such institutions produce technologies which enhance the ability to produce the means of life via a "systematic application of knowledge to the problem-solving process," for the greater benefit of the community at large (Junker 1983). Ceremonial institutions, on the other hand, are more restrictive, elitist, and exploitative, characterized by status hierarchies and invidious distinctions. They produce technologies that are of greater service to the few vested interests than to the broader community, which is why they typically require some sort of ceremonial or mythical justification. Ceremonialism includes various institutional practices, such as colonialism, racism, caste, corporatism, sexism, witch hunts, etc., which require myths, traditions, or legends that are "used but not questioned," in order to rationalize their goals of exploitation and inequality (Waller Jr. 1982).[32]

While both ceremonial and instrumental institutions coexist side by side in society, there is an inherent tension between the two, due to their conflicting goals. To ensure their own survival, ceremonial institutions must establish and maintain a system of ceremonial dominance and cultural hegemony over other institutions. One method of carrying out this function is by using ceremonial power to focus the development and use of technology towards ceremonial goals. If ceremonial

[32] Each institution exhibits some features of both ceremonialism and instrumentalism, so that no institution is either completely ceremonial or perfectly instrumental. Rather, the Veblenian dichotomy is best understood as a continuous spectrum where institutions lie somewhere between the two extremes of absolute ceremonialism and absolute instrumentalism, and ceremonial institutions are those which primarily fulfill ceremonial functions, while they may still exhibit some relatively minor instrumental features at the same time.

institutions are successful in this effort, technology will become "captured" or "encapsulated" by the ceremonial institutions. In *The Place of Science in Modern Civilization*, Thorstein Veblen described the effects of ceremonial institutions on science, knowledge, and the process of thought itself:

> The questions of life are questions of expedient conduct as carried on under the current relations of mastery and subservience. The habitual distinctions are distinctions of personal force, advantage, precedence, and authority. A shrewd adaptation to this system of graded dignity and servitude becomes a matter of life and death, and men learn to think in these terms as ultimate and definitive. The system of knowledge, even in so far as its motives are of a dispassionate or idle kind, falls into the like terms, because such are the habits of thought and the standards of discrimination enforced by daily life. (Veblen 1906)

The system of ceremonial dominance will only incorporate new knowledge and new applications of that knowledge to the extent that the knowledge and applications (technology) can be made ceremonially adequate, that is, only if they can fit within the ceremonial narratives.[33] The scientist's "canons of validity are made for him by the social situation," (Veblen 1906) because when ceremonial institutions are dominant and technology is ceremonially encapsulated, instrumental institutions may still exist and develop, but only if they can be squared with this rubric of ceremonial adequacy (Bush 1986). So even though various instrumental institutions exist throughout society, ceremonial institutions still exert more influence than instrumental institutions,

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[33] Paul Bush (1986) uses the G.I. Bill as an example of the importance of ceremonial narratives, even for an instrumental institution like socialized higher education costs:

> The enactment of the G.I. Bill signified major institutional changes in American life. While the manifest function of this public policy was rationalized by the ceremonially adequate notion that we were 'rewarding our returning veterans for the sacrifices they made for our country,' the instrumentally significant changes that it entailed were changes in the standards of judgment by which the society went about allocating educational resources…. Under capitalist ideology, as it was generally understood at the time, the Federal government had no legitimate function to perform in the allocation of resources for higher education. It was, however, ideologically proper for the Federal government to provide for the national defense, and it was under this national defense rubric that the G.I. Bill could be made ceremonially consistent with capitalist ideology.

and ceremonial institutions can limit *which* instrumental institutions exist in society, as well as *how* these instrumental institutions develop (Dugger 1980).

The ceremonial encapsulation of science and technology need not be enforced in an overt, explicit way, nor guided by conspiracy. In fact, through more subtle processes, such as the emulation of ceremonial practices, behaviors, and goals by researchers and developers, or the subordination of research and development (R&D) institutions to the goals of ceremonial institutions, scientists and engineers advance ceremonial goals while appearing to retain the individual autonomy and freedom of inquiry idealized by R&D institutions (Dugger 1980). The process of encapsulation could arguably be even more effective by operating in this manner. Rather than using obviously totalitarian methods, ceremonial institutions can guide the paths of science and technology towards their own goals, while generating relatively little resistance to or awareness of this process. For instance, by concentrating research grants on a relatively small area of inquiry, ceremonial institutions can narrow the field of discovery while still maintaining the illusion of technological determinism (Goodman 1967).

**The Role of Funding in Research and Development**

The major role played by the source of R&D funding (often the Federal government) in determining the feasibility of any R&D project means that the project is largely done in the service of its sponsors. Investments made in R&D may have some unique characteristics not shared by other types of investments, but they are still investments, and investors will expect some kind of return on that investment. Exactly what form the return on investment will take is relatively uncertain with R&D, but most institutional sponsors of R&D still expect their R&D to produce something that will support the goals of that institution, whether those goals are ceremonial or instrumental. Even if the goals of the scientists are to advance the frontiers of knowledge as far as possible, the extent to which they can advance them, but also the *direction* in which they can advance them, depend largely on where they can acquire funding. Scientists' ability to acquire R&D funding will in turn depend largely on the R&D goals of the dominant ceremonial institutions, which control the largest shares of funding coming from both industry and government. Scientists who have internalized the ceremonial institutions' goals, or who are at least willing to do work in support of these goals, will have an easier time obtaining funding for their work and will likely be more successful in advancing R&D that serves the goals of ceremonial institutions.

Despite the best efforts of many scientists, it is nearly impossible to completely insulate themselves from the biases of society, particularly because of these financial requirements. "Researchers may themselves (at least theoretically) be completely free of oppressive social values and interests, and yet find that their interests in so-called pure science and so-called basic research lead them to do research that clearly advances the values and interests of their sponsors and funders." (Harding 2015) In academia, where an important metric of research success is often the amount of money acquired by a department, administrators will often pursue R&D grants or contracts for work which may or may not be aligned with the research and teaching interests of their faculty. Either faculty are seduced or coerced into new secondary lines of interest, or other personnel will be hired who already fit the needs of the contract (Fulbright 1970). The best scientists typically also have to spend most of their time writing grant proposals, often straining to frame the researchers' goals in ways that can appeal to the goals of potential funding sources, whether private corporations or the government (Nieburg 1966). Focusing R&D spending on particular fields of STEM or in particular industries, for example, can lead to a "brain drain" effect because the demand for R&D work in certain areas influences the supply of R&D workers, as they gravitate toward where the money is concentrated (Ehrenberg 1991; Freeman 1975).

The need to obtain large amounts of money for extended periods of time often leads to dependence on the Federal government for R&D funding. Not only does the Federal government have access to vast amounts of money, it's also not subject to the dictates of the market as private corporations are. The government is more capable of providing funding over long periods of time, for more basic research which doesn't have an obvious immediate application, since the government need not be concerned with translating its R&D investments into short-term profits in order to stay competitive in the market).[34] The R&D priorities of the government, however, are subject to social evaluation. They must be politically justifiable, and the government as well as the entire political process are heavily influenced by ceremonial institutions. Ceremonial institutions and their vested interests are quite effective at influencing the U.S. government's spending practices by channeling their wealth and power through lobbying efforts, political action committees, and the revolving door system, while other non-organized groups can mainly just express their political influence through the ballot box (Kapp 2012). Politicians are also more likely to steer money toward projects which are politically (ceremonially) beneficial (i.e., they support profit- and/or job-growth for their particular constituents), not necessarily the projects that have the highest scientific (instrumental) potential to produce more widespread benefits.

President Eisenhower, in his famous "military-industrial complex" speech at the end of his final term in office, cautioned against this reliance on the government for R&D funds (a relatively

[34] Even though the role of the government in funding R&D in the U.S. has diminished relative to the role of industry in recent decades, the differences in the qualitative aspects of government funding relative to industry funding (such as reliability) ensure that government R&D still has a large influence on the path of technological change (Block 2008; Mazzucato 2014).

new but increasingly significant phenomenon in 1961): "Partly because of the huge cost involved, a government contract becomes virtually a substitute for intellectual curiosity" (Eisenhower 1961). Another prominent critic of the military-industrial complex, Senator J. William Fulbright, further described this process in 1970:

> The corrupting process is a subtle one: no one needs to censor, threaten, or give orders to contract scholars; without a word of warning or advice being uttered, it is simply understood that lucrative contracts are awarded not to those who question their government's policies but to those who provide the government with the tools and techniques it desires.

