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Commercialization and Gender Gaps in STEM Graduate Student Labor Mechanisms: An Analysis Using HLM

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ABSTRACT OF THE DISSERTATION

Commercialization and Gender Gaps in STEM Graduate Student Labor Mechanisms:
An Analysis Using HLM

by

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Women in STEM fields often face multidimensional gendered disadvantage via gendered occupational segregation within academic labor in terms of pay, type of work, institution of employment, rank of position and perceived prestige of work and job (Baker, 2012; Ceci, Ginther, Kahn, & Williams, 2015; Ecklund, Lincoln, & Tansey, 2012; Fox, 2001; Fox & Stephan, 2001; Frehill, Abreu, & Zippel, 2015; Kulis, Sicotte, & Collins, 2002; Mavriplis et al., 2010; Umbach, 2007). Additionally, these multidimensional gender gaps are persisting in a context of increasing commercial influence, resulting in increased commodification of academic research(Slaughter & Leslie, 1997; Slaughter & Rhoads, 2004). Using critical frameworks, this study applies a multilevel model to data with departments nested within higher education institutions, to analyze gender funding disproportionality among those receiving reproductive (R-GFD) funding mechanisms and those receiving productive funding mechanisms (P-GFD). Results find that field average ratio of productive funding to reproductive funding is associated with increased P-GFD and decreased R-GFD, while both department and field average gender disparities were both significantly associated with change in R-GFD.

Furthermore, this study found an association between the share of R&D expenditures, representing market influence with a department, and R-GFD. Results as they relate to the expectations based in the theoretical frameworks are discussed.

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Chapter 1: Introduction and Theoretical Perspective

Introduction to the Problem

According to U.S. policy makers, increasing the production rate of science, technology engineering and math (STEM) graduates is necessary for maintaining international economic competitiveness (Beede, D., Julian, T., Lagdon, D., McKittrick, G., Khan, B., & Doms, M., 2013). Increasing the rate of STEM degree attainment among American citizens requires growth in the rate of women's participation at all educational levels (Beede et al., 2013), as well as growth among other underrepresented student groups. Overall, rates of women receiving STEM doctorate degrees have increased over previous decades (see figure one). Between 1986 and 2016, the rate of women receiving doctorates in STEM (which includes Life Sciences, Physical and Earth Sciences, Mathematics and Computer Sciences, Psychology and Social Sciences and Engineering) increased 185%, while the rate of increase for men was 66%. However, as of 2016, women continue to earn fewer than half the doctorates awarded in STEM fields (42%). This picture is further complicated when one considers the variation in rates of women's participation between separate STEM fields. As Figure two shows, the rate of women's participation increased across all fields, or groups of fields, between 1986 and 2016. However, while Life Sciences, Psychology and Social Science fields experienced a reversal in the gendered majority in doctorate recipients, the rates of doctorates awarded to women in Mathematical, Computer and Engineering Science fields are persistently low.

Although these trends are often interpreted neutrally as a reflection of differences in preferences between men and women, critical perspectives are useful for identifying complex and multidimensional systems of inequality. For example, utilizing Acker's (1992) "gendered understructure of society's institutions" (p.567) as a framework requires a researcher to consider broader connotations of the construction of gender in the way we value fields and labor. In this way, women may face compounded disadvantage such as lower average salaries due to overrepresentation in fields like the life sciences, where salaries are, on average lower than in fields such as the physical sciences (Shulman et al., 2017). Even when women enter into fields with higher wages, such as engineering or computer science, they tend to continue to face wage gaps (Michelmore & Sassler, 2016). Furthermore, in their work on the effects of gender composition on STEM field wage gap, Michelmore and Sassler (2016) found that as women grow as a proportion of doctorate holders in a field, wages decrease.

In addition to disciplinary differences, women in STEM fields often face other multidimensional gendered disadvantage via gendered occupational segregation within academic labor in terms of pay, type of work, institution of employment, rank of position and perceived prestige of work and job (Baker, 2012; Ceci et al., 2015; Ecklund et al., 2012; Fox, 2001; Fox & Stephan, 2001; Frehill et al., 2015; Kulis et al., 2002; Mavriplis et al., 2010; Umbach, 2007). These multidimensional aspects of gender gap and disadvantage may relate to women's limited ability to conform to the "ideal worker," which often reflects masculinized ideals, defined in opposition to feminization (Acker, 1990). According to Acker, the ideal worker, according to is one that conforms largely to white, masculine traits such as limited role in procreation and lack of emotionality. Although the concept of the ideal worker creates a value system emphasizing masculinized professional values, the disadvantages faced by women extend to anyone unable to conform to the ideal worker, which is likely to also embody other normative values such as whiteness and heteronormativity. The current work seeks to apply Acker's (1990; 1992) concepts to analyzing gender disparities and disproportionality between men and women in academic work among STEM graduate students.

In addition to focusing on disproportionality in graduate student funding mechanisms, this research takes a unique approach by considering current political and social contexts affecting American higher education. Of primary importance for the current work is the trend of state disinvestment in higher education as a share of overall state spending (Archibald & Feldman, 2011; Tandberg & Griffith, 2013). In this context, colleges and universities increasingly rely on non-public funders to generate revenue necessary to pursue institutional mission, teaching, public service and research (Slaughter & Leslie, 1997; Slaughter & Rhoads, 2004; Weisbrod, Ballou, & Asch, 2008). Policy changes, including the Bayh-Dole act (1980) and increased protections for intellectual property, as well as significant scientific advances in highly applied fields partially driven by such policy changes (Mowery, Nelson, Sampat, & Ziedonis, 2001), has resulted in increased industry involvement in academic research, providing additional revenue for institutions to pursue research missions (Mowery et al., 2001; Shane, 2004).

Scholars identify that commercialization in academic research influences graduate students indirectly through its effects on institutional and departmental culture, and directly through interactions with faculty engaged in commercial research (Mars, Slaughter, & Rhoades, 2008). Additionally, researchers argue that funding type and mechanisms, such as teaching assistantships, research assistantships and fellowships, are an important aspect of career socialization (Gardner, 2008; Mendoza, 2012, 2012; Szelényi, 2013; Thune, 2009; Weidman, Twale, & Stein, 2001). Because of this, scholarly work has concentrated on understanding whether or not industry funding for academic research has a unique effect on doctoral student socialization either through receiving industry funded research assistantships or fellowships (Gardner, 2008; Szelényi, 2013; Weidman et al., 2001) or through interactions with faculty engaged in industry partnerships (Mars et al., 2008; Slaughter, Campbell, Holleman, & Morgan, 2002). However, current approaches to understanding industry effects on graduate student socialization do not fully take into consideration gendered dimensions.

In addition to works focused on the effect on graduate students resulting from increased commercialization, research on gender gaps in graduate students funding mechanisms also inform this study. Ampaw's (2010) work analyzing progression through doctoral programs at an institution between the years 1994/5-1998/9, found that gender disparities in progression through doctoral programs resulted from inequities in the way men and women are funded, with women graduate students having less access to research assistantships, which is associated with longer time to degree and lower rates of completion (F. Ampaw, 2010). This finding is echoed in further works by Ampaw and Jaegar (2011; 2012) that also found that doctoral student men receive research assistantships at a higher rate than women. Specifically, Ampaw and Jaegar (2011) found that the semester during which the most research assistantships were available, disparities by gender were stark with 38% of men receiving research assistantships compared with only 16% of women. The current work builds on Ampaw and Jaegar's (2011; 2012) work by considering variation in gender disparities between STEM fields.

Purpose

The central problem that the current work seeks to better understand is the gendered organization of labor among graduate students in STEM fields, in light of increasing reliance on private and/or commercial sources of revenue. The current analysis is informed by the wealth of scholarly literature on multidimensional gender gaps in academic labor, but instead explores gendered inequality in labor among graduate students in STEM fields. This work uses critical and feminist quantitative approaches to examine whether similar gender disparities in academic work are also evident in graduate student labor and worsened in departments heavily influenced by industry. I use the theory of gendered organizations and feminist institutionalism, which asserts that the underrepresentation of women in academic settings necessarily reinforces gendered hierarchies in institutions, to hypothesize that commercialization in STEM fields is associated with gender disparities in the way graduate students are funded with women and men graduate students more likely to be funded through mechanisms that allow them to conform to institutionally determined gender roles. If true, this may be a contributing factor towards broader occupational segregation present in the academic labor market.

Theory

The theoretical perspectives informing this study address the broader political and economic contexts affecting higher education as well as institutional cultures that determine, norms, values and roles for individuals. This work utilizes academic capitalism (Slaughter & Leslie, 1997; Slaughter & Rhoades, 2004) and resource dependence theory (Pfeffer & Salancik, 2003) to describe growing commercial influence in higher education generally, and within academic research in science and engineering. Within the institutional context, feminist institutionalism (Chappell & Waylen, 2013; Kenny, 2007; Mackay, Kenny, & Chappell, 2010) and Acker's theory of gendered organizations (1990) is used to describe how institutions determine and value gender roles differently and the extent to which different types of academic labor fulfills traditional gender roles. These perspectives are then used to identify assumptions of the current research and develop hypotheses for the work moving forward.

Resource dependence theory and academic capitalism. Bess and Dee (2008) describe resource dependence theory as "…a range of strategic actions that are likely to enable the organizational leaders to reshape external environments in ways that advance the goals of the institution" (p. 138). This theory asserts that institutions are dependent upon external actors for resources because institutions are unable to create all necessary resources internally (Bess & Dee, 2008; Pfeffer & Salancik, 2003). The level of reliance upon external actors is dependent on the level of the resource's criticality and scarcity (Bess & Dee, 2008). If an institution is very reliant on an outside actor for resources that are both critical and scarce, then the outside actor will command considerable power within an institution to determine institutional priorities (Bess & Dee, 2008; Pfeffer & Salancik, 2003).

One approach to managing reliance on outside actors is through external linkages (Bess & Dee, 2008). In this approach, the institution becomes necessary for the pursuit of outside actors' missions (Bess & Dee, 2008). University-industry partnerships, where higher education institutions partner with industry actors to perform research allows industry actors to benefit from university research and allows universities to secure reliable streams of revenue for academic research (Bess & Dee, 2008; Slaughter & Leslie, 1997), are one example of this. While mutually beneficial, such linkages run the risk of reducing institutional autonomy (Bess & Dee, 2008). Therefore, significant reliance on industry for resources for research may result in significant industry influence on research priorities, goals, and culture.

In the current economic and political context, state funding for higher education has decreased as a share of overall state spending (Archibald & Feldman, 2011; Tandberg & Griffith, 2013), necessitating increased reliance on non-state entities for revenue (Slaughter & Leslie, 1997; Slaughter & Rhoades, 2004). Although overall state investment in higher education has decreased over previous decades, federal monies for academic research increased until about 2011 and has decreased only slightly since that time (National Science Board, 2016; Slaughter & Rhoades, 2004). Academic capitalism, defined as "…pursuit of market and market-like activities to generate external revenues" (Slaughter & Rhoades, 2004, p. 37), is helpful for understanding increased commercialization across the university system even in places where state investment is comparably less scarce. Within academic research, specifically, authors Slaughter and Rhoades (2004) describe that with the emergence of academic capitalism, higher education institutions leveraged federal funding to best harness revenue from private industry.

The policy context which enabled higher education institutions to leverage federal and private funding emerged from the “social contract” understanding of academic research in which basic, academic research was seen as enabling research and discovery necessary for the United States department of defense to remain competitive during the cold war (Slaughter & Rhoades, 2004). In the late 1980’s, under the label of “competitiveness legislation,” federal funding for research undertook a strategy focused on transfer of technology from federal laboratories and universities into private industry (Slaughter & Rhoades, 2004). This blurred the boundaries between public and private and created incentives within academic research to pursue applied, potentially revenue generating research (Slaughter & Rhoades, 2004).

For the current work, resource dependence theory and academic capitalism are used to describe why increased reliance on commercial and/or private funding for academic research may have implications for higher education institutions, departments, and the individuals within them. Although private industry and higher education institutions develop mutually beneficial relationships in which each may leverage their areas of research to efficiently deliver the benefits of research to the American public, there are also potentially negative side effects.

Slaughter and Rhoades (2004) argue that academic capitalism leads to unintended, negative consequences including the restructuring of work in academic settings. The authors identify increased reliance on part-time instructional labor as an example of restructured work in relation to teaching labor (Benjamin, 2015; Slaughter & Rhoades, 2004). In relation to academic research labor, Slaughter and Rhoads (2004) identify changes relating to commercial influence such as increased ownership of research by academic institutions, decreasing the free exchange of public knowledge, and increasing the commodification of academic research (Jacob, 2009; Pestre, 2005; Radder, 2010). Similar changes are echoed in Pestre's (2005) work where the author identified the perceptions of academic research as a financial good since the 1980's "…rooted in aggressive extension of property rights", while it had been previously conceptualized as a public and industrial good (p. 29). Additionally, Slaughter and Rhoades (2004) identify academic capitalism's effect of increasing competition, particularly between academic fields and disciplines, resulting in stratification within the institutions.

Although resource dependence theory and academic capitalism are informative to the research proposed here because they describe how increased reliance on commercial funding is expected to result in increased power to shape institutional values, goals and norms, the perspectives do little to predict gender inequities in the way graduate students in science and engineering fields are funded. Importantly, these theories provide context for the current research and predict increased commodification of academic research as funding for research is increasingly derived from private sources and, to a lesser extent, federal sources. The next section will address theoretical perspectives that connect exterior processes to interior functions within academic institutions.

New institutionalism and feminist institutionalism. New institutionalism grew out of sociological approaches to institutional theory (DiMaggio & Powell, 1991). DiMaggio & Powell (1991) describe "This perspective emphasizes the ways in which action is structured and order made possible by shared systems of rules that both constrain the inclination and capacity of actors to optimize as well as privilege some groups whose interests are secured by prevailing rewards and sanctions" (p. 11). The authors go on to note that in this theoretical perspective, environments "penetrate the organization, creating the lenses through which actors view the world…" (DiMaggio & Powell, 1991, p. 13). Therefore, while resource dependence theory portrays institutional agency in the selection of environmental actors from which to derive resources, theories related to new institutionalism focus on constraints enforced by the influence of environmental actors on institutional actors.

Meyer and Rowan (1977) further this argument through their perspective that environmental "myths" are more salient in institutional structure and practice than "…the demands of their work activities" (p. 41). The authors describe the process of institutionalization in which "…social processes, obligations or actualities come to take on a rule like status in social thought and action" (Meyer & Rowan, 1977, p. 42). They go on to note that such institutionalization constrains individuals to conform to organizational and institutional myths and rules, thereby dictating the actions and organization of individual institutional actors (Meyer & Rowan, 1977). The authors identify that the impact of the environment occurs both at the boundaries but also are reflected within internal institutional practices (Meyer & Rowan, 1977). Meyer and Rowan (1977) assert that organizations that best conform to the myths of environmental actors will be legitimated and rewarded, a process otherwise known as institutional isomorphism. Thus, in higher education environments in which departments are highly reliant on private sources of revenue, conforming to the norms and values of their funders, are likely to be rewarded and legitimated likely resulting in increased prestige. Therefore, while resource dependence provides an explanation for why the current higher education contexts conform to commercial norms and values broadly, new institutionalism details the effects of environmental influence on institutional actors and organizations.

In this study, I use these theoretical perspectives to argue that environmental actors, such as private and commercial industry funders for academic research, shape practices, norm, values, and roles within institutional contexts. Feminist institutionalism applies this specifically to gender roles and norms within institutions (Chappell & Waylen, 2013; Mackay et al., 2010; Waylen, 2014). Building on previous feminist scholarship, feminist institutionalism identifies the social and culturally constructed nature of gender and its' role as signifier of power hierarchies, as well as the ways institutions may reinforce and reproduce gender inequities (Hawkesworth, 2005; Mackay et al., 2010; Scott, 1986). Mackay, Kenny and Chappell (2010) describe that gender, "…not only operates at the level of the subjective/interpersonal (through which humans identify themselves and organize their relations with others); but also as a feature of institutional and social structures, and a part of the symbolic realm of meaning-making, within which individuals are 'nested'" (p. 580). Through my application of feminist institutionalism, I argue that gendered divisions in academic labor are representative of power hierarchies within higher education contexts.

Another advantage to using feminist institutionalism, is its' focus on gender inequity as a broader problem in a social context, rather than an individual attribute (Kenny, 2007). Kenny (2007) notes, "An understanding of gender as 'practice' or 'performance' shifts analytical focus away from individual to social and political institutions, processes and practices, opening up the field for theoretical and empirical work in the area of gender and institutions" (p. 93). From this, I theorize that the persistence of gender inequality broadly in the academic labor force, despite efforts to disrupt it, as well as growth among women doctorate holders, is in part, related to the rise of commercial influence in higher education research, particularly evident in science and engineering fields.

Although new institutionalism is helpful for understanding the permeation of environmental actors into the norms, values and roles within institutional contexts and feminist institutionalism provides insight into hierarchies of power that are likely to emerge through institutionally determined gender roles, the theories presented thus far do not make explicit specific examples of gender roles. Chappell (2006) refers to the "gendered logic of appropriateness" which indicates acceptable forms of masculinity and femininity within an institutional context. In the next section, I will integrate such feminist institutionalist works with Acker's (1990; 1992) theory of gendered organizations to identify specific examples of gendered labor and discuss how this relates to commercialization.

Theory of gendered organizations. While the historical absence of women within many organizations, including higher education, has long been recognized by scholars, little work had discussed these organizations as inherently gendered (Acker, 1990). Therefore, organizations have largely been considered to be, and studied as, gender neutral (Acker, 1990). Acker's (1990) theory of gendered organization approaches organizations and institutions as inherently gendered. She states "To say that an organization, or any other analytic unit, is gendered means that advantage and disadvantage, exploitation and control, action and emotion, meaning and identity, are patterned through and in terms of distinction between male and female, masculine and feminine" (Acker, 1990, p. 146). Just as Acker (1990) describes a dichotomized version of gender and gendered effects, such as "advantage and disadvantage" and "masculine and feminine," in their description of critical theory and postmodernism, Tierney and Rhoads' (1993) identify that power mediates relationships between such dichotomies. They state, "Dominant groups are thus more able to legitimate their own versions of the social world. As a result, groups with limited power become culturally marginalized as their norms and values remain on the borders of societal acceptance" (Tierney & Rhoads, 1993 p. 320-321).

Acker's (1990) work suggests that perceptions of organizations, workers and jobs as gender neutral refers instead to a "default" masculinity, from which power is derived. She refers to the ideal "disembodied worker" as one with limited role in procreation and stereotypically masculine control or absence of emotions (Acker, 1990). Furthermore, she describes penalizing of the feminine body's relative larger role in procreation and stereotypical "mythic 'emotionality'" through "...control and exclusion" (p. 152). She goes on to note the trend of lower ranking of jobs most often undertaken by women, typically justified by women's seeming inability to conform to the ideal disembodied worker due to their relationship to procreation (Acker, 1990). She states "They are devalued because women are assumed to be unable to conform to the demands of the abstract job" (Acker, 1990, p. 152). This results in gendered segregation and gendered hierarchies in organizations that are largely enacted through labor.

Acker's (1990) "disembodied worker" tends to advantage men, generally, but it also reflects a specific form of masculinity that is valued in the workplace to which many men may be limited in their ability to conform. This "disembodied worker" echoes the concept of Connell's hegemonic masculinity. Connell (2005) identifies hegemonic masculinity as "…the pattern of practice that allowed men's dominance over women to continue" (p. 832). Furthermore, Connell and Messerschmidt (2005) identifies that hegemonic masculinity is "…defined in the terms of logic of a patriarchal system" (p. 832). Therefore, hegemonic masculinity is time and space dependent, reflecting the ideal masculinity with most utility for the setting. Thus, the disembodied worker can be understood as a hegemonic masculinity within workplace settings.

Acker's (1990) theory of gendered organizations provides a basis for understanding the embedded existence of gender segregation and gender hierarchy in organizations. Further work by Acker (1992) identifies dichotomized gendered roles within organizations. She argues that the defining characteristic segregating feminine from masculine is production vs. reproduction (Acker, 1992). She defines the terms as "…the division between the daily and intergenerational reproduction of people and the production of material goods, or commodities, in capitalist societies" (Acker, 1992, p. 567). She argues that while reproductive work has traditionally been reflective of domestic spheres, and therefore, generally unpaid work, its' transition into the paid labor force has not alleviated gendered segregation in work but has instead carried gendered divisions into the professional world (Acker, 1992). The author refers to these divisions of work as the "gendered understructure of society's institutions" (Acker, 1992, p. 567).

One example of reproductive work, as indicated by Acker (1992) is education. Teaching, exemplifies reproductive work because it serves a reproductive function, preparing the next generation for the workforce. Acker (1992) notes that, while reproductive work is often invisible, it is a necessity for the survival of any institution. In the case of doctoral labor in higher education, teaching labor among doctoral students is necessary for ensuring that the teaching mission, specifically teaching undergraduate students, is pursued. Further, in the current context of decreased state funding for higher education, institutions are increasingly reliant on tuition from individual students (Archibald & Feldman, 2011; Slaughter & Leslie, 1997; Slaughter & Rhoades, 2004), thereby necessitating expanded student bodies and increased numbers of teachers. Because of these trends, institutions have increasingly relied upon part-time lecturers, including graduate student teaching assistants, to fulfill increased teaching demands

(Benjamin, 2015). Therefore, the role of graduate student teaching assistants exemplifies reproductive labor.

Although research labor is not wholly centered in the productive sphere of labor because it is not always involved in the "….production of material goods…" (Acker, 1992 p. 567), the influence of commercialization to commodify research (Irzik, 2013; Jacob, 2009; Slaughter & Leslie, 1997; Slaughter & Rhoades, 2004) propels it as productive work. Moreover, Acker (1992) emphasizes that productive work is valued and prioritized over reproductive work because it is perceived as wealth generating, while reproductive work is considered wealth consuming. This is particularly evident in research resulting from outside funding agencies as revenue is directly levied in the name of research, and revenues may be generated from patenting. The prioritizing of research over teaching is also evident in tenure and promotion processes, which tend to weigh research more heavily than teaching or service (O'Meara & Bloomgarden, 2011). In academic capitalism, this prioritization of productive work is also assumed as it describes a prioritizing of research related to physical structures over intellectual, theoretical works (Slaughter & Leslie, 1997; Slaughter & Rhoades, 2004). Thus, graduate student labor oriented toward research, including research assistantships and fellowships, are indicative of masculine, productive work. Using this theoretical basis, this research predicts that as commercial influence grows, research is likely to be considered further commodified and more definitively embodying of productive labor.

Predictions and hypotheses. The theoretical frameworks proposed for this work span from the higher education policy context to roles for institutional actors. Figure three provides a visual representation of the use of, and relationships between, theoretical concepts and related predictions used in the work. Resource dependence theory and academic capitalism (shown across the top of the diagram) are used to predict that increased support for, and reliance on, private or commercial entities for academic research will be associated with increased power commanded by private or commercial funders over academic research. Academic capitalism is then used to predict increased commodification of academic research (shown in top right side of diagram).