Government contracts have become a significant determinant of the direction of scientific inquiry, with a very large role played by Department of Defense (DoD) contracts in the *scientific*-military-industrial complex. Without overtly censoring the scientific agenda, the Federal government has centralized R&D funding within the DoD, effectively concentrating the focus of a vast number of researchers and developers toward its own goals. While the Federal government has many different agencies with a variety of goals and missions, roughly half of all Federal R&D funding comes from the DoD, which focuses mostly on development, as shown in Figure 1.2. This scientific-military-industrial complex plays a major role in ceremonially encapsulating the path of technological change by directing government policy and flows of capital towards defense technologies and those who develop them.

**The Scientific-Military-Industrial Complex**

The connections between science, technology, and the military go back centuries (Brodie & Brodie 1973). Military powers have long sought to obtain the upper hand on the battlefield through technological superiority; even the word "engineer" originally referred to: "a constructor of military engines; a person who manages engines of war; a soldier in a corps of an army that specializes in designing and constructing military works" (OED). The effects of this push for new technology have often spilled over into the realm of basic science, as evidenced by Galileo's development of the principles of gravity partly from his study of cannon projectiles, or the increased understanding of atomic physics garnered from the Manhattan Project (Williams 2017). Partly due to the aftermath of the Manhattan Project, which irrevocably changed the processes of science, technology, and warfare, partly due to economic reasons, the Cold War saw science and technology become more closely intertwined with the U.S. military than ever before. Rather than the large-scale direct fighting of a typical war, the Cold War was characterized more by a heightened *technological* competition between the United States and the Soviet Union, which motivated the U.S. to develop new research universities, government agencies (NASA, NSF), and tech industries as part of the national defense apparatus (Sarewitz 2000).

Not just science, but industry also became increasingly entangled with defense spending shortly after World War II. Military spending greatly benefits defense contractors and other private corporations both by supplying subsidies for R&D and by demanding commodities produced by the private defense industry. For example, the DoD paid more than one third of IBM's R&D budget in the 1950s and 1960s (Ruigrock & Van Tulder 1995), and it purchased most of the output of the semiconductor industry when this technology was still in its infancy (Tyson 1992). By investing large amounts of capital in advanced technology and establishing defense contracts of long duration, both of which provide businesses with reliable streams of revenue that are more difficult to come by in the market, private firms are greatly incentivized to tailor their work to the DoD's goals (Galbraith 1978). At the beginning of the Cold War, as the U.S. economy was emerging not only from World War II, but also the Great Depression, businesses recognized the important role of state spending in ensuring a strong, stable flow of profits. This effectively wedded private industrial institutions with military and R&D institutions in a scientific-military-industrial complex knit tightly enough to persist long after the end of the Cold War.

In the scientific-military-industrial complex, science tends to play a subordinate role as the military-industrial complex (MIC) ceremonially encapsulates science and technology by adapting the goals of R&D institutions to the goals of military and industry, such as national defense, private profit, and the growth of high-tech industry. By manipulating funding streams, the MIC coerces scientists and engineers "to see the same urgency in weapons development, the same security in technical pre-eminence, the same requirement for a particular weapons system" as the particular defense contractor or branch of the military they work for (Galbraith 1978). When the goals of the military merged with the goals of industry to form the MIC after World War II, the funding of science and technology became necessary not just to maintain military superiority, but to maintain economic superiority on an international scale, as well. This means that the imperative for technological advancement may originate from private industry, particularly in the post-Cold War era, but since private industry still relies on the government to provide a large, stable flow of support for technological development, private industry also must cater to the needs of the DoD. While the largest, most powerful private contractors can sometimes mold and shape contract specifications to accommodate their own technology development needs (Higgs 2007), in most cases the DoD will typically specify the requirements for a development contract, then go to the contractors to ask for the new technologies (Edwards 2006). Either way, this indicates that in order for a scientist/engineer to gain access to a large, stable source of R&D funding, he or she will probably find it useful to cater to the needs of the DoD. Catering to these needs may even be largely unconscious on the part of the scientist/engineer, and they may find it more useful to simply try to ignore the end uses of their work. "[C]ivilian engineers or physicists pursuing a corporate career in an arms manufacturing firm can become militarized insofar as they decide not to question the uses to which their knowledge and skills are being put." (Enloe 2016)

The institutional structures of the MIC play a significant role in influencing university research as well. Both the DoD and private defense contractors, such as General Electric, Northrop Grumman, and Halliburton, form university partnerships to fund academic research that is relevant to the military. Sometimes the influence of defense contractors on universities is quite explicit, as described in one 2006 article: "Prodded by state government officials fearful of alienating a key Massachusetts industry, nine Bay State colleges and universities have agreed to adapt their engineering curriculums, and in some cases introduce new courses, to meet the needs of defense contractors." (Weisman 2006) But again, there is no need to *dictate* to researchers precisely what they will be researching or developing, but the MIC can use grants, contracts, and other funding resources to channel researchers' foci of interest toward defense goals by offering greater support to those who pursue these goals. By designating priority areas of research for which substantial funding will be granted on a reliable basis, other concerns, such as the free exchange of ideas, the pursuit of science and technology for their own sake, and the ethical implications of R&D work, are subordinated to the military requirements of the funding source. And this can have lasting effects on scientists' research agendas: "Once an individual is part of a team which is supported by the military sector it is likely that they will continue within that sector and may well be lost to other [STEM] activities." (Langley 2005) The presence of the MIC is felt on university campuses throughout the U.S., despite the DoD being only the third largest source of Federal R&D funding to universities (after the NIH and the NSF), but the DoD plays a much larger role in other R&D sectors. In 2015 the DoD provided more than 57 percent of Federal funding for intramural government R&D and more than 75 percent of Federal funding for R&D performed in the private sector (NSF 2017). As the go-to source of R&D grants for so many researchers and developers working in private industry, academia, and within the Federal government itself, the DoD has cemented itself a key role in shaping many STEM fields (especially aerospace, electrical, and mechanical engineering) and in guiding the development of new technologies.

If researchers and developers effectively adopt the goals of the MIC, R&D becomes encapsulated by this ceremonial institution. The MIC exemplifies ceremonial institutions because the types of technologies it aims to produce are primarily intended to strengthen systems of inequality, hierarchy, neo-imperialism, neo-colonialism, and to benefit vested interests by subsidizing the profits of high-tech firms. The myth of national security is used to justify this allocation of taxpayers' money towards the research, development, and eventual purchase of new military products.[35] By redefining war, destruction, and profits to mean defense, security, and jobs, this is meant to justify why the U.S. spent over $611 billion on defense in 2016, more than the next eight highest spending countries *combined*. This $611 billion also represented nearly 3.3 percent of gross domestic product in the U.S., a higher percentage than is seen in any country in the OECD, except Israel. It is hard to justify such high levels of defense spending on instrumental grounds in a country that has almost never been invaded by a foreign country and that maintains good relations with its only two bordering neighbors. An employee of Lockheed[36] once wrote: "the government doesn't really need this stuff. It's just the best way to get rich quick. If they really needed all these nuclear bombs and killer satellites, they wouldn't run this place the way they do" (qtd. in Higgs 2007). If national security truly was the primary goal of the MIC, perhaps

[35] Many of the products developed with DoD funding have civilian uses, sometimes called "dual-use" or "spillovers" (Bellais & Guichard 2006). However, if many of the civilian products were developed as on off-shoot of a project originally predicated on defense priorities, these products still reflect some of the bias in technological change caused by the DoD providing 80-90 percent of all Federal spending on technology development.