For the current research, the main independent variable of interest s grounded in resource dependence and academic capitalist theory. Increased support for academic research by private or commercial entities is operationalized both by the share of R&D originating from industry, expended within STEM departments, is representative of market proximity. Therefore, the current research predicts the following:

1) As an institution or field within an institution receives more funding for research from private sources, the level of commercialization also increases due to increased power commanded by commercial entities providing funding
2) As commercialization increases, commodification of research also increases

New institutionalism (shown below resource dependence theory and academic capitalism in figure 1) connects broad social trends to institutional-level phenomenon, such as cultures that determine acceptable norms and values within institutional contexts. In the diagram, feminist institutionalism is shown within new institutionalism because it is a subset of new institutionalism, which concentrates specifically on the ways institutions determine gender roles and norms. This is then directed at the theory of gendered organizations, which provides more specificity regarding gender roles within institutional contexts in terms of productive and reproductive labor. Using these theories, the following predictions emerge:

3) Commodification of research reinforces research labor as masculine, productive work, defined against reproductive, teaching labor
4) Productive work is valued and privileged above reproductive work

Concerning the final prediction, in addition to the theoretical works included thus far, other research bolsters this claim through investigating conceptions of prestige. In Metcalf and Slaughter's (2008) work on administrators in increasingly commercialized higher education settings, the authors argue that a consequence of academic capitalism has been to "shift" conceptions of prestige from "expert-based" to "market-based" (p. 81). The authors argue that this environment allows men to reinforce their power and privilege within the academy (A. S. Metcalf & Slaughter, 2011; Metcalfe & Slaughter, 2008). Weeden, Thebaud and Gelbgiser's (2017) work provides further context for prestige as a means of segregation. In the author's investigation of both prestige and field segregation, they found that that men doctoral students were systematically more likely to receive degrees from more prestigious sources (Weeden, Thebaud, & Gelbgiser, 2017). Further, the authors identify that fields with the largest degree of gender segregation are also those with the highest degree of prestige segregation (Weeden et al., 2017). This means that women are disproportionately underrepresented in prestigious departments in fields in which they are most underrepresented, generally. Although the authors do not take degree of commercialization into consideration, prestige derived through reliance on private entities for research revenues may systematically privilege men students most likely to be engaged in productive labor. Further, as women graduate students in fields where they are most underrepresented may be attending the less prestigious programs, research-oriented labor opportunities may be limited and reliance upon teaching labor for graduate student funding may be more common when compared with more prestigious programs. Given these works, the following prediction is also used in the current work:

5) Institutional and program prestige is partially derived from commercial influence and market proximity

Given the above predictions based in the theoretical perspectives described, the follow hypotheses emerge:

1) As commercial influence increases, gender funding disproportionality among those receiving productive funding mechanisms (P-GFD) will increase
2) As commercial influence increases, gender funding disproportionality among those receiving reproductive funding mechanisms (R-GFD) will increase

The theoretical perspectives informing the work proposed here suggest connections between commercialization and gender inequity in higher education. Although no work has addressed through graduate student funding mechanisms, this work relates to many areas of previous scholarship. The following section provides scholarly context for the current work.

Commercial in Policy Context

In the same period during which state funding for higher education institutions decreased as a share of overall state funding, since about the 1970s, (Archibald & Feldman, 2011; Tandberg & Griffith, 2013), regulation of academic research was also undergoing significant change. The Bayh-Dole act, passed in 1980, is generally considered to have had a broad impact on the relationship between higher education institutions and the marketplace. The act changed the patenting process, allowing institutions to generate revenue from publicly funded research resulting in patents (Schacht, 2012; Slaughter & Rhoades, 2004). The goal of this piece of legislation was to ensure that the benefits of academic research would be transferred to the private sector by encouraging collaboration between universities and private industry, thereby commercializing research (Perkmann et al., 2013; Schacht, 2012).

Although the Bayh-Dole Act provided institutions with incentive to patent the products from academic research during a time in which previous funding sources were declining, Mowery et al., (2001) identify that, although impactful, the Bayh-Dole act was part of a broader range of policies aimed at protecting intellectual property rights which facilitated commercialization in academic research. In this context, Bayh-Dole created an incentive to engage in patenting due to the opportunity to generate revenue and, as Slaughter and Rhoades (2004) note, increased protections for intellectual property increased the value of patentable research and materials. This discrepancy between patentable and non-patentable knowledge varying between fields and research areas means that any effects of commercialization, such as changes to academic or research culture, would be expected to be non-uniform.

Although between 1980 and 2000 overall federal funding for academic research and development grew at a relatively consistent rate, Slaughter and Rhoades (2004) note a shift from physical science fields, such as physics or chemistry, toward biological science and biotechnology fields over previous decades (Slaughter & Rhoades, 2004). Instead of funding concentrated within fields whose research largely benefitted the Department of Defense or the Department of Energy (DOD and DOE respectively), funding has disproportionately shifted toward the National Institute of Health (NIH). Because of this, fields related to biotechnology received significant support (Slaughter & Rhoades, 2004). Mowery et al. (2001) argued that this support was concentrated in biotechnology fields because these fields were, and continue, to be engaged in research that is likely to produce patentable materials.

These findings are echoed in Shane's (2004) work, in which he argued that the primary effect of Bayh-Dole and associated legislation was to shift patenting activity into fields most likely to produce patents that could generate revenue. He suggests that the act "…provided incentives for universities to focus resources on the commercial exploitation of technology" (Shane, 2004, p. 128). The author found significant disparities between academic fields in their participation in patenting and other commercial research activities. Therefore, while research documents a disproportionate effect of industry influence within scientific fields when compared with non-scientific fields, the variation in which science departments within institutions participate in patenting or other commercialized activities varies greatly between fields (Shane, 2004).

The above research identifies growth in commercialization in academic research in relation to specific policies regulating and affecting academic research. Importantly, this research suggests that the effects of Bayh-Dole and related policies varies between institutions, fields as well as departments (Mowery et al., 2001; Shane, 2004; Slaughter & Rhoades, 2004). Resource dependence theory would therefore predict that the influence of commercialization would vary in relation to level of support from private firms (Pfeffer & Salancik, 2003). Within academic research, particularly among science, engineering and technology fields, commercialization has been facilitated by shifts in federal policies regulating academic research (Mowery et al., 2001; Schacht, 2012; Slaughter & Leslie, 1997). Such commercialization is associated with commodification of research and its' associated products (Irzik, 2013; Slaughter & Rhoades, 2004), however; the influence of commercialization even within STEM fields has varied (Mowery et al., 2001; Slaughter & Leslie, 1997), which has been documented by the varied rate of patenting across fields (Shane, 2004) or by increased applied research in engineering fields (Bentley, Gulbrandsen, & Kyvik, 2015). Thus, the rate and level of commodification of academic research is also expected to vary as it is related to the extent of commercial influence within an institution and/or department.

Commercialization and the culture of academic science. In their work, Slaughter and Rhoades (2004) argue that growth in academic capitalism has fundamentally changed the culture of academic science research. This is also emphasized in Baycan's (2013) work. He states "The recent literature suggests that there are two different cultures in today's universities: academic culture and commercial culture. While the academic culture is concerned with production of knowledge and scientific excellence, commercial culture is concerned with valorization of knowledge and generation of wealth" (Baycan & Stough, 2013). In this section, I will describe the ways commercialization affects academic culture. Specifically, I will focus on knowledge valorization and the ways it results in increased privatization in academic research, as well as the effects that commercialization has on the type of research questions being asked and type of research being done.

Baycan (2013) defines knowledge valorization as "…the need to turn knowledge into value in the knowledge-based economy." Baycan (2013) identifies that turning knowledge into value in a knowledge-based economy does not necessarily refer specifically to monetary value and may instead be referring to a "societal benchmark" (Baycan & Stough, 2013). In a review of literature relating to engagement in university-industry relations, Perkmann, Tartari, McKelvey, Autio, Brostrom, D'Este, Fini, Grimaldi, Hughes, Krabel, Kitson, Llerena, Lissoni, Salter, and Sobrero (2013) emphasize the role that commercialization plays in the current context to transfer knowledge from universities into society in beneficial ways. Although distinct concepts, the authors identify the overlap between commercialization and engagement in university-industry relations, particularly when such collaboration leads scholars to better understand the needs and culture of industry, which may make participation in commercialization in their research more attainable (Perkmann et al., 2013).

Importantly, Perkmann et al. (2013) tentatively suggest significant cultural changes relating to industry relations including "…increased secrecy and restricted communication of open research findings" (p. 429), a finding supported by later works (DiMaggio & Powell, 1991; Gerbin & Drnovsek, 2014). Increased privacy and secrecy aligns with the expectations of the academic capitalist knowledge regime (Rubins, 2007; Slaughter & Rhoades, 2004). Rubbins (2007) argues "The academic capitalism model makes the case that science is embedded in its commercial possibilities" (p. 4). These works evidence that commercialization can affect culture in scientific fields through its' challenging norms and values which have traditionally emphasized transparency and open communication (Perkmann et al., 2013; Weisbrod et al., 2008), in ways predicted by academic capitalism (Rubins, 2007; Slaughter & Rhoades, 2004).

Scholars such as Caulfield and Ogbogu (2015) and Cooper (2009) also provide insight into shifting cultures in academic science, as it pertains to the type of research being performed. Cooper's (2009) argues in his work that, "…particular faculty engagements with commercialization of the university tied to the selection of problems that biological scientists pursue and that changes within the practice of academic biological science result in a shift from science in the public interest to science for private goods" (p. 632-633). Further, Caulfield and Ogbogu (2015) argue that, within institutional contexts, commercialization is "…often presented as an unqualified social good…" and commercializable research is supported by both higher education institutions and governmental agencies (p. 5).

Slaughter and Rhoades (2004) argue that increased commercialization, particularly within the academic capitalist knowledge regime, is related to a shift from basic research toward more applied research topics. This aligns with a resource dependence theory perspective as increased funding from commercial sources would be expected to be associated with research that is more beneficial to those sources. But, as Bentley, Gulbrandsen and Kyvik (2015) describe, basic research continues to be a primary focus of academic research. The authors state "…more academics are engaged in applied research than basic research," and found in their international study that academics engaged in both applied and basic research "leaned towards applied over basic" (Bentley et al., 2015, p. 703). Furthermore, the authors found that basic research was performed at particularly low levels in professional fields such as business or education and applied scientific fields including engineering or medicine (Bentley et al., 2015). Although this increased focus on applied research may result from increased commercialization, which resource dependence and academic capitalism would predict, scholars have contested this, instead attributing such shift in subject material researched to policy changes such as increased protections for intellectual property and growth in biotechnology sectors (Mowery et al., 2001; Shane, 2004).

Graduate students and commercialization. Although the purpose of this study is not to look at graduate student outcomes in relation to interaction with commercialization, research in this area provides context for the current work. In a review of literature on the topic, Thune (2009) found trends in existing scholarly work suggesting that graduate students engaged in industry collaboration research receive significantly different research training than those engaged in non-industry collaboration research, but that productivity and reports of the PhD experience were not significantly different. Therefore, research into the differential effects for students engaged in commercial research may affect graduate student socialization which may shape postdoctoral career outcomes.

Azoulay, Ding, and Stuart (2009) argue that patenting in academic departments likely affect graduate student and postdoctoral researcher career trajectories significantly. They state “For instance, patenters may have much thicker and more diverse relationships with researchers in firms than non-patenting scientists, which may in turn facilitate apprentice scientists’ job searches in the private sector. Therefore, patenters (perhaps unintentionally) encourage their students to select private-sector careers above academic posts” (Azoulay, Ding, & Stuart, 2009, p. 671). Azoulay et al.’s (2009) work suggests that graduate students working with “patenters” may have broader career prospects. However, the extent to which this may be connected to gender disparities is not explored.

Mars, Slaughter and Rhoads (2008) identify the “state-sponsored entrepreneur,” arguing that the values of academic capitalism will affect graduate student socialization. Further, Slaughter, Campbell, Holleman and Morgan (2002) state “We see a learner-graduate education system in which student learning was transformed by exchanges with industry until the culture of capitalism, as marked by profit taking, was normalized in the laboratories of the professors we studied” (p. 307). The authors argue that academic capitalism, specifically within academic research, shapes academic culture and exchanges with industry encourages capitalistic culture and prioritizes profit making in research settings. Therefore, graduate students will be socialized to value these capitalistic values within academic settings. However, this is challenged in Mendoza's (2007) work, which found that professors may counteract opportunities for graduate student socialization to be altered due to commercial interaction, through reinforced emphasis on traditional academic values. Overall, research suggests that academic capitalism within academic research will affect culture which stands to shape graduate student socialization (Mendoza, 2007; Slaughter et al., 2002; Thune, 2009), and potentially pathways to or away from academic careers (Azoulay et al., 2009). However, the extent to which this relates to institutionally determined gender roles in graduate student funding mechanisms which also may shape postdoctoral careers is not addressed in these works.

In sum consideration of the commercialization context, these scholarly works suggest that policies have enabled an increase of commercialization in academic settings, particularly within academic research (Irzik, 2013; Mowery et al., 2001; Shane, 2004; Slaughter & Leslie, 1997; Slaughter & Rhoades, 2004). Moreover, commercialization affects institutional culture broadly, and specifically as it relates to academic research (Caulfield & Ogbogu, 2015; Cooper, 2009; Gerbin & Drnovsek, 2014; Perkmann et al., 2013; Walsh & Huang, 2014). Although the commercial influence has grown, gender segregation is evident among academic researchers participating in commercial research (Ding, Murray, & Stuart, 2006; Fox & Stephan, 2001; Murray & Graham, 2007; Perkmann et al., 2013; Sugimoto, Ni, West, & Larivière, 2015; Whittington & Smith-Doerr, 2005). Scholars largely relate this to socialization factors affecting men and women differently (Meng, 2016; Murray & Graham, 2007; Sugimoto et al., 2015), often giving unequal access to social ties and institutional support (Whittington & Smith-Doerr, 2005), as well as a perception that commercialization is “masculine” (Murray & Graham, 2007). Further, works considering graduate students interacting in increasingly commercialized settings suggest that career outcomes may be affected (Azoulay et al., 2009; Thune, 2009), but existing work does not take into consideration whether or not commercial influence is related to disparities in mechanisms of support received by graduate student men and women. While the above section provides analysis of scholarly work on commercialization, it does not address graduate student funding and funding mechanisms, which are also relevant to the current study. In the following section, I will analyze works in that area before exploring overall connections and gaps in these bodies of literature.

Chapter 2: Literature Review

The research presented in this study integrates three areas of scholarly work: Commercialization and the policy context, gender and academic labor, and graduate student funding mechanisms. I begin with works analyzing the growth of commercial and industry influence in higher education to provide context for this work. I will begin this section by reviewing works concentrating on the main federal government policies affecting commercialization in academic research. Next, I review works focusing on the effects of commercialization on institutional and departmental culture. The final two sub-sections will look at works researching the effects of commercialization in academic research on women and then graduate students. Next, I will review scholarly work on gender and academic labor by exploring multiple dimensions of gender gap and discussing the extent to which gender gaps in academic labor, broadly, are likely to manifest among graduate students. The next section will shift focus to research on graduate student funding. Within this broad topic, I will first review works analyzing gender as it relates to graduate student funding mechanisms. Next, I will review works that look at graduate student funding mechanisms and labor, such as teaching assistantships and research assistantships, as mechanisms of socialization for postdoctoral careers. In the final section I will integrate the works analyzed, identify gaps and argue that research considering graduate student labor in terms of gender roles to evaluate the extent of gender gaps in graduate student labor and funding mechanisms among science and engineering graduate students.

Gender and Academic Labor

Although limited research exists that looks at gender gaps in graduate student labor, a wealth of scholarly work focuses on a variety of gender gaps facing women in the academic labor pool. In this section, I review works focused on gender gaps and inequity in academic labor to identify potential mechanisms that cause inequity. In her work, Reskin (2005) identifies four mechanisms that cause ascriptive inequalities, like gender gaps. First, intrapsychic mechanisms are social-cognitive factors that encourage inequality and are generally considered to be unobservable (Reskin, 2005). Second, interpersonal mechanisms are mechanisms relating to interactions between individuals which may encourage inequality (Reskin, 2005). Both of these mechanisms effect people individually and directly. Alternatively, societal mechanisms are social and economic factors that indirectly affect ascribed inequality. Finally, organizational mechanisms are those cause ascribe inequality through the practices of organizational actors (Reskin, 2005 p. 90). Reskin (2005) states:

> Although personnel practices are unlikely to override organizational policies mandating differential treatment, the personnel practices that organizations implement can check or permit the effects of intrapsychic and interpersonal mechanisms. And societal mechanisms shape organizational practices. Thus, organizational practices are an immediate cause of variation in ascriptive inequality.
>
> Reskin, 2005 p. 91

Because intrapsychic factors are considered unobservable, this section will concentrate on research that relates to interpersonal, societal and organizational mechanisms of gender gaps in academic labor, particularly within STEM fields.

Gender gaps in academic labor. Baker's (2007) work found that in "liberal states" (Canada, Australia, United Kingdom and the United States), women are disproportionately concentrated at teaching institutions and in fields with disproportionately heavy teaching loads. Umbach (2007) also identified that women were disproportionately concentrated in teaching careers in her study of American faculty salary equity. Within science and engineering fields, women faculty tend to spend more time than men performing teaching labor (Misra, Lundquist, Holmes, & Agiomavritis, 2010; Winslow, 2010). Women doctorate holders account for a higher proportion of those in teaching careers, and within institutions with research expectations for faculty, women tend to spend more time teaching than the men in their departments (Baker, 2012; Misra et al., 2010; Umbach, 2007; Winslow, 2010). These works suggest occupational segregation among women doctorate holders. Thus, even if women graduate at similar rates as men, their occupational paths may differ significantly, even between institution types or within the same departments.

In addition to women's high rate of participation in teaching labor (Baker, 2012; Misra et al., 2010; Umbach, 2007; Winslow, 2010), women are also likely to be negatively affected by cultures that undervalue teaching relative to other types of labor, such as research. One prominent mechanism identified in these works is the of undervaluing of teaching is evident in university rewards and incentives. O'Meara

(2007) identifies that, in the pursuit of prestige, universities place heavy emphasis on research in tenure and promotion evaluations. This is emphasized in Misra et al., (2010) and Winslow (2010) where the authors argue that women's increased time spent teaching slows progress toward tenure. Furthermore, Umbach (2007) found that more hours spent teaching was associated with pay decreases, while research activity is associated with pay increases, and, even after controlling for individual and institutional level characteristics. These works suggest institutional practices that may systematically disadvantage women through the undervaluing of teaching labor. This pattern will also likely affect other social groups likely to take on disproportionate amount of teaching labor.

The tendency of elevated time spent teaching among women to slow tenure processes (Misra et al., 2010; Winslow, 2010), may be part of a broader trend of disadvantaging women in academic settings, which may reflect societal mechanisms causing inequality because it may be related to persist gender roles and norms. Women are underrepresented in tenured or tenure-track positions at research institutions, in the first place (Kulis et al., 2002; Misra et al., 2010). Specifically, Kulis et al. (2002) found that in all science and engineering fields, women account for a smaller proportion of tenured positions than the proportion they represent in the doctoral labor supply. Further, Kulis et al., (2002) notes that before 1976, the proportion of tenured women faculty roughly correlated with their representation in the doctoral labor pool, but the trend did not continue through the end of the 1990's. Kulis et al.'s (2002) analysis illustrates a specific dimension of gender gap that persisted after representation of women had increased in the doctoral labor supply, suggesting that simply increased attainment of doctoral degrees in science and engineering among women is not necessarily sufficient to increase their representation as tenured and tenure-track faculty.

In addition to the gender gaps discussed above, further gaps exist between the types of fields in which women are over- or underrepresented. Scholars have identified significant differences in the participation of women in science and engineering fields between specific fields (Ceci, Ginther, Kahn, & Williams, 2014; Ecklund et al., 2012; Heilbronner, 2012; Kulis et al., 2002). Many scholars have noted the increased participation among women in social science fields, particularly psychology (Ceci et al., 2014; Kulis et al., 2002). Further, life science fields also tend to have higher levels of participation among women (Ceci et al., 2014; Ecklund et al., 2012; Heilbronner, 2012; Kulis et al., 2002). Engineering and physical science fields are consistently identified as those having the lowest participation of women (Ceci et al., 2014; Ecklund et al., 2012; Heilbronner, 2012; Kulis et al., 2002). However, as Kulis et al (2002) notes, even in fields with high rates of participation among women, the rate of doctoral production still greatly exceeds representation as research faculty within those fields.

Although the current work focuses on graduate students, trends in major selection among undergraduates shapes sex segregation by field at the graduate level, as well as in the STEM workforce (Shapiro & Sax, 2011). In their work investigating variation in gender gaps between STEM fields, Sax and Newhouse (2018) outline a variety of common explanations for describing the gender gap between STEM fields. One common theme in works considering variation in gender gaps between STEM fields is the relative focus on quantitative skills and reasoning, and students' mathematical self-concept or sense of self efficacy (Nix, Perez-Felkner, & Thomas, 2015; Parker, Marsh, Ciarrochi, Marshall, & Abduljabbar, 2014; Perez-Felkner, McDonald, Schneider, & Grogan, 2012; Sax, Lehman, Barthelemy, & Lim, 2016; Sax & Newhouse, 2018). This line of reasoning is often used to explain the persistent underrepresentation of women in physics, engineering, computer science and mathematics, while women are overrepresented in biological and social science fields (Sax, 1994; Sax et al., 2016; Sax & Newhouse, 2018; Shapiro & Sax, 2011).

In addition to field segregation, other contextual factors appear to be associated with gender segregation in academic settings. Across fields, institutions and departments, the level of commercial influence varies significantly (Slaughter & Leslie, 1997; Slaughter & Rhoads, 2004; Weisbrod et al., 2008). A considerable amount of scholarly work finds that women participate in commercial research and entrepreneurial activity at a lower rate than men, suggesting another dimension of gender gap (Ding et al., 2006; Fox, 2001; Murray & Graham, 2007; Perkmann et al., 2013; Sugimoto et al., 2015; Tartari & Salter, 2015; Whittington & Smith-Doerr, 2005). However, further analysis is needed in order to understand the ways gender gaps are or are not related to variation in commercialization or market proximity.

Analyzing gender gaps in academic labor. When taken alone, any of the dimensions of gender gap identified above may be easily dismissed, particularly in light of recent trends in which increasingly more women receive doctorates and more women participate in STEM fields (Ceci et al., 2014, 2015). However, when taken together, a more complex picture of gender gap emerges within academic labor, generally. By using a critical approach, this study aims to analyze gender gaps in graduate student labor in light of a broader context of multidimensional gender gaps affecting women in academic careers. In addition to providing context for the current analysis, it is also important to keep in mind that the above gender gaps do not exist apart from one another and the dimensions of gender gap relate to and affect one another. Thus, when considering gender gaps in graduate student labor, it is reasonable to consider the extent to which the experiences in graduate school affect postdoctoral career aspirations and outcomes.

Although the above works document multidimensional gender gaps in academic labor as well as the ways it may disadvantage women doctorate holders broadly, they do not focus on similar gender gaps extending into graduate education. Fox and Stephan (2001) provide some evidence of similar gender divisions in the type of labor among science and engineering graduate students. In their work, the authors found that women graduate students express desire for teaching careers at higher rates than graduate student men. Furthermore, through interviews with STEM graduate students, Austin et al., (2009) found that students expressed increased perceptions of prestige associated with graduate student research experience, while teaching experience was not perceived as prestigious. These works evidence graduate student women associating more strongly with teaching as well as perceptions of research as more prestigious than teaching among graduate students.