[36] Lockheed Martin received far more defense contract money than any other contractor in 2016: over $43 billion. Boeing was the next highest with $29.5 billion. (Defense News 2017)

it would devote more resources to promoting peace and to solving climate change, which Pentagon officials and Defense Secretaries (from both Democrat and Republican administrations) have claimed poses a significant threat to national security.[37]

The high levels of military spending may be a means to achieving some instrumental goals, such as macroeconomic growth and stability, but there are many different types of government spending and different Federal agencies that could facilitate these goals, perhaps more effectively. In fact, two studies (Pollin & Garrett-Peltier 2009, 2011) found that a given amount of government spending on defense creates fewer jobs than the same amount of government spending on clean energy, healthcare, or education. Even if any type of government spending could serve roughly the same function of job creation and macroeconomic stability, some argue that military spending is much better at fostering rapid technological development than building more parks and schools. It also makes it easier for the high-tech economy to accept government subsidies while still clinging to free market ideologies, since the national defense apparatus has traditionally operated within the state, and the public provision of national defense is accepted by even the most strict adherents to free market doctrines. On the other hand, defense spending may simply be the type of spending most effective at maintaining the dominance of ceremonial institutions over instrumental institutions. Military institutions tend to be characterized by more hierarchy, authoritarianism, limited democracy, and secrecy than civilian institutions that focus on the

[37] The White House's National Security Strategy of February 2015 stated: "Climate change is an urgent and growing threat to our national security, contributing to increased natural disasters, refugee flows, and conflicts over basic resources like food and water." As part of his confirmation hearing in 2017, Trump's Defense Secretary James Mattis wrote: "The effects of a changing climate — such as increased maritime access to the Arctic, rising sea levels, desertification, among others — impact our security situation…. I will ensure that the department continues to be prepared to conduct operations today and in the future, and that we are prepared to address the effects of a changing climate on our threat assessments, resources, and readiness." (Sicard 2017) While officials have acknowledged the threat posed by climate change, changes in spending patterns to address this issue have been negligible with respect to the potential size of the threat posed by climate change to the U.S. economy and national security.

instrumental goals of education, health, or the environment. While many useful civilian technologies with instrumental applications have come from defense R&D, if producing instrumental civilian technologies is the main goal of government subsidies for R&D, civilian agencies would likely be more effective at supporting R&D for civilian uses.

With so much of its funding concentrated within the DoD, the Federal government is denied a more diversified, pluralistic approach to R&D, allowing for many different types of biases to emerge in science and technology. For one, R&D is biased more towards development than research: 89 percent of DoD R&D spending in 2015 went to development (NSF 2017). Because the DoD is primarily focused on the immediate procurement of weapons systems (which may be more lucrative for contractors who can patent new technologies) this mitigates the positive externalities of producing new knowledge, especially when taking into account the heightened secrecy surrounding technologies developed specifically for military purposes.[38] With civilian technologies receiving less support from the Federal government than military technologies, developers who focus more on civilian technologies will have fewer job opportunities and face higher unemployment rates, unless they are willing to shift their focus to military technologies. What types of people are more willing to adapt their goals to the goals of the MIC? If science and technology adopt some of the masculine biases of the military, as a result of the emphasis on defense R&D, this would likely be a greater deterrent to women in STEM than to men. If masculinity plays a salient role in the institutions and products of STEM, this will have major implications for gender norms, occupational segregation, gender-essentialist views, stereotypes,

[38] Many important defense technologies with civilian applications have come from the Defense Advanced Research Projects Agency (DARPA), which was created to focus more on basic research while the DoD was focused more on short-term tech development. Whereas in 2015 only 11 percent of DoD R&D spending went to research (as opposed to 89 percent for development), over 47 percent of DARPA R&D spending went to research. However, in 2015 DARPA's budget represented only 4.6 percent ($2.8 billion) of the DoD's overall R&D budget of $61.5 billion (NSF 2017).

etc. that could pose staunch barriers to women entering and remaining in STEM. Several writers have emphasized the importance of masculine biases in science and technology institutions (Cockburn 1999a, 1999b; Haraway 1988; Harding 1991, 2015; Keller & Longino 1996), focusing on masculine biases in the philosophy and practices of science. Below, I discuss how the bias toward funding R&D from military sources has also given the products and institutions of science and technology a masculine bias. This may help to explain the low representation of women in STEM, particularly in engineering fields where technology development is much more biased towards defense than research is.

**The Importance of Gender in STEM**

The issues of masculinity and masculine biases in STEM often come down to a chicken-or-the-egg type of debate. Do STEM institutions exhibit masculine biases because most people in STEM are men, or are most people in STEM men because STEM institutions have masculine biases? Perhaps the answer is a bit of both, but manipulating policies to reduce institutional biases could be particularly effective for increasing female participation in STEM, especially in those STEM fields (engineering and computer science) which haven't made as much progress towards achieving gender parity as other fields (biology, chemistry). Given the collaborative nature of science, altering institutional structures will likely prove to be more fruitful than focusing just on altering individuals' behavior (Stephan 1996). As one National Academy of Sciences report stated in 2007:

> In most organizations in which women's advancement and leadership opportunities have been limited, the problem is not old-style, overt sex discrimination, but rather *unrecognized features of the organizational culture that affect men and women differently.* Those features tend to be so embedded in organizational life as to be invisible. They generally also bear no obvious relationship to gender. The only indication that such issues exist may be an unexplained inability of the organization to attract, retain, or promote women in sufficient numbers despite an apparent willingness to do so. [emphasis added]

One of the "unrecognized features" of STEM is the sources of funding and the militaristic, masculine biases that accompany them, perhaps originating with the biases of the leaders of ceremonial political and economic institutions. These particular militaristic features are likely to affect men and women differently due to military institutions' bias against women, but also due to women's bias against militarism. When characterizing predatory, "barbarian" societies, where the capacity for violence and militaristic exploit is highly valued, Veblen described the concomitant devaluation and ostracism of women and women's work in society:

> Infirmity, that is to say incapacity for exploit, is looked down upon. One of the early consequences of this deprecation of infirmity is a tabu on women and on women's employments….so that even now we feel the impropriety of women taking rank with men, or representing the community in any relation that calls for dignity and ritual competency… (Veblen 1899)

Military institutions in the U.S. and other countries have shown some aversion towards women, sometimes manifesting as sexism, discrimination, sexual harassment, and bullying of women (Silva 2008). Research has indicated that members of military institutions also hold more traditional views of gender roles and are less accepting of women in certain positions within the military (Matthews et al 2009; Robinson Kurpius & Lucart 2000). Effective soldiering is typically equated with masculine qualities, such as assertiveness and coolness, and increasing numbers of women in the military may be perceived as a threat to the masculinity and prestige associated with the armed services (Koeszegi et al 2014). In the U.S., it wasn't until 2015 that all military occupations and positions were opened to women (Pellerin 2015). As members of these institutions internalize some of these biases against women and norms of femininity, the biases may affect their allocation of R&D funding, perhaps more in favor of male scientists and engineers or more in favor of development projects with more masculine qualities.[39] The DoD may also be

[39] For instance, DoD funding may focus more on technical, rather than social solutions.

more susceptible to such biases than agencies like the National Science Foundation (NSF) or National Institutes of Health (NIH), since the awarding of DoD contracts depends more on personal relationships and networks than NSF or NIH grants do, because the NSF and NIH more frequently rely on peer review to decide these awards. Such institutional dynamics which limit competition and reduce the size of the potential labor pool may allow more room for biases to influence funding decisions (Blau & Jusenius 1976).

On the other hand, there is also evidence that women are typically more averse to militarism than men are. One of the most consistent, well-established gender differences (in the U.S. as well as various other countries) in policy preferences is that women are less supportive of both defense spending and the use of military force. (Eichenberg 2007, 2012; Wilcox et al 1996) Not only do women tend to hold these different values from men, it is also more likely that women's personal values will affect their job choice than it is that men's values will affect their job choice. Psychological research shows that in the labor market, women tend to place more value on the altruistic and social aspects of their work. Women are typically more focused on their ability to help people through their work, as well as the broader social purpose and meaning of their work. Men on the other hand are typically more concerned with status, power, and pay (Croft et al 2015; Diekman et al 2011; Marini et al 1996). The DoD's focus on technology and physical sciences may alienate more women than men due to dualistic perceptions of gender which associate men more with technical occupations and tasks and women more with social occupations and tasks (Faulkner 2000). These preferences held by women could deter them from joining the armed services, working as a civilian employee of the DoD, or working at a STEM R&D institution that receives a substantial amount of funding from the DoD, such as an aerospace engineering firm.