Furthermore, while it is often suggested that gender gaps such as those identified throughout this section result from individual preference, critical perspectives can be used to deconstruct this assumption. In their work on critical theory and postmodernism in organizational contexts, Tierney and Roads' (1993) description of "false consciousness" is helpful for understanding why a class of people would largely gravitate toward undervalued labor. They state "…false consciousness refers to a state of human existence when we are unaware of the constricting or imprisoning quality of our existence deeply rooted in cultural patterns and structures" (p 320). Thus, although personal preferences may be able to explain gender gaps to some extent, critical perspectives focus largely on cultural means by which individuals come to be constrained into particular roles (Tierney & Rhoads, 1993). Therefore, instead of focusing on the individual decisions of women, which cannot be detangled from those resulting from a "false consciousness," Blackmore (2013) argues that we must instead focus on "social and political relations of organizations" (p. p. 149). In doing so, we focus on the ways institutions unequally distribute privilege and prestige in socially, organizationally and politically predictable ways (Blackmore, 2013).

Graduate Student Funding Mechanisms, Socialization, and Postdoctoral Outcomes

Many researchers demonstrate that funding, particularly the type of funding received by a graduate student, is important for a variety of outcomes such as rates of completion, and lower time to degree (F. Ampaw, 2010; F. D. Ampaw & Jaeger, 2011; Ehrenberg & Mavros, 1992; D. Kim & Otts, 2010; Mendoza, 2007; Mwenda, 2010). While this research focuses on funding for graduate students as well, it does not seek to measure the extent to which graduate student funding is associated with any particular type of success. Instead, this research is aimed at understanding the organization of graduate student labor and whether commercialization is associated with disproportionately higher rates of women graduate students receiving funding opportunities that align with institutionally determined gender roles. Therefore, the following sections review literature, relying on much of the work that considers the connections between funding and graduate student success, but also seeks to identify the extent to which graduate student labor fulfills gender roles, enables and/or reinforces gender stratification and socializes graduate students for postdoctoral careers.

Gendering graduate student funding mechanisms. As stated above, the type of funding received by graduate students has been associated with variation rates of completion as well as time-to-degree (F. Ampaw, 2010; F. D. Ampaw & Jaeger, 2011; Ehrenberg & Mavros, 1992; D. Kim & Otts, 2010; Mwenda, 2010). In a landmark study on the subject, Ehrenberg and Mavros (1992) found that students funded via fellowships and research positions to be highly predictive of completion and also associated with lower time-to-degree, while teaching assistantships, tuition waivers and self-support (generally through student loans) were found to be associated with longer time-to-degree and higher rates of drop-out (Ehrenberg & Mavros, 1992). Kim and Otts (2010) also found that time to degree is associated with funding type, thus offering more recent support to Ehrenberg and Mavros (1992) findings. Ampaw (2010) offered further insight into the role funding type plays for time-to-degree. She found that the time at which a student receives a particular type of funding is also influential, noting that paid researcher positions help students move more quickly once he or she advanced to the research stage of his or her graduate program (F. Ampaw, 2010).

Kim and Otts' (2010), Ampaw's (2010), Mwenda's (2010) and Ampaw and Jaegar's (2011) studies also provide insight into potential areas of stratification across relating to funding. Specifically relating to gender, Ampaw and Jaegar (2011) found that women were less likely than men to receive paid researcher positions. Moreover, Ampaw (2010) found that women graduate students are more likely than men graduate students to receive either a teaching assistantship or no assistantship at all. Lower rates of research assistantship among doctoral students is then identified as a possible explanation or lower rates of retention and completion among women graduate students (F. Ampaw, 2010; F. D. Ampaw & Jaeger, 2011, 2012). Given research finding that different types are differentially associated with graduate student success, the lower rate of women receiving highly valued researcher position may partially explain their underrepresentation among faculty researcher due to low numbers present in hiring pools.

Although these works looked at some effects of doctoral funding mechanisms on graduate student outcomes, they did not address explanations regarding why women are disproportionately represented in teaching-oriented funding opportunities. Acker's (1992) work suggests that teaching is feminized, reproductive work while research is productive, masculinized work, which may explain to some extent why women are supported via teaching-oriented mechanisms at a higher rate than men. Further, commercialization's effect to commodify academic research (Irzik, 2013; Jacob, 2009; Radder, 2010; Slaughter & Leslie, 1997; Slaughter & Rhoades, 2004) may reinforce the gendering of doctoral labor mechanisms, particularly reinforcing research-oriented mechanisms as masculinized productive work. Ampaw and Jaegar's (2011) work finds that the in science and engineering fields, specifically, graduate student men received research assistantships at a higher rate than female graduate students. This gendering of doctoral labor may contribute to the gender disparities evidenced in works included here because graduate student women must resist gender norms through their engagement in research-oriented work. However, the extent to which commercialization may reinforce this has not been fully investigated and further research in this area is needed.

Funding mechanisms as socialization for postdoctoral careers. In addition to encouraging success in doctoral programs, funding opportunities are also an important aspect of doctoral student career-socialization (Austin, 2002; Weidman et al., 2001) and a means by which students derive and interpret prestige (Austin, 2002). Weidman, Twale, Stein and Lehay (2001) identify that graduate student socialization entails learning "…knowledge, skills and values…" that are necessary for attaining employment after graduating (p. 5). Austin (2002) identifies that experiences of funding mechanisms, such as teaching or research assistantships "…can provide learning opportunities" (p. 105). He notes that while research assistantships often provided graduate students with experiences necessary for research-oriented careers, teaching was generally perceived to be not particularly valuable (Austin, 2002). In other work, researchers identify the perception that teaching is a "low-prestige" means of funding doctoral education in STEM fields, specifically (Austin et al., 2009). Therefore, the type of funding a student receives has implications for postdoctoral careers both as training as well as its' perception as prestigious work.

Importantly, Austin, Campa III, Pfund, Gillian-Daniel, Mathieu and Stoddart (2009) emphasize the perception that teaching is a “low-prestige” means of funding doctoral education. They indicate that teaching is merely a funding source until a student “…wins a place on the research team” (Austin et al., 2009). However, the role that commercialization plays is not well-understood, but the tendency of commercialization to commodify research, reinforcing it as masculine work may further propel the undervaluing of feminized, teaching-oriented work. An expected outcome of this would be low rates of women in prestigious, research-oriented careers after graduating as well as systemic undervaluing of fields and types of work most often performed by female doctorate holders.

Little work exists that looks at doctoral funding mechanisms and postdoctoral career outcomes. However, Blume-Kohout and Adhikari’s (2016) work on the topic found that doctoral students’ mechanism of funding was predictive of early career employment. In the authors’ study, graduate students funded via research-oriented mechanisms, such as a research assistantship, were more likely to find research focused jobs after graduating (Blume-Kohout, 2014). Although the study did not compare or consider teaching-related funding mechanisms, nor did it consider gender disparities and gaps, the work suggests that paid researcher opportunities are important for socializing and development of skills necessary for a research-oriented career. However, their work does suggest that the absence of research-related funding mechanisms will likely disadvantage a student interested in a research-oriented career when compared to others who did have research-related funding opportunities.

Researchers identify that graduate student funding mechanisms are important for socialization for postdoctoral careers (Blume-Kohout, 2014) and that different types of funding mechanisms are perceived as more or less prestigious (Austin et al., 2009). However, the extent to which this is related to gender or gender roles is not explored in existing scholarly work. Through the application of Acker's (1990; 1992) theory of gendered organizations, this work makes these connections in order to evaluate the extent to which gender disparities in graduate student funding mechanisms are reinforced and/or expanded in highly commercial settings.

Connections, Gaps, and Conclusion

Researchers demonstration that not only do gender gaps persist in academic labor within science and engineering fields, but that they exist along many dimensions including gendered divisions in the type of labor typically undertaken by men and women, perceptions of prestige and value of labor type, and field segregation by sex (Ceci et al., 2014; Ecklund et al., 2012; Ehrenberg & Mavros, 1992; Fox, 2001; Fox & Stephan, 2001; Frehill et al., 2015; Kulis et al., 2002; Nix et al., 2015; Sax & Newhouse, 2018). However, while these broad trends in academic labor indicate multidimensional gender gaps, the works provided as context for this study, but they not address whether the aforementioned trends extend into doctoral labor.

Although significant attention has been paid to the role that graduate student funding has played for predicting outcomes such as success and time to degree (F. D. Ampaw & Jaeger, 2011, 2012; Ehrenberg & Mavros, 1992; Mavriplis et al., 2010; Mwenda, 2010), works concentrating on stratification across gender are particularly relevant to the current research. Ampaw's (2010) finding that, when aggregated across all fields, women are more likely to receive teaching assistantships or no assistantships, accounted for lower persistence rates among women, suggests some degree of gender gaps apparent in graduate student labor. However, Ampaw (2010) suggested that this may be due to the high propensity of women graduate students to be enrolled in fields with lower rates of completion, such as English or History low-completion fields with high rates of teaching assistantships. When considering science and engineering fields, specifically, Ampaw and Jaegar (2011) found that men received research assistantships at a higher rate than women. Although, these studies do indicate gendered divisions in graduate student funding, the authors rely on explanations involving field of study. It is not explored whether mechanisms of funding allow students to either conform to or resist institutionally determined gender roles as well as to what extent institutional factors affect gendered perceptions of academic labor.

Fox's (2001) work also seeks to understand how graduate education experiences may be related to gender gaps, stratification and hierarchies in academic labor more broadly. She states "…increasing numbers of women may not alter the 'norms' and 'standard practices' of education and work" (Fox, 2001, p. 661). She argues that science, and norms within scientific fields, tend to be constructed as masculine. As with Acker's (1990; 1992) assertion that the ideal academic is masculine, disembodied worker, Fox (2001) asserts that the masculinity norm of science is also "disembodied" and "male" (p. 662). However, while Fox's (2001) work is important for understanding gendering in scientific fields, she does not address the extent to which different types of labor performed in academic, scientific settings are gendered. Therefore, given Ampaw (2010), Ampaw and Jaegar (2011) and Fox's (2001) work, there is reason to investigate dimensions of gender gaps in academic science, relating to norms and values implicit in these settings. The current research seeks to fill this gap, using Acker's (1990; 1992) theory of gendered organizations, applied to graduate student funding mechanisms.

Evidencing that the labor undertaken by graduate students is gendered is based in more than simple overrepresentation of men in research positions and women in teaching positions. This assertion also relates to perceptions of value of labor type. In the broad academic labor market, undervaluing of reproductive, teaching labor is evident through lower rates of pay (Fairweather, 2005; Umbach, 2007) for those positions. Austin et al.'s (2009) work on doctoral students in STEM fields indicates similar perceptions that teaching work in doctoral education is not valuable for those interested in research faculty positions. Literature on the high rate of women doctorate holders in teaching positions, and perceptions broadly and within doctoral education, that teaching is non-valuable in the way that research-oriented funding mechanisms are, informs this study.

Although the above research suggests gender gaps in academic work generally, and in graduate education specifically, as well as the perceptions of prestige relating to different types of work, none of the above work focus on the role that commercialization may play for reinforcing and furthering gender gaps in science and engineering fields. Of relevance to this research project, Kulis et al., (2002) found that before 1976, as the proportion of women earning doctorates in science and engineering grew, their representation as research faculty also grew. However, that trend did not continue after

1976 (Kulis et al., 2002). Although Kulis et al., (2002) did not address whether growth in commercialization in academic settings may be related to this disruption in the trend identified, policies enabling commercialization were beginning to be put in place in the late 1970's, thereby warranting consideration in this study.

Research on commercialization in higher education does suggest that commercialization has affected institutional culture, particularly as it relates to academic research (Caulfield & Ogbogu, 2015; Cooper, 2009; Irzik, 2013; Jacob, 2009; Slaughter & Rhoades, 2004). Further, the effects of commercialization have been concentrated in certain areas, particularly in biological science and biotechnology fields. However, even though growth among women doctoral holders has grown significantly in the biological and life science fields (Whittington & Smith-Doerr, 2005), their participation in commercial research, even within those fields, remains lower than men (Ding et al., 2006; Fox, 2001; Murray & Graham, 2007; Perkmann et al., 2013; Sugimoto et al., 2015; Tartari & Salter, 2015; Whittington & Smith-Doerr, 2005). Other fields receiving significant support from private industry, such as engineering fields, tend to have low participation rates among women (Kulis et al., 2002; Perkmann et al., 2013; Whittington & Smith-Doerr, 2005). Although this research demonstrates, somewhat reliably, that women participate in commercial research at lower rates, researchers have not explored to a large degree the extent to which commercialization may reinforce gender roles, thereby reinforcing gendered divisions in academic labor.

While this work provides context for broad gender gaps, potentially relating to commercialization in academic science, it does not focus on postdoctoral career outcomes. However, the importance of the current study relates to postdoctoral career outcomes. Because of the reproductive role graduate education plays within the academic labor market (Gemme & Gingras, 2012), it serves as an important aspect for shaping the future academic labor market. Although research in this area is sparse, Blume-Kohout and Adhikari's (2016) study found postdoctoral career outcomes among students in their sample to be related to the type of funding they received as a graduate student. While further research is needed to offer robust evidence for connecting graduate student funding mechanisms and experiences to postdoctoral careers, the current research provides important context and theoretical basis for such scholarly work.

Considering these effects at the doctoral student level is helpful because of the reproductive role that graduate education plays in academic labor (Gemme & Gingras, 2012). By fully understanding the implications of doctoral funding mechanisms received by a student as socialization and training for postdoctoral careers, the extent to which doctoral funding mechanisms allow men and women to either resist or conform to institutionally determined gender norms and comparing this across fields with varying commercial influence, researchers may be able to understand how commercialization has the potential to intensify gender gaps. Such research could fill a large gap in the current body of scholarly work, providing insight into why women continue to make tremendous gains in earning doctorate degrees but are not making such significant gains in their representation among prestigious academic positions, specifically as research faculty.

Chapter 3: Methodology

The current work takes a critical quantitative approach to analyze commercial influence in STEM academic research, and the extent to which it is associated with broader gender gaps in the way that graduate students are funded, or GFD. According to Stage (2007), critical quantitative researchers use quantitative data to deconstruct normative assumptions and perspectives that color the way that models and results are interpreted. In the current work, I question the assertion that the types of funding graduate students receive is a neutral means of support. On the contrary, I use Acker's (1990; 1992) work to argue that gender norms and values are communicated and interpreted within different types of academic labor and that these gendered divisions are reinforced in departments with significant commercial influence. Thus, the research questions, data operationalization and model building processes are designed in order to best identify gender funding disproportionality (GFD) among STEM graduate students.

Research Questions

This research considers whether, on average, women and men receive reproductive or productive funding mechanisms at disproportionate rates, as well as differences in field-level research and development (R&D) expenditures originating from industry are associated with disproportionality in the way men and women graduate students are funded within STEM fields. The following research questions guide this study:

RQ 1: To what extent is there gender disproportionality in reproductive (R-GFD) and productive (P-GFD) funding in STEM graduate programs at U.S. research universities?

RQ 1a: To what degree does GFD vary among departments within universities, and between institutions?

RQ 2: To what extent are field and department gender disparities, and ratios of productive funding to reproductive funding associated with GFD?

RQ 2a: After controlling for within-institution department gender-disparities, what is the effect of a field being more- or less- "male-dominated" on GFD, and does that effect vary across institutions?

RQ 2b: After controlling for within-institution department funding ratio what is the effect of a field more or less reliant on productive or reproductive funding mechanisms on GFD, and does that effect vary across institutions?

RQ 3: To what extent is variation in market proximity associated with GFD among men and women STEM graduate students?

RQ 4: To what extent are variations in institutional characteristics, institutional prestige, institutional size and institutional control, associated with GFD among men and women STEM graduate students?

RQ 5: Is the relationship between a department's share of R&D originating from industry and GFD different in social science STEM fields when compared with non-social science STEM fields?

RQ 6: Is the relationship between level one covariates and GFD significantly different in quantitative STEM fields vs. non-quantitative STEM fields?

To answer the proposed research questions, I will use cross sectional data from the 2016 annual National Science Foundation (NSF), the Survey of Graduate Students and Postdoctorates (GSS) and the Higher Education Research and Development Survey (HERD). I will use a random intercept, multilevel modeling strategy, utilizing full maximum likelihood as the method of estimation, to analyze variance at two levels. The first level, STEM departments, are conceived of as nested within the level two, higher education institutions. The following sections describe the data and sample, dependent and independent variables, as well as the model used and the model building process.

Sample

For this work, I will use both the NSF Survey of Graduate Students and Postdoctorates (GSS) as well as the Higher Education Research and Development Survey (HERD). For both of these surveys, 2016 data is used. The HERD survey is an annual census of all institutions expending at least $150,000 on R&D annually (National Science Foundation [NSF] National Center for Science and Engineering Statistics [NCSES], 2015). Therefore, institutions included in this survey each expended at least $150,000 in 2016. The GSS survey is also an annual census of all U.S. institutions offering masters or doctoral degrees in STEM as well as selected medical fields.

For the current analysis, the sample used is limited to those institutions expending at least $150,000 on R&D annually, due to the HERD survey's qualification for inclusion, and must also report R&D expenditures funded by industry on the HERD for 2016, therefore demonstrating potential influence of industry at the institution. The sample is also limited to those institutions classified as Moderate, Higher and Highest

Research Activity or Doctoral Research Institutions according to the 2015 Carnegie Classification update) and is comprised of all institutions that meet the above criteria (institutions offering masters and doctoral degrees, Carnegie classification high, very high research activity or doctoral research universities, R&D expenditures above $150,000). Furthermore, three institutions were dropped due to lack of data, as well as the uniqueness of the institutions. Therefore, the final sample used for this study is 210 institutions.

This sample includes science, engineering as well as social science fields included in both the HERD and GSS data sets. However, although both surveys include science and engineering fields, there are places where fields do not perfectly match one another. Therefore, certain similar fields are aggregated together and collapsed into a larger category. Fields that are collapsed together are grouped together in two ways primarily. First, the GSS survey utilizes both specific field categories, as well as broad field categories. Where the broad fields match the HERD survey categories, detailed fields are collapsed into the broad categories. However, to be as specific as possible, certain fields are not aggregated to the broad category level, such as in the case of engineering fields. In these cases, similar fields are groups together. In cases when fields matched perfectly, such as in the case of chemistry, no further action was taken.

Table two shows the fields that have been combined for the current analysis. Within engineering fields, the first category, metallurgical and materials engineering, includes the GSS categories industrial and manufacturing engineering as well as metallurgical and materials engineering. These fields are combined because they all deal with research on materials and production processes of materials.   The second category, chemical engineering, includes both the GSS category chemical engineering and petroleum engineering. These fields are combined due to the similarity of fields which is evident in that combine chemical and petroleum engineering into a single department (example University of Kansas). The next category, biological and biomedical engineering, includes from the GSS agricultural, biomedical and biological and biosystems engineering fields. These categories are combined due to the large degree of "crossover" in these fields throughout the surveys used. In the GSS survey broad categories, biological and biosystems engineering is considered a sub-field of agricultural engineering, while in the HERD survey, biomedical engineering is combined with bioengineering. The final engineering category, other engineering, includes the remaining GSS engineering fields, engineering science and engineering physics, mining engineering and nuclear engineering.

Within non-engineering fields, several large categories are utilized that match the GSS broad categories which are better matches to the categories used in the HERD survey. First, the GSS mathematics and statistics categories are combined for the mathematic sciences category. The biological sciences categories include GSS categories, biochemistry, biology, biometry and epidemiology, biophysics, botany, cell and molecular biology, ecology, entomology and parasitology, genetics, microbiology, immunology and virology, nutrition, pathology, pharmacology, zoology as well as biological sciences. Finally, the psychology category combines the GSS categories general psychology clinical psychology and non-clinical psychology.

Two broad fields, Physics and Astronomy and Earth Sciences, are composed of sub fields that are found in both the GSS and HERD survey. However, they have been combined due to their similarity and the low numbers of students reflected in the survey. As such, Physics and Astronomy includes both the GSS categories physics and astronomy fields as well as the other physical sciences field. The Earth Sciences field includes the GSS categories atmospheric sciences, geosciences, oceanic sciences as well as earth, atmospheric and ocean sciences not included elsewhere. In addition to table one showing combined fields, table two shows all fields that were not aggregated and table three includes a complete list of fields included in this analysis, their frequency in the sample.

In the final sample, 19 distinct fields are used for the proposed analysis. However, in certain cases fields within institutions are removed. First, fields within institutions reporting that zero graduate students receiving funding are removed. Additionally, fields within institutions reporting that there are zero funded women, or zero funded men are also dropped. Therefore, to be included in this sample, fields within fields must report both funded men and women graduate students. Furthermore, fields reporting zero expenditures on R&D were also removed. Because of this, not all 19 fields are necessarily represented at each of the institutions included in this sample.

Dependent Variables

For the proposed analysis, two dependent variables are used to adequately understand the relationship between R&D funding originating with industry and GFD. The first will be the proportion of men, out of all men in a department, who receive reproductive funding mechanisms, minus the proportion of women, out of all women in the department, who receive reproductive funding mechanisms. Similarly, the second dependent variable is the proportion of men out of all men in the department who receive productive funding mechanisms, minus the proportion of women out of all women in the department who receiving reproductive funding mechanisms. These variables assume that equity between men and women would mean that the same proportion of men and women receive either productive or reproductive funding mechanisms. Therefore, at zero, the outcome variable indicates that the same rate of men and women receive either productive or reproductive funding mechanisms. These variables were both standardized, making the mean zero and the standard deviation one.

The dependent variables used are rooted in the theoretical perspective informing this study. Acker (1992) contends that institutions are inherently gendered and that the traditional absence or low participation rates at institutions results in a privileging of masculine, productive work over feminine, reproductive work. The dependent variables are used as proxies for productive and reproductive work. First, institutional support is representative of reproductive work, primarily teaching. Although institutional support does not only support teaching funding opportunities, the correlation between institutional support and the number of students funded via teaching assistantships is high (.72) therefore indicating that institutional support is primarily used for teaching-related funding opportunities. Moreover, institutional support is considered to be less prestigious (Austin et al., 2009; Fox, 2001) and has been demonstrated to be associated with a lower likelihood of pursuing research careers in the biomedical sciences (Blume-Kohout, 2014).

Therefore, a disproportionate number of women receiving institutional support when compared with men may be reflective women graduate students taking on a larger proportion of reproductive work.

The second dependent variable is indicative of productive, or research-oriented funding and combines the number of students receiving federal funding or funding from Other U.S. Sources. As the theoretical perspective section describes, one expected effect of commercialization in academic research is that it will result in research being increasingly commodified (Slaughter & Leslie, 1997; Slaughter & Rhoades, 2004), which reinforces the relation between research and productive work. Again, a correlation between the number of students receiving this type of support with the total number of students receiving research assistantships and fellowships was high (.87)[1], suggesting that funding from these sources is primarily used for research-oriented support.

As such, the first dependent variable is the proportion of men minus the proportion of women receiving productive funding mechanisms, or funding from either a federal agency (Department of Energy, National Institute of Health, etc.) or from "Other U.S. Sources." The second dependent variable is the proportion of men minus women receiving reproductive funding mechanisms, or those receiving institutionally supported funding. Descriptive data for dependent variables is shown in table four.