In Anne Preston's 2004 study of what causes women to leave STEM jobs, she found that women were more likely than men to cite discontent with the nature of the work itself (rather than pay or prestige) as their reason for leaving, and many women left STEM to go into jobs with more of a nurturing component (teaching, psychology, healthcare, etc.). The women typically had more job flexibility due to greater financial security provided by their husbands. So although men may have also been disillusioned with their work, they were more likely to put up with it because of the good pay. This may help explain why only 9 percent of aerospace engineers were women in 2012, when the average annual salary paid to aerospace workers was \$80,175, compared to \$44,410 for the average U.S. worker (McCartney & McCartney 2015).[40]

Gender roles and norms play a substantial role in explaining differences between women's and men's job choices, including in STEM. In Xie and Shauman's 2003 study *Women in Science: Career Process and Outcomes*, they emphasize how girls' and boys' "seemingly free choices are constrained by assumptions about what they'll like or be good at." These choices are not completely free because they depend on the broader structures of society to some extent. This argument for women's relative incompatibility with militarism is not founded on a gender-essentialist view that due to biological reasons women are fundamentally less capable of accepting and integrating into militaristic institutions than men are. Rather, socially constructed gender norms of masculinity and femininity are more likely to encourage militaristic attitudes among males and to discourage militaristic attitudes among females, creating a divergence between norms of femininity and violence, aggression, militarism, etc.

[40] In 2012, the aerospace industry received almost \$16.9 billion in R&D funding from the U.S. Federal government, mostly from the Air Force, which accounted for roughly 13 percent of all Federal R&D spending in that year (NSF 2015). Fairygodboss, a website that allows users to rate employers in terms of their female-friendliness, reported that the aerospace industry was consistently ranked last (out of about 30 different industries) for gender equality, whether or not women would recommend other women work in the industry, and women's overall work experience.

Furthermore, the divergence in gender roles and categorizations of certain types of work as masculine or feminine may play an *increasingly* important role in explaining occupational segregation of men and women in countries like the U.S. Charles and Bradley (2009) argue that women's and men's job preferences "encompass values socialized and internalized at the individual level, as well as the performative enactment of cultural scripts. Both dispositional processes are likely to result in a great deal of sex segregation across fields of study." They emphasize that ideologies and desires for self-actualization may be influenced by views of what types of work are most appropriate for women and men, and that these ideologies and desires play a more significant role in determining job choice in economies where women have relatively greater economic freedom, explaining why there is actually *more* sex segregation in the most economically developed Western countries, compared to less developed countries. If female gender roles are seen as incompatible with STEM, or particular fields of STEM, women's success in these fields may depend on the extent to which they are able to deny or undermine their own femininity, to think and act "more like men" (Des Jardins 2010). An inability to de-gender oneself would put a woman at greater risk of failure in fields perceived as being more masculine, especially if success requires securing funding from such hyper-masculine institutions as the DoD. Men, of course, do not face the same trade-offs of de-gendering in most STEM fields. Though many man are undoubtedly deterred by militarism, due to the divergence in male and female gender norms, the deterrent effect is much stronger for women. It is worth reiterating the importance of the *masculine* bias in science here, to emphasize that feminine gender norms do not necessarily deter girls and women from doing science and engineering *per se*, but that they are deterred from doing science and engineering *that exhibit a masculine bias*. This bias is also towards a specific type of *militaristic* masculinity, which may also deter many men who are more averse than other men to this particular manifestation of masculinity amongst many possible masculinities.[41]

**An Empirical Analysis of Grants Proposed and Funded at Colorado State University**

One way to test this theory of female aversion towards militarism and militaristic R&D funding sources is by looking at the statistics for grant proposals and awards at Colorado State University (CSU). I collected all data available on both grants proposed to and funded by the top three government R&D funding agencies in the U.S. and at CSU: the National Institutes of Health (NIH), the National Science Foundation (NSF), and the DOD. Throughout academia in the U.S., and specifically at CSU, the NIH provides more research funding than any other agency, followed by the NSF, and the DOD provides the third most funding. The data available for these three agencies covers more than 30 years at CSU, encompassing several thousand observations for each agency, and it includes the names of the primary principal investigators, the direct sponsor of the grant, dates proposed and/or obligated, and the amount of funding proposed and/or obligated.

The main purpose of empirically analyzing this data is to look for any differences in the frequency of women either proposing or receiving grant money from the DOD compared to the other two major funding agencies. If relatively fewer women receive funding from the DOD than the NIH and NSF, this could support either of the above hypotheses: that women are more averse to the DOD than men are and/or that the DOD is more averse to women than men. By also looking at the frequency with which women actually propose grants to the DOD, compared to the NIH and NSF, this could help indicate which of these hypotheses may have more validity. For instance, if women propose to the DOD at the same rate as for the NIH and NSF, yet receive fewer awards

[41] Just as the Veblenian dichotomy is made up of a spectrum of institutions lying somewhere in between absolute ceremonialism and absolute instrumentalism, gender norms are also best understood as a spectrum compromising infinite possible gender identities and gender expressions between absolute masculinity and absolute femininity. The genders of individuals both male and female all lie somewhere on this spectrum between the two extremes.

from the DOD, this could indicate that most of the bias is held by the DOD and not the women themselves. On the other hand, if women systematically propose to the DOD less frequently than the other agencies, this could indicate that at least some of the bias is held by women against the DOD.

In my analysis of this data, I determined the proportion of the number of grants that were proposed by female primary principal investigators and the proportion of the total aggregate dollar amount proposed that was proposed by female primary principal investigators. I also determined the same proportions for the number of grants and total amount of grant money actually funded. Table 3.1 shows the results of this analysis. The DOD received significantly fewer proposals from women and also funded significantly fewer grants from women than both the NSF and the NIH. Women's proposals to the DOD also accounted for a significantly smaller proportion of the total money asked from the DOD, when compared to the NSF and NIH. Women, however, did not actually receive a significantly smaller proportion of money from the DOD than from the NSF, but their portion of the total money funded by the DOD was significantly less than the amount funded by the NIH.

**Table 3.1: Grants with Female Primary Principal Investigators**

| | Number of Grants Funded | Dollar Amount Funded | Number of Grants Proposed | Dollar Amount Proposed |
|---|---|---|---|---|
| **NIH** | 24.43% | 20.49% | 26.67% | 23.10% |
| **NSF** | 19.12% | 18.78% | 21.45% | 22.64% |
| **DOD** | 13.33%* | 17.87%† | 17.87%* | 19.25%* |

* DOD proportion significantly different from NSF and NIH with 99.9% confidence
† DOD proportion significantly different from NIH with 99% confidence

*Source:* Colorado State University Vice President for Research, Research Analytics: History of Proposals Submitted; History of Award Dollars Obligated

These results could support the hypothesis that women are more averse than men to obtaining R&D funding from the DOD, possibly due to a greater general aversion to militarism among women than among men. Still further research is needed to help determine the fundamental cause of these results. Is it projects with explicitly militaristic aims that deter women, or is it simply the association with the DOD? Are women deterred by perceptions that the DOD will be less likely to fund their proposals due to biases held by the DOD? There appears to be no strong indication in these results that the DOD is also more averse to funding women than the NSF or the NIH are, as it appears that all three agencies tend to award smaller proportions of their grants to women than are proposed by women. It is still difficult to completely rule out the possible impact of biases originating from the DOD from these results, though. It is also worth noting that all three agencies receive proposals from and award funding to men much more than they do to women, reflecting the general lack of women in STEM, but the results in Table 3.1 indicate that this issue is exacerbated to the extent that large proportions of funding must be obtained from the DOD. The larger the proportion of funding that is obtained from the DOD relative to the NIH and NSF could then potentially increase the bias toward men receiving more government funding than women. And though the NSF and NIH do provide more funding than the DOD in academia, the DOD plays a much larger role in funding R&D outside of academia, particularly in the private sector. This may help to explain why there are also relatively lower percentages of women working in R&D in the private sector than in higher education.

**The Political Economic Context of Government Funding**

In order to be deemed legitimate, science and technology institutions must also adopt many of the social and cultural standards set by the ceremonially dominant patriarchal institutions. By channeling government funding for R&D specifically through the MIC and the DoD, this funding adopts some of the masculine biases of these institutions. It should come as no surprise then, that the paths of science and technology would be more favorable to men, given that men make up the vast majority of those who hold the political and economic power to decide the direction of those paths. The DoD employs roughly 2.9 million people, including 1.3 million active duty forces, 826,000 National Guard and reserve forces, and 742,000 civilian personnel (DoD 2017). In 2013, women made up about 20 percent of all DoD employees, 15 percent of all active duty and reserve forces, and just under 34 percent of all DoD civilian personnel. More importantly, among both civilian and non-civilian employees, the concentration of women is lowest in the highest pay grades, indicating that women have even less access to the decision-making power of the high-ranking positions in the DoD (DoD 2013). Also, the Defense Science Board, "a committee of civilian experts appointed to advise the Department of Defense on scientific and technical matters," had only 8 female members out of 46 total (17.4 percent) in 2016. The Defense Science Board has had nearly 350 total members, going back to its establishment in 1956, and less than 7 percent of them have been women (DSB 2016). By contrast, the National Science Board, which establishes the policies of the NSF and advises the U.S. President and Congress on science and engineering policies, had 10 female members out of 24 total (41.7 percent) in 2017, with women making up over 17 percent of all current and previous members, going back to its establishment in 1950 (NSB 2017).[42] NSF R&D spending is typically only about 5-10 percent of DoD R&D spending, however, indicating a much larger R&D funding role for the more male-biased DoD.

The masculine biases of the scientific-military-industrial complex go beyond just the DoD. This chapter previously addressed the question of why the DoD is given such a prominent role in supporting technology development. The prominence of the DoD could also be due to the biases held by those who occupy key positions of political and economic power in the U.S. There are

[42] The current Chair and Vice Chair of the National Science Board, as well as the Director of the National Science Foundation, are all female. There has never been a female Chairman of the Defense Science Board or a female Secretary of Defense in the U.S.

arguably two levels of ceremonial encapsulation at work here: while on one level STEM institutions are encapsulated by the DoD, on another level the DoD is ceremonially encapsulated by a patriarchal Federal government and private economy in the U.S., which create and reinforce a biased approach to national security that is based less on peace initiatives and creating economic security and more on fighting fire with fire, leading to ever-increasing defense expenditures and the proliferation of weapons around the globe.

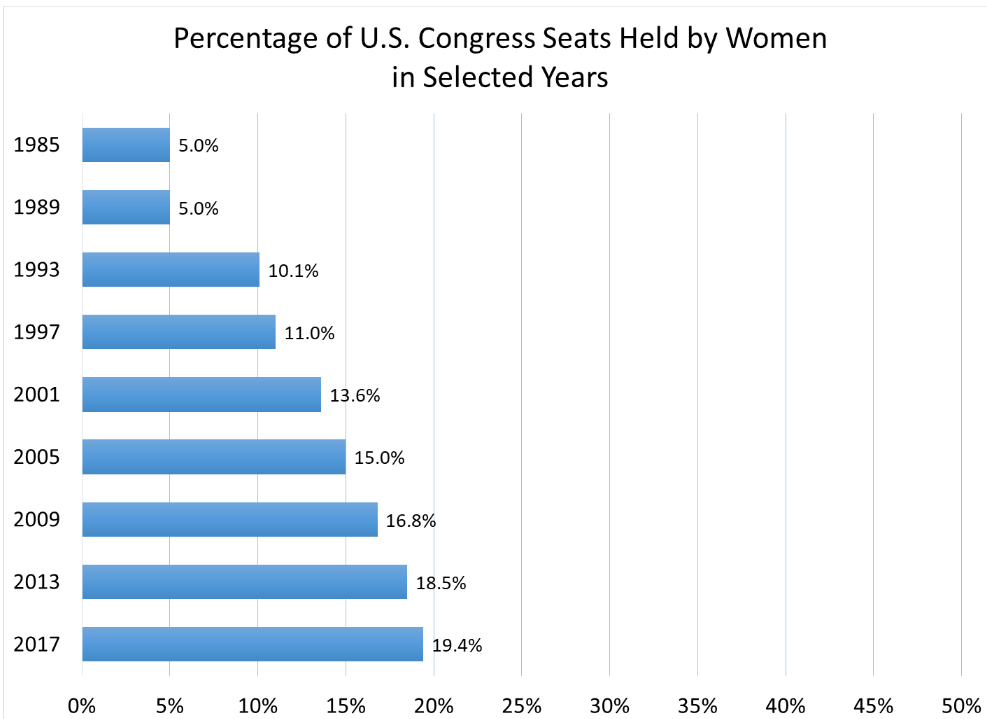


Figure 3.2

*Source:* Center for American Women and Politics, Eagleton Institute of Politics, Rutgers University. *History of Women in the U.S. Congress.*

Though the percentage of females in the U.S. Congress has increased steadily over the past 30 years, as shown in Figure 3.2, in 2017 women still held only 105 (19.6 percent) of the 535 seats in Congress.[43] The U.S. Congress plays a major role in bolstering the strength of the MIC, often

[43] Interestingly, the percentage of women in engineering in the U.S. has followed a somewhat similar trajectory to the percentage of women in the U.S. Congress since the early 1970s, indicating they both may be similarly affected by systems of patriarchy.

purchasing items that the DoD has specifically said that it does not need for defense purposes. The implicit reason that politicians still do this anyway is to bolster the economy in their districts and to support campaign donors (McCartney & McCartney 2015). But the tendency to focus on the DoD, and the ceremonially adequate concept of national security, as the chosen means through which the Federal government will support particular aspects of the economy, may be partly due to the fact that most people in Congress are men. Multiple studies have shown a positive correlation between state militarism and sexism (Caprioli 2000; Reardon 1996), and even without the economic imperatives of the MIC, the psychological bias towards war and militarism may persist in U.S. culture, particularly among men, due to norms of violent masculinity and the fear of being seen as *weak* on foreign policy. (Lofgren 2011, McCartney & McCartney 2015)

Focusing on industry leaders also reveals a male dominance in the economy. Among the top decision-makers of S&P 500 corporations in 2016-17, only 5.2 percent had a female CEO, just 21.2 percent of board seats were occupied by women, and 26.5 percent of executive/senior-level officials and managers were women (Catalyst 2017). While a few prominent defense contractors (Lockheed Martin, General Dynamics, and BAE Systems) have made headlines by appointing female CEOs in recent years, the defense industry still struggles to recruit more female engineers. Some of the largest contractors are investing large amounts of resources in recruiting and retaining women, for fear that they will gravitate away from defense, towards fields with a less male-dominated culture, such as biomedical engineering (Shalal-Esa 2012). These efforts are based on a recognition of the dissonance between the values of the ceremonial institutions funding the defense contractors and the values of female engineers and potential female engineers. By focusing most of its development spending on defense projects, the Federal government may be alienating large numbers of potential engineers, reducing the size of the pool of talent in this important field. A more pluralistic funding scheme by the Federal government might be more effective in realizing the engineering potentials of a larger and more diverse group of aspiring technology developers.

**Conclusion and Implications for Future Research**

There is less mystery around the question of why most DoD employees are male than there is around the question of why most engineers in the U.S. are male. The military has historically been an exclusively male domain and still today has a culture associated with hyper-masculinity, even despite its relative openness to women in recent years.[44] Even long before 1802, when the first engineering school in the U.S. was established at the United States Military Academy at West Point, New York, engineering had been closely tied to the military, and these two male-dominated (previously male-only) spheres of society share some of the same biases toward masculinity. Combined with the recognition that the biases of this particular agency will be passed on to STEM when a significant portion of STEM R&D funding is provided by the DoD, this can improve our understanding of the low numbers of women in STEM, particularly in engineering. Importantly, this could also offer insight into new strategies that may help increase women's participation in STEM.

In order to solidify and quantify the effects of military spending on women's participation in STEM, additional data is needed to demonstrate on a finer level what specific mechanisms allow military spending to deter more women than men from entering or staying in STEM fields. It is still not entirely clear whether it is specifically the process of obtaining funding, or the perception of the general culture of particular STEM fields, or that the DOD tends to favor men because the

[44] In one of seven guidelines given by Defense Secretary Ash Carter for integrating women into the military, he made a key distinction: "Equal opportunity likely will not mean equal participation by men and women in all specialties, and there will be no quotas." (Pellerin 2015) Carter's statement implies that even if the military was not at all biased against women, women would likely still be biased against the military.

DOD has more male employees making decisions pertaining to research grants, or whether the DOD simply has closer ties to STEM fields that tend to have more men in them for other completely non-militaristic reasons, or if it is something else entirely that is driving the results in this study. It seems likely that the true answer is a combination of multiple reasons, but this opens up the possibility for many useful new research questions to be investigated in the future.