[1] The correlation between students who are supported as researchers (research assistants, graduate student researchers, etc.), not including fellowship recipients, and the number of students receiving funding from "Other US Sources" and Federal sources is also high: .89.

Many scholars find that the way graduate students are funded is important for graduate student success and their competitiveness for postdoctoral careers (F. Ampaw, 2010; F. D. Ampaw & Jaeger, 2011, 2012; Ehrenberg & Mavros, 1992; D. Kim & Otts, 2010; Mwenda, 2010). Researchers in this area found more positive outcomes (higher likelihood of completion, lower time to degree) correlated with fellowships and research assistantships, while teaching assistantship, tuition waivers and self-support are associated with less favorable outcomes (Ehrenberg & Mavros, 1992; D. Kim & Otts, 2010). Moreover, work suggesting that women are less likely to receive researcher positions (F. D. Ampaw & Jaeger, 2011, 2012), specifically in STEM, evidence existing gender disparities in the mechanism of graduate student support. However, the current study focuses instead on differences in rates of men and women receiving productive/reproductive labor funding mechanisms in relation to department and institutional research expenditures. In doing so, the current research seeks to provide more complex insight into existing gender disparities among science and engineering graduate students, while also providing further insight into the types of disparities identified in previous literature (Ampaw & Jaeger, 2011, 2012).

Although this study is uniquely considering disproportionality among men and women graduate students within a field and an institution are funded by specific sources, it relies similarly on the role that teaching assistantships and other institutionally funded positions play for signaling prestige and socializing graduate student to prestigious research careers. When compared with institutional funding, both federally and industry financed support is likely to be considered more prestigious, evidenced by the high concentration of this type of funding at prestigious institutions (Weisbrod, Ballou, & Asch, 2008). Moreover, in studies on biomedical sciences, funding mechanism has been found to affect postdoctoral careers, with teaching assistantships and institutionally supported research assistantships negatively affecting graduate students' likelihood of pursuing a career in R&D, while federally funded fellowships were associated with an elevated likelihood (Blume-Kohout & Adhikari, 2016). This analysis considers to what extent women are disproportionately represented as those funded by institutional support and whether this is related to the extent of industry funding in a department and institution. The implications of women receiving institutional support at disproportionate levels may explain to some extent, the underrepresentation of women in research careers after graduating.

Independent Variables

The structure of the data used in this analysis informs some of the decision-making for including variables in the model. Specifically, the analysis is focused on understanding how differences between field shape GFD. One way to do this, would be to enter variables indicating each of the individual field. However, this approach is not sufficient for the current analysis for a few reasons. First, given that there are 19 field categories, this would add significant complexity into the model, unnecessarily. One solution to this problem would be to aggregate fields into broader categories (such as the biological sciences, engineering sciences, physical sciences and social sciences). However, the first problem with using broad categories would be that there still exists significant variation, particularly as it relates to gender disparities, within subfields that comprise broad field categories. Second, to include a variable indicating field, it would be necessary to use one of the fields as a reference category. This reference category should be theoretically driven. However, in the current analysis, there is no theoretical reasons to look at effects of a particular field in reference to a different field. For example, it does not make theoretical sense to analyze each of the broad fields in reference to a field like biological sciences or social science.

To analyze differences between fields, two approaches are taken. First, field attributes are included in the model, indicating field averages in gender disparities and the ratio of productive to reproductive funding awarded to students in the field. This allows analysis of variation between fields based upon typical conditions in departments within that particular field. The second approach is to distill STEM fields down to two simple categories that speak to primary divisions between fields. The first division considered in this research analyzes whether the relationship between the outcome variables and market proximity is significantly different in social science fields, due to the conventional thinking that social science is very different from other STEM fields. The second division considered focuses on whether there are significant differences in the relationships between the outcome variables and covariates in highly quantitative STEM fields, when compared with those that are not highly quantitative. Further description of these approaches is detailed in the following sections.

Field attribute variables. Two field-attribute variables will be entered into the model at the within-institution-fields-level (level 1). The first field attribute variable I will be investigating is the degree to which a field is “male-” or “female-dominated.”

This is operationalized as the field-average ratio (across all departments within a field) of men to women. The purpose of including this variable is to analyze the extent to which women's overall representation in a field is associated with variation in disproportionality between men and women. In a relatively straight-forward way, the balance of men and women in the field roughly represents the dominance of masculinity or femininity within a field. To control for individual differences within fields, I will also include a variable indicating each within-institution department gender disparity as well.

Next, I will add a variable that describes a field-average reliance on productive vs. reproductive funding mechanisms for their students. Specifically, this variable will be constructed as the field-average ratio (across all departments within a field) of number of students funded via productive funding mechanisms, to the number of students funded via reproductive funding mechanisms. Although the above example, gender disparity, is very transparently representative of gendered differences within field, this variable draws on Acker's (1990) theory of gendered organization to apply a gendered lens to the average, relative availability of labor types within a field. As described in the theory section, the primacy of productive labor over reproductive labor is used as an additional indicator of gendered divisions within a field, with productive labor representing masculinized labor and reproductive labor represented as feminized. Furthermore, this variables also allows consideration of field differences in the way students are typically funded. To control for individual differences within fields, I will also include a variable indicating each within-institution department funding ratio as well.

The interpretation of the field-attribute variables, first, will indicate whether there is a significant relationship between these field attributes and GFD. Next, the coefficient for the degree of male/female dominance will indicate the effect of a one-unit change in a field's average gender disparity. However, because the measure is a ratio, a one-unit change represents an additional man per one woman in a field, on average. The coefficient for the average, relative reliance of productive vs. reproductive funding mechanisms in a field will indicate what a one-unit change in the ratio of students receiving productive funding to students receiving reproductive funding. Again, the interpretation of this variable, a ratio, will indicate what change in the outcomes is associated with a one- unit change, or an additional man per one woman in a department.

Taken together, the field averaged variables used in this analysis represent differences between fields that would be expected to affect the culture within a field. If students can reasonably expect to be supported via productive funding mechanisms, then it is reasonable to expect that the culture of that field is heavily centered on research. However, in a field heavily reliant upon reproductive funding mechanisms, then it is reasonable to expect that a difference in culture. Furthermore, the average gender disparity in a field is also likely to shape perceptions and expectations in field, as well. For example, is greater gender disparity associated with increased conforming to gender roles, evidenced through broadening of rates of P-GFD and R-GFD?

Within-institution-department variables. In addition to considering field-averaged differences, I will also consider department data, also entered at the within-institution-field-level (level 1). As this work theorizes, market proximity of a department is expected to be associated with reinforced gender roles, evidenced through disproportionately high rates of women being funded via reproductive funding mechanisms and disproportionality low rates of women being funded productive funding mechanisms. Therefore, to indicate a department's proximity to the market, I will include the department's share of R&D expenditures originating from industry. Additionally, as mentioned previously, control variables indicating department gender disparity and funding ratio are also included at the within-department level. Descriptive information about within-department variables included in table six.

Institution-level variables. At the institution-level, control variables for institutional size (number of graduate and professional students enrolled in fall 2016[2]), as well as institutional control (public/private) are included in the analysis to control for normal institutional variation. However, the main independent variable of interest at the institutional level is prestige. The conception of institutional prestige used in this analysis is based on the U.S. News and World Report annual ranking of colleges and universities. According to Bastedo and Bowman (2010) "In the field of higher education organizations, prestige is one of the most important factors in assessing organizational performance, and the *U.S. News* rankings are the most prominent assessment of that performance" (p. 164). Thus, the use of U.S. News and World Report college and university rankings is justified due to its prominence and importance in the field of higher education (Bastedo & Bowman, 2010; J. Kim, 2018; Volkwein & Sweitzer, 2006).

[2] 2016 IPEDS enrollment data for graduate and professional students

Although the U.S. News and World Report rankings do not equate institutional prestige, the ranks are determined in part, by two measures of institutional reputation, or prestige ("How U.S. News Calculated the 2019 Best Colleges Rankings," 2018). The first, an assessment from high school counselors, is focused on an institution's reputation for undergraduate admissions. The second component of institutional reputation, the peer assessment score, measured on a scale between 0-5, is based on the average responses to surveys administered to top academics during the previous two springs (for the 2016 rankings, the peer assessment scores would be based upon surveys administered in the springs of 2014 and 2015) ("How U.S. News Calculated the 2019 Best Colleges Rankings," 2018).

Although the peer assessment score itself would be an optimal measure of institutional prestige, data are not reported for institutions ranked beyond 264, of which 16 are included in this study's sample. Therefore, to approximate institutional prestige for the purpose of this analysis, I include a simplified version of the U.S. News and World Report rankings, assigning ranks to institutions in groups of 10, through institutions ranked up to 200. For example, institutions ranking among the top 10 receive a rank of one, and institutions ranking between 11 and 20 receive a rank of two. Institutions ranked between 200 and 264 are ranked 21[3] and finally, institutions included

[3] Individual ranks are not reported for institutions in the "second tier" (ranks 200-264). Forty-two "second tier" institutions are included in this analysis and assigned the rank of 21.

in the sample that rank beyond 264 are assigned a rank of 22[4]. Frequencies of institutions included at each rank included in table seven.

The use of U.S. News and World report rankings is justified due to similarities between institutional prestige and institutional rank (Bastedo & Bowman, 2010; Kim, 2018). This can be demonstrated through the high degree of correlation that exists between these concepts within my sample. For example, institutional peer assessment scores among the top 200 in the U.S. New and World Report correlates highly and negatively with U.S. News and World Report Rankings significantly (-0.899**). Once simplified into bands using the method described above, this correlation decreases just slightly (-0.898**). Once "second tier" institutions are added, and assigned a rank of 21, this correlation is still high and significant (-0.875**). These correlations suggest that a higher peer assessment score is associated with a lower U.S. News and World Report ranking. This relationship indicates a high degree of interrelatedness and similarity between U.S. News and World Report overall ranking and an institution's peer assessment score. Thus, the current work uses the simplified U.S. News and World Report rankings as a proxy for institutional prestige. However, one key limitation associated with this measure of prestige is that it does not account for within institution variation in prestige among departments which is particularly important for graduate education (Weeden et al., 2017).

[4] Data for unranked institutions not available. Sixteen institutions included in this analysis are unranked.

Interaction terms. Because STEM fields are not monolithic, variation between STEM fields may affect this analysis. Therefore, two strategies for understanding how different fields may interact with key variables are considered for this analysis. First, a variable indicting whether or not fields are social science or not is constructed. Then, this variable is interacted with the main independent variable of interest, the share of R&D expenditures originating from industry, representing market proximity. This method is used to assess whether or not the relationship between gender funding disproportionality and market proximity is significantly different in social science fields when compared with non-social science fields.

In addition to investigating differences in social science fields, I will also consider a key division within STEM fields, the focus on quantitative skills. As such, I created a dichotomous variable indicating whether or not a field was considered to be "quantitative STEM" or not. Fields considered to be quantitative STEM fields include engineering, physics and astronomy, math and statistics, and computer science. On the other hand, fields not considered to be non-quantitative STEM include social sciences (economics, psychology, sociology and pubic administration/political science), biological sciences, earth and other geosciences and chemistry. (justify this the use of quant stem vs. non quant stem). This term is then interacted with significant covariates in order to assess whether or not relationships between covariates and the outcome variables are significantly different in quantitative STEM fields, compared to non-quantitative STEM fields.

Model

For the current analysis, I will utilize a two-level MLM model for the year 2016 for each of the dependent variables. In these models, fields are conceptualized as nested within institutions. By using this technique, the current research seeks to assess institutional and within-institution, field-level effects of commercialization on the two outcome variables, P-GFD and R-GFD. Therefore, the model building process will be repeated for each of the dependent variables included in the analysis.