One potentially fruitful avenue for future research could be to generate more data on the differences between women's and men's job preferences, particularly in STEM, by conducting job surveys and audit-like studies. For example, a group of STEM workers and STEM students could be given a selection of potential STEM job openings, each with varying degrees of association with militarism and the DOD. Some jobs could be given explicit militaristic implications, such as weapons development projects, while other jobs could exhibit clear funding ties to the DOD even while the research bears no obvious military applications. Even further, potential applicants could be tested to see if their preferences differ significantly between DOD-funded work and DARPA-funded work, considering that DARPA is a subdivision of DOD which emphasizes basic research. By using jobs with fairly similar characteristics, only substantially varying them by their relationships with the DOD and the military, this could give greater insight into what specifically might be deterring people from certain jobs and whether these factors vary significantly between men and women. Conducting further surveys of both men and women who have left STEM positions for STEM positions in other fields or who have left STEM entirely, building on Anne Preston's work (2004), would also help to pinpoint the effects of government spending and organizational culture on the career choices of men and women.

More and better data from the private sector would also serve to increase our understanding of the impacts of military spending on the economy, especially since the DOD awards much more money to the private sector than any other agencies. As both the private sector and the DOD seem to be biased more towards development than the public sector and higher education are, the private sector is likely where any biases created by DOD spending will have their greatest impact. Unfortunately, there also seems to be less data available on R&D work in the private sector, particularly with the relatively heightened secrecy around military projects. The effects of this heightened secrecy around military projects, both in the private sector and elsewhere, is still yet another issue worth pursuing in the future, especially when considering the importance of information transmission and knowledge sharing for innovation and scientific progress.

Establishing a more solid link between military spending and gender in STEM would also open up more questions about what links military spending has to gender and the entire rest of the economy beyond just STEM. The U.S. DOD employees millions of individuals, in addition to the vast number of people employed by defense contractors (also largely within the U.S.). This implies that the DOD can heavily influence the gender composition of many occupations in the broader economy. Generating data on the amount of human capital generated by people working within the DOD and defense contractors, as well as veterans who receive money for higher education and job hiring preference, would all help to quantify the economic impact the DOD has in the economy, and particularly how this impact may favor men in the economy more than women. It is crucial to assess all the ways that Federal spending biases towards the DOD influence the entire U.S. economy, and potentially the global economy, too, in addition to the ways that gender diversity in STEM may be limited by the lack of diversity in government R&D funding channels.

Greater gender diversity in engineering and other STEM fields would open up more job opportunities for women, but it would also change how the world we live in is designed and created (Wajcman 2010). If the groups funding research and development are relatively homogeneous, and the groups of people performing research and development are also homogeneous, then we can expect the future to also look homogenous (Kennedy 2016). National defense and military superiority need not be the primary goals of the state sponsorship, and this narrow focus leads to the production of a narrow spectrum of new technologies by a narrow spectrum of engineers for a narrow spectrum of beneficiaries. Diversifying the Federal government's R&D portfolio and giving non-defense agencies a larger role in supporting R&D may encourage more women to work in R&D jobs, and it could also help to ensure that the investments produce greater benefits for a wider range of the U.S. population. Even just the DoD's portfolio of R&D investments could be diversified to address national security issues in different ways that might appeal more to women (and men) disillusioned by the DoD's narrow approach to national defense, by focusing more on social issues like climate change and poverty.

Whether or not making such instrumental changes to ceremonial institutions is actually feasible, though, fundamentally comes down to the question of democracy. Reducing the dominance of ceremonial R&D institutions and focusing technology more towards the purposes of the broader community would require democratic institutions to give the broader community a more prominent role in determining the focus of R&D funding, the path of technological change, and thus the future of their community. When looking at the future from the standpoint of probabilities, the inherent unpredictability of what technological achievements our society will realize means that the future is a crapshoot. But there are ways in which the dice can be loaded. The relative secrecy surrounding the development of technologies by and for the DoD has fostered an environment of low external accountability of DoD researchers and developers to the taxpayers who provide their funding. By limiting the public's participation in determining the focus of research and development that they fund with their tax dollars, there is a greater risk of failing to address the scientific and technological challenges which are most pressing for the American public.

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**APPENDIX A**

For the SGS dataset, dividing the eight engineering subfields used into two groups, one with relatively high percentages of females and one with relatively low percentages of females, was straightforward based on the first graph shown in Figure 1.7. The second graph in Figure 1.7 shows that this division is not as straightforward for the CPS dataset. Further explanation is also required as to how non-engineering fields from the CPS are differentiated into male and female groups.

Table A-1 shows all eleven non-engineering fields used from the CPS dataset, and Table A-2 shows all six engineering subfields used, seventeen groups in total. To sort the non-engineering fields, the percentage of female employees in each field was averaged over the entire period studied with this dataset, 1983-2001. Then the average of those eleven averages was computed, and is shown in the middle of Table A-1, 37.81 percent. The five groups whose average percentage of female employees fell below this number were then sorted into the male group, assigning them each a zero value for the $dFem_i$ variable. The six groups with higher averages were sorted into the female group, assigning them each a one value for the $dFem_i$ variable.

A similar, but separate, method is used to divide the engineering subfields into male and female groups. Again, the percentage of female employees in each subfield was averaged over the entire period studied with this dataset, 1983-2001. Then the average of only these six subfields was computed, 8.92 percent. By comparing each engineering subfield to this new average, they can then be sorted into relatively male and relatively female subgroups within the overall male-dominated field of engineering. Based on this method, the civil engineering subfield clearly falls within the male group. However, the CPS dataset is still tested with civil engineering as both a male and female subfield because of the relatively rapid increase of the percent of female employees in this subfield during the time period studied, the relatively high percent of female employees in civil engineering in more recent years, and the inclusion of civil engineering as a female subfield in the SGS dataset.

For calculating $Fem_{it}$ in Model 2, the same basic procedure is used, except the average of all eleven non-engineering subfields and the average of all six engineering subfields were both calculated for each year. Then, rather than sorting each subfield based on that year's average, the average was subtracted from each subfield's percentage of female employees for that year, producing a negative number (instead of a 0) for relatively male-biased subfields or a positive number (instead of a 1) for the relatively female-biased subfields. Finally, these numbers were averaged across two-year intervals to match the two-year intervals used to calculate percentage yearly growth rates.

**Table A-1: Women as a Percent of Total Employed in Non-engineering Fields (Average 1983-2002)**

| | | |
|---|---|---|
| Precision production, craft, and repair occupations | 8.65 | Male Fields |
| Transportation and material moving occupations | 9.21 | |
| Farming, forestry, and fishing occupations | 17.62 | |
| Handlers, equipment cleaners, helpers, and laborers | 18.40 | |
| Operators, fabricators, and laborers | 24.84 | |
| **Average of all 11 fields** | **37.81** | |
| Executive, administrative, and managerial occupations | 41.02 | Female Fields |
| Sales occupations | 48.96 | |
| Technicians and related support occupations | 50.26 | |
| Professional specialty occupations | 57.64 | |
| Service occupations | 59.98 | |
| Administrative support occupations, including clerical | 79.36 | |

*Source*: Current Population Survey Tables, Annual Averages (Table 11)

**Table A-2: Women as a Percent of Total Employed in Engineering Subfields (Average 1983-2002)**

| | | |
|---|---|---|
| Mechanical engineers | 5.23 | Male Subfields |
| Civil engineers | 7.21 | |
| Aerospace engineers | 7.23 | |
| Electrical and electronic engineers | 8.36 | |
| **Average of all 6 subfields** | **8.92** | |
| Chemical engineers | 11.51 | Female Subfields |
| Industrial engineers | 13.98 | |

*Source*: Current Population Survey Tables, Annual Averages (Table 11)

## APPENDIX B

An additional test using lagged dependent variables will help to show if the change in R&D spending in one year has any significant effects on the engineering population in ensuing years. The new lagged model structure will be applied to the base cases for each dataset. For example, the lagged version of Model 1 for the SGS is the same as before, except $y_{it+1}$ is now substituted in place of $y_{it}$:

$$y_{it+1} = \beta_0 + \beta_1 dTrtmt_t + \beta_2 dFem_i + \beta_3 (dTrtmt_t * dFem_i) + e_{it}$$

This change in model specification is applied to all eight regressions of the SGS and all six OLS regressions of the CPS, and the results are shown below in Tables B-1 and B-2. Comparing these results to the above results in Table 1.1, the lagged results for the SGS displayed in Table B-1 show a uniform increase in the magnitude and statistical significance of all difference-in-difference estimates. Compared to the results above in Table 1.2, however, the lagged results for the CPS displayed in Table B-2 show a uniform decrease in magnitudes and no statistically significant difference-in-difference estimates in most cases.[45] These results suggest not only that there is a stronger lagged effect of R&D spending for engineering graduate students than for engineering employees, but that the one-year lagged effects on engineering graduate students is actually slightly stronger than the non-lagged effects on graduate students. This could be due to the different time structure of graduate student positions which typically have a set term of multiple years in school, as opposed to regular engineering positions which may have a more variable time structure.