Model 1. The model building process for the current study will begin with the fully unconditional model (random-effects ANOVA model). In this model, no field level or institutional level variables are included (Raudenbush & Bryk, 2002). This model will determine the total variability in the outcome variables between institutions and between fields. Furthermore, to address the first research question, this model will also be used to address whether or not, on average, GFD is significant.

$$Y_{ij} = \beta_{0j} + r_{ij}$$

In the above equation, Y_{ij} represents each of the dependent variables at each field (*i*) at an institution (*j*). Thus, it represents in each of the models the following:

1) Proportion of men in department (out of all men in department) who receive productive funding mechanisms, minus the proportion of women in department (out of all women in department) who receive productive funding mechanisms

2) Proportion of men in department (out of all men in department) who receive reproductive funding mechanisms, minus the proportion of women in department (out of all women in department) who receive reproductive funding mechanisms

The next variable, β_{0j} indicates the field-level average GFD for either productive or reproductive funding. The error term, r_{ij}, refers to the individual deviation of each individual field from the field-average.

The institution level equation is as follows:

$$\beta_{0j}{=}y_{00} + u_{0j}$$

In the above equation, β_{0j} is represented as a function of the grand mean, y_{00}, and it's associated error, u_{0j} (Raudenbush & Bryk, 2002). In the current research, the grand mean represents the mean GFD across all institutions included in this sample. The combined equation is as follows:

$$Y_{ij} = y_{00} + u_{0j} + r_{ij}$$

In the above equation, gender disparity at a field within an institution (Y_{ij}) is represented as a function of the group mean (y_{00}) and the individual deviation of an institution from the group mean (u_{0j}), and the individual variation of a field from its' associated institutional mean (r_{ij}).

Model 2. The second model included in this analysis aims to answer research question two, or what extent field and department differences in gender disparities and patterns in the way students are funded affect GFD. This will be done by entering four variables, using group mean centering, over two steps. The first two variables, entered simultaneously, are indicative of gender disparities in the department, as well as the average gender disparity in the department. These variables are used to indicate variation in "male dominance" within a field and within individual departments. The next step will involve entering two variables, simultaneously, indicating the ratio of productive funding mechanisms awarded to students, relative to reproductive funding mechanisms both in the department and on average, within the field.

After entering the variables over two steps, the following equation is developed for the level-one equation for model two:

$$Y_{ij} = \beta_{0j} + \beta_{1j}(field\ average\ gender\ disparity) + \beta_{2j}(department\ gender\ disparity) + \beta_{3j}(field\ average\ funding\ ratio) + \beta_{4j}(department\ funding\ ratio) + r_{ij}$$

In the above equation, the outcomes are modeled as a function of the intercept, or average R-GFD and P-GFD, the field average gender disparity , the department gender disparity, the field average ratio of productive funding to reproductive funding mechanisms awarded to students, as well as the department ratio of productive to reproductive funding mechanisms awarded to students. Variables are entered into the models using group mean centering.

The level two equations are as follows:

$$\beta_{0j} = y_{00} + u_{0j}$$

$$\beta_{1j} = y_{00}$$

$$\beta_{2j} = y_{00}$$

$$\beta_{3j} = y_{00}$$

$$\beta_{4j} = y_{00}$$

Model 3. The third model will address the third research question, considering the effects of the field- R & D expenditures originating from industry. The level one equation is as follows:

$$Y_{ij} = \beta_{0j} + \beta_{1j}(field - average\ gender\ disparity)$$

$$+ \beta_{2j}(department\ gender\ disparity)$$

$$+ \beta_{3j}(field - average\ funding\ ratio)$$

$$+ \beta_{4j}(department\ funding\ ratio)$$

$$+ \beta_{5j}\ (industry\ R\&D\ expenditures) + r_{ij}$$

With the addition of the variable, the share of expenditures for R&D originating with industry, the dependent variables are predicted as a function of gender disparity and reliance on productive and reproductive funding mechanisms (both field-averaged and department-level) as well as the department's proximity to the market. In the level-two equations (below), as with the previous level-two equations, β_{5j} is specified as fixed.

$$\beta_{0j} = y_{00} + u_{0j}$$

$$\beta_{1j} = y_{00}$$

$$\beta_{2j} = y_{00}$$

$$\beta_{3j} = y_{00}$$

$$\beta_{4j} = y_{00}$$

$$\beta_{5j} = y_{00}$$

Model 3: Interaction. To address research question five, two interaction terms will be entered into the model in order to assess whether the relationship between social science STEM fields and non-social science STEM fields and gender funding disproportionality is significantly different. Therefore, a term representing whether or not a field is a social science STEM field, or a non-social science STEM field is entered into the model using group mean centering. Additionally, the model will then include an interaction term between the social science/non-social science variable and the share of R&D expenditures originating from industry. The level one equation will be as follows:

$$Y_{ij} = \beta_{0j} + \beta_{1j}(field - average\ gender\ disparity\ )$$

$$+ \beta_{2j}(department\ gender\ disparity)$$

$$+ \beta_{3j}(field - average\ funding\ ratio)$$

$$+ \beta_{4j}(department\ funding\ ratio)$$

$$+ \beta_{5j}\ (industry\ R\&D\ expenditures)$$

$$+ \beta_{6j}\ (social\ science\ STEM\ field)$$

$$+ \beta_{7j}\ (industry\ R\&D\ expenditures * social\ science\ STEM\ field)$$

$$+ \ r_{ij}$$

As such, the level two equations are as follows:

$$\beta_{0j} = y_{00} + u_{0j}$$

$$\beta_{1j} = y_{00}$$

$$\beta_{2j} = y_{00}$$

$$\beta_{3j} = y_{00}$$

$$\beta_{4j} = y_{00}$$

$$\beta_{5j} = y_{00}$$

$$\beta_{6j} = y_{00}$$

$$\beta_{7j} = y_{00}$$

Model 4. The final model used in this study will include level-two, or institutional-level variables. While the majority of variance in the outcomes occurs between fields and department, key variables including institutional size and control (public/private) are controlled for, and I will also include a variable indicating institutional prestige to test whether or not institutional prestige significantly predicts funding disproportionality among men and women graduate students in STEM. The level-one equation will remain the same as above. However, the level-two equations will be modeled as the following:

$$\beta_{0j} = y_{00} + y_{01}(Institutional\ control) + y_{02}(Institution\ size) + y_{03}(Institution\ prestige) + u_{0j}$$

$$\beta_{1j} = y_{00} + y_{01}(Institutional\ control) + y_{02}(Institution\ size) + y_{03}(Institution\ prestige)$$

$$\beta_{2j} = y_{00} + y_{01}(Institutional\ control) + y_{02}(Institution\ size) + y_{03}(Institution\ prestige)$$

$$\beta_{3j} = y_{00} + y_{01}(Institutional\ control) + y_{02}(Institution\ size) + y_{03}(Institution\ prestige)$$

$$\beta_{4j} = y_{00} + y_{01}(Institutional\ control) + y_{02}(Institution\ size) + y_{03}(Institution\ prestige)$$

$$\beta_{5j} = y_{00} + y_{01}(Institutional\ control) + y_{02}(Institution\ size) + y_{03}(Institution\ prestige)$$

Model 5. The purpose of model five is to analyze the whether or not quantitative STEM fields demonstrate significant different relationships with key variables included in this analysis, when compared with non-quantitative STEM fields. Level one covariates used in this analysis are interacted with the dichotomous variable indicating that a field is quantitative STEM or not. For each significant predictor, a separate analysis will be performed, and models will be compared to model four, using the LRT method to assess model change and improvement, while considering the increased complexity resulting from additional variables added to the model. The dichotomous variable will be entered using group mean centering, and the interaction terms are entered without using any type of centering (Nezlek, 2012).

Limitations

In keeping with the critical perspective used in this analysis, many of the limitations of this study are rooted in the way data was gathered, and the way these categories of information fundamentally include and exclude groups of individuals. Metcalf (2016) notes that "Critical quantitative research takes into deep consideration the variables and their underlying measures, contexts (social, political, historical, etc.), and potential interpretations and the implications of each of these for respondents, researchers, policy makers, communities, etc." (p. 80). Importantly for the current research, the data used simply divides gender categories into male or female. Although the use of the terms male and female implies biological sex, these are also the only categories indicating any level of gender identity. Because of this, gender is inferred from the sex categories used in this survey. In addition to those whose biological sex differs from their gender identity, these categories also stand to exclude any individuals who do not identify their gender within the woman/man binary. In addition to limitations related to the non-inclusive categorization of gender and sex, the data available publicly does not disaggregate funding mechanism source by gender *and* race, although the data is disaggregated by race and gender separately. Thus, the current study unable to assess the extent to which gendered effects are greater or lesser for people of color.

Because of the way data categories necessarily exclude information, often reflecting underlying power relations, many critical researchers utilize qualitative methods or mixed methods approaches. However, quantitative approaches that are informed by critical perspectives can be useful for identifying multiple and interacting areas of marginalization. Metcalf (2014) states "While many critical theorists utilize qualitative methodologies in their work, they have also demonstrated that, despite problematic aspects of our scientific and quantitative histories, it is possible and necessary to conduct scientific and quantitative work from critical and socially just perspectives" (p. 79). Thus, although data limitations are evident, these limitations are primarily addressed through analyses that are informed by critical perspectives.

Similarly, although measures indicating R&D expenditures funded by private industry suggest direct ties to industry, this measure is also an imperfect measure of market proximity or commercialization. As the theoretical perspective argues, commercialization is associated with commodification of academic research, thereby embodying masculine, productive work (Acker, 1992; Jacob, 2009; Radder, 2010; Slaughter & Leslie, 1997). However, the extent to which R&D funded by industry commodifies academic research is an assumption of this research and, the extent to which this may vary between different research project certainly represents a significant limitation of the current research. Furthermore, at the institutional level, prestige is indicated by an institution's general performance on the U.S. News and World Report ranking. As discussed previously, this is not an exact measure of institutional prestige and may not reflect a department's prestige relating to graduate education, presenting another a limitation to this analysis.

In addition to the above limitations, the use of cross-sectional data may also be considered a limitation of the current work. However, because growth is not expected over the five-year time-period for which data exists, there was no theoretical reason to include additional years of data. Furthermore, the use of cross-sectional data does also have weaknesses related to the change in graduate students' funding situation over time. For example, some students may be admitted with funding packages that guarantee several years of funding, while other students may not. However, students without guaranteed may indeed find funding opportunities, so the division between funded and non-funded students is not entirely distinct. Therefore, it is a limitation of this research for the original funding packages and funding opportunities related to policy to be unknown.

Finally, one significant limitation for this current analysis is that it is unable to assess any differences in admissions offers between men and women. For example, if men are being offered more, larger financial aid packages within certain fields, then their representation would likely be skewed. The data used for this analysis does not include any information about admission offers or financial aid packages. Therefore, this key piece of information is not considered in this current analysis. This represents a significant limitation for the current analysis. However, this work does provide insight into differences in the experiences of men and women, as it relates to funding, once admitted into graduate programs.

Importantly, the current research is aimed at providing evidence of a significant relationship between commercialization and gender disparities in the way graduate students are funded. However, it is not within the scope of the study to provide causative claims. Further, appropriate steps are taken to address, as much as possible, the limitations identified above. Still, when interpreting the current work, these limitations must be considered in order to ensure that the results of the current work are not overstated and that claims made are fully supported by evidence.

Conclusion

The work here seeks to understand the extent to which commercialization in academic science research is associated with gender disparities in the way men and women graduate students in STEM are funded. Given that the increased attainment of doctoral degrees in STEM fields among women in recent decades has not necessarily been associated with proportionate representation of women in tenure or tenure-track research faculty positions (Kulis et al., 2002) and that this has occurred during the same period in which commercial influence in academic science has grown (Slaughter & Leslie, 1997; Slaughter & Rhoades, 1996), research investigating these trends is warranted. This section will detail expectations for the current work and connect it to the context discussed previously