[45] Regressions using lags greater than 1 year were also tested, but as lags were increased beyond one year, all DD and DDD estimates decreased in magnitude and statistical significance compared to the no-lag or one-year-lag cases.

Why should the growth of the number of employees in a subfield increase in the same year that government spending in that field increases, rather than a more lagged effect? Undoubtedly, some of the money coming from the government will be spent on new capital for R&D, but a significant portion of this increased spending must be spent specifically on additional R&D labor. If a significant proportion of R&D spending goes to R&D labor, when the spending increases the number of laborers increases or when the number of laborers increases spending has to increase, meaning they are basically contemporaneous.

However, the "hiring" process for graduate students is somewhat different because graduate students are enrolled into an educational program at one point of the year during the application process. This means that the impact of spending on graduate students is less likely to be contemporaneous because they can't be hired on (or let go) at any given point in the year when funding is increased (decreased). Engineering departments and faculty members basically have to wait until the fall semester begins to bring on new students with their additional R&D funds. The number of engineering graduate students accepted or rejected each year will depend largely on how much (government) funding is available during the application period in the winter/spring.

**Table B-1: One-year Lagged Effects (SGS)**

| Variables | Model 1 Results | | | |
|---|---|---|---|---|
| *dFem* | 0.000214 | 0.000214 | -0.0106** | -0.0106** |
| | (0.0109) | (0.0116) | (0.00359) | (0.00386) |
| *dTrtmt* | -0.0286*** | -0.0641** | -0.0286*** | -0.0736** |
| | (0.00515) | (0.0219) | (0.00520) | (0.0224) |
| ***dFem* X *dTrtmt*** | **0.0238**** | **0.0238**** | **0.0268**** | **0.0268**** |
| | (0.00713) | (0.00760) | (0.00726) | (0.00781) |
| Observations | 240 | 240 | 210 | 210 |
| Adj. R-Squared | 0.0588 | 0.3932 | 0.0921 | 0.4984 |
| Year Effects | No | Yes | No | Yes |
| Biomedical Included | Yes | Yes | No | No |
| **Variables** | **Model 2 Results** | | | |
| *Fem* | 0.109* | 0.112 | -0.122* | -0.119** |
| | (0.0593) | (0.157) | (0.0708) | (0.0520) |
| *Trtmt* | -0.184** | -1.340* | -0.134* | -1.517*** |
| | (0.0721) | (0.587) | (0.0734) | (0.550) |
| ***Fem* X *Trtmt*** | **3.280**** | **3.300**** | **4.399***** | **4.703***** |
| | (1.283) | (1.210) | (1.481) | (1.087) |
| Observations | 240 | 240 | 210 | 210 |
| Adj. R-Squared | 0.0466 | 0.3995 | 0.0754 | 0.503 |
| Year Effects | No | Yes | No | Yes |
| Biomedical Included | Yes | Yes | No | No |

Standard errors in parentheses

*** $p<0.01$, ** $p<0.05$, * $p<0.1$

## Table B-2: One-year Lagged Effects (CPS)

| Variables | Model 1 Results | | | |
|---|---|---|---|---|
| *dTrtmt* | -0.00274 | -0.0269 | -0.00274 | -0.0269 |
| | (0.00720) | (0.0202) | -0.00718 | (0.0201) |
| *dTrtmt* X *dEngr* | -0.0177 | -0.0177 | -0.0162 | -0.0162 |
| | (0.0118) | (0.0116) | (0.0108) | (0.0106) |
| ***dTrtmt* X *dEngr* X *dFem*** | **0.0270** | **0.0270*** | **0.0347**** | **0.0347**** |
| | (0.0164) | (0.0162) | (0.0170) | (0.0167) |
| Observations | 289 | 289 | 289 | 289 |
| Adj. R-Squared | 0.008 | 0.0326 | 0.0148 | 0.0397 |
| Year Effects | No | Yes | No | Yes |
| Civil Engineering | Female | Female | Male | Male |

| Variables | Model 2 Results | |
|---|---|---|
| *Trtmt* | -0.142 | -0.413 |
| | (0.128) | (0.382) |
| *Trtmt* X *dEngr* | -0.144 | -0.144 |
| | (0.324) | (0.333) |
| ***Trtmt* X *dEngr* X *Fem*** | **4.387** | **4.387** |
| | (6.957) | (7.425) |
| Observations | 289 | 289 |
| Adj. R-Squared | -0.0041 | 0.0142 |
| Year Effects | No | Yes |

Standard errors in parentheses

*** $p<0.01$, ** $p<0.05$, * $p<0.1$

## APPENDIX C

We have defined "researcher" in the broadest sense to be able to capture the dynamics across three core institutional sectors – government, higher education, and the business enterprise sectors – with the knowledge that 70% of researcher counts are in science and engineering. However, we have also assessed the importance of a horizontal segregation effect similar to that found in Charles & Bradley (2009), where gender participation varies across broad fields of inquiry. Data availability effectively necessitates a tradeoff between evaluating gender participation by sector, which is the main focus of the present work, versus by field, as in Charles & Bradley. To cope with the lack of data availability, the latter used a single year of analysis rather than the cross-sectional time-series leveraged in this chapter.

In their paper, Charles and Bradley found that GDP per capita and TIMSS survey data could explain much of the relative concentrations of women in engineering, math, and natural sciences versus social sciences, health sciences, and humanities. For instance, countries with higher GDP per capita tend to have more women in social sciences, health sciences, and humanities, but *fewer* women in engineering, math, and natural sciences. Therefore, there is greater horizontal segregation in countries where incomes are higher.

Pursuing a similar question, we apply the same methodologies as above to five new dependent variables: percentage of female researchers in engineering and natural sciences, percentage in social science and humanities, percentage in medical sciences, the difference between the percentage in engineering/natural sciences and the percentage in social sciences/humanities, and the difference between the percentage in engineering/natural sciences and the percentage in medical sciences. We replace the control variable related to tertiary graduates of STEM fields with one more appropriate to the fields represented by each different dependent variable.

When assessing the effects of defense spending on horizontal segregation, however, the Pooled OLS and Between-effects models[46] yield weak results, as shown in Tables C-1, C-2, C-3, and C-4. Across both models, defense spending has a consistently negative relationship with female representation in engineering, math, and natural sciences, similar to the results in Tables 2.3-2.6 above. Defense spending appears to have a significant negative effect on female representation in natural sciences and engineering, based on Tables C-1, C-2, and C-4, but there appears to be no significant effect of defense spending on female representation in other fields. This finding indicates that the effects of defense spending on natural science and engineering may be greater than the effects on medical science, social science, and the humanities. The estimated effects of defense spending on the *difference* between female representation in different fields show no consistent patterns and little, if any, statistical significance.

[46] Results from the two-stage model are excluded due to the difficulty of obtaining reliable standard error estimates when using the bootstrapping method, given the relatively low number of observations for data detailing fields.

## Table C-1: Pooled OLS (Fields)

| Variables | % of researchers who are female | | | | |
|---|---|---|---|---|---|
| | % in Nat. Sci. & Engr. | % in Soc. Sci. & Hum. | % in Medical Sci. | Dif. between NSci./Engr. & SSci./Hum | Dif. between NSci./Engr. & Med. Sci. |
| ***% of govt. spending to defense*** | **-0.841*** | **0.472** | **-0.308** | **-1.064*** | **0.374** |
| | **(0.337)** | **(0.521)** | **(0.430)** | **(0.417)** | **(0.295)** |
| *% female STEM grads* | 1.014*** | | | | |
| | (0.192) | | | | |
| *% female social science grads* | | 0.436* | | | |
| | | (0.175) | | | |
| *% female medical science grads* | | | 0.898*** | | |
| | | | (0.171) | | |
| *Difference in % female STEM grads and social science grads* | | | | 0.405** | |
| | | | | (0.128) | |
| *Difference in % female STEM grads and medical science grads* | | | | | 0.161 |
| | | | | | (0.114) |
| *% women in parliament* | 0.073 | 0.488** | 0.047 | -0.445** | 0.013 |
| | (0.153) | (0.176) | (0.161) | (0.145) | (0.126) |
| *FLFP/MLFP* | -0.011 | 0.274* | -0.058 | -0.177* | -0.056 |
| | (0.086) | (0.107) | (0.112) | (0.085) | (0.070) |
| *Log GDP per capita* | -5.041 | 5.291 | -11.364** | -12.960*** | -0.566 |
| | (3.821) | (4.159) | (3.833) | (3.561) | (3.114) |
| *Fertility rate* | -3.573 | 6.605 | -2.654 | -11.529** | 2.731 |
| | (3.776) | (4.030) | (3.874) | (3.758) | (3.068) |
| *Days of paid mat. leave* | 0.004 | 0.021 | 0.031 | -0.019 | 0.006 |
| | (0.018) | (0.022) | (0.022) | (0.018) | (0.015) |
| Year dummy variables | Yes | Yes | Yes | Yes | Yes |
| N | 49 | 47 | 57 | 46 | 49 |
| n | 24 | 25 | 28 | 24 | 24 |
| Adjusted R-Squared | 0.5068 | 0.3559 | 0.4787 | 0.4320 | 0.1983 |

*** p<0.001, ** p<0.01, * p<0.05, † p<0.10

## Table C-2: Pooled OLS (Fields) with TIMSS math scores

| **Variables** | **% of researchers who are female** | | | | |
|---|---|---|---|---|---|
| | % in Nat. Sci. & Engr. | % in Soc. Sci. & Hum. | % in Medical Sci. | Dif. between NSci./Engr. & SSci./Hum | Dif. between NSci./Engr. & Med. Sci. |
| ***% of govt. spending to defense*** | **-1.290*** **(0.460)** | **0.581** **(0.881)** | **-0.035** **(0.452)** | **-1.842** **(1.203)** | **-0.531** **(0.623)** |
| *% female STEM grads* | 0.190 (0.281) | | | | |
| *% female social science grads* | | 0.627† (0.316) | | | |
| *% female medical science grads* | | | 0.731** (0.214) | | |
| *Difference in % female STEM grads and social science grads* | | | | 0.575 (0.328) | |
| *Difference in % female STEM grads and medical science grads* | | | | | -0.002 (0.232) |
| *% women in parliament* | 0.312* (0.139) | 0.484* (0.217) | 0.131 (0.189) | -0.192 (0.198) | 0.153 (0.167) |
| *FLFP/MLFP* | 0.136 (0.139) | -0.053 (0.185) | 0.148 (0.158) | 0.086 (0.150) | -0.304† (0.146) |
| *Log GDP per capita* | -12.273* (4.617) | 1.261 (4.953) | -12.715** (4.353) | -9.074† (4.865) | -8.639 (5.633) |
| *Fertility rate* | 6.398 (6.767) | 1.503 (5.163) | -0.008 (4.908) | 2.515 (10.042) | -5.197 (7.566) |
| *Days of paid mat. leave* | -0.002 (0.027) | 0.045 (0.045) | 0.039 (0.033) | -0.048 (0.053) | -0.034 (0.033) |
| *Difference in TIMSS scores (female - male)* | 0.630** (0.152) | 0.582** (0.150) | 0.517*** (0.130) | -0.117 (0.165) | 0.250 (0.172) |
| Year dummy variables | Yes | Yes | Yes | Yes | Yes |
| N | 26 | 26 | 30 | 25 | 26 |
| n | 15 | 15 | 17 | 15 | 15 |
| Adjusted R-Squared | 0.8649 | 0.6677 | 0.7852 | 0.6662 | 0.3146 |

*** p<0.001, ** p<0.01, * p<0.05, † p<0.10

## Table C-3: Between Regression (Fields)

| Variables | % of researchers who are female | | | | |
|---|---|---|---|---|---|
| | % in Nat. Sci. & Engr. | % in Soc. Sci. & Hum. | % in Medical Sci. | Dif. between NSci./Engr. & SSci./Hum | Dif. between NSci./Engr. & Med. Sci. |
| ***% of govt. spending to defense*** | **-0.321 (0.462)** | **0.238 (0.712)** | **-0.482 (0.591)** | **-0.694 (0.576)** | **0.712† (0.393)** |
| *% female STEM grads* | 1.184*** (0.278) | | | | |
| *% female social science grads* | | 0.341 (0.252) | | | |
| *% female medical science grads* | | | 0.828** (0.274) | | |
| *Difference in % female STEM grads and social science grads* | | | | 0.405* (0.180) | |
| *Difference in % female STEM grads and medical science grads* | | | | | 0.149 (0.166) |
| *% women in parliament* | 0.139 (0.247) | 0.562† (0.282) | -0.012 (0.229) | -0.409 (0.256) | 0.061 (0.208) |
| *FLFP/MLFP* | -0.036 (0.133) | 0.292† (0.145) | -0.011 (0.159) | -0.262† (0.131) | -0.059 (0.106) |
| *Log GDP per capita* | -1.589 (5.970) | 6.596 (6.902) | -11.408† (5.774) | -12.314† (5.995) | 2.397 (4.862) |
| *Fertility rate* | -1.158 (5.637) | 8.062 (6.769) | -5.339 (6.141) | -11.604† (6.000) | 5.119 (4.644) |
| *Days of paid mat. leave* | 0.012 (0.036) | 0.035 (0.048) | 0.010 (0.045) | -0.034 (0.040) | 0.015 (0.030) |
| Year dummy variables | Yes | Yes | Yes | Yes | Yes |
| N | 49 | 47 | 57 | 46 | 49 |
| n | 24 | 25 | 28 | 24 | 24 |
| Adjusted R-Squared | 0.5409 | 0.3596 | 0.4979 | 0.3181 | 0.2901 |

*** p<0.001, ** p<0.01, * p<0.05, † p<0.10

## Table C-4: Between Regression (Fields) with TIMSS scores

| | % of researchers who are female | | | | |
|---|---|---|---|---|---|
| **Variables** | % in Nat. Sci. & Engr. | % in Soc. Sci. & Hum. | % in Medical Sci. | Dif. between NSci./Engr. & SSci./Hum | Dif. between NSci./Engr. & Med. Sci. |
| ***% of govt. spending to defense*** | -1.112† | 0.586 | -0.103 | 0.952 | -0.159 |
| | (0.562) | (1.564) | (0.652) | (2.389) | (1.079) |
| *% female STEM grads* | 0.117 | | | | |
| | (0.308) | | | | |
| *% female social science grads* | | 0.528 | | | |
| | | (0.557) | | | |
| *% female medical science grads* | | | 0.878* | | |
| | | | (0.306) | | |
| *Difference in % female STEM grads and social science grads* | | | | -0.199 | |
| | | | | (0.695) | |
| *Difference in % female STEM grads and medical science grads* | | | | | -0.202 |
| | | | | | (0.503) |
| *% women in parliament* | 0.376 | 0.675 | -0.062 | -0.316 | -0.071 |
| | (0.230) | (0.482) | (0.305) | (0.507) | (0.426) |
| *FLFP/MLFP* | 0.177 | 0.074 | 0.072 | 0.192 | -0.367 |
| | (0.150) | (0.284) | (0.195) | (0.229) | (0.224) |
| *Log GDP per capita* | -13.830* | -4.100 | -11.191† | -5.408 | -11.902 |
| | (5.225) | (7.584) | (5.100) | (7.614) | (9.621) |
| *Fertility rate* | 7.345 | -2.525 | 0.357 | 29.790† | -3.907 |
| | (6.158) | (7.569) | (5.311) | (15.034) | (9.358) |
| *Days of paid mat. leave* | -0.001 | 0.020 | 0.056 | 0.085 | -0.019 |
| | (0.024) | (0.080) | (0.035) | (0.102) | (0.044) |
| *Difference in TIMSS scores (female - male)* | 0.801** | 0.781* | 0.597** | 0.202 | 0.426 |
| | (0.183) | (0.227) | (0.154) | (0.357) | (0.328) |
| Year dummy variables | Yes | Yes | Yes | Yes | Yes |
| N | 26 | 26 | 30 | 25 | 26 |
| n | 15 | 15 | 17 | 15 | 15 |
| Adjusted R-Squared | 0.9135 | 0.7282 | 0.8064 | 0.6966 | 0.4985 |

*** p<0.001, ** p<0.01, * p<0.05, † p<0.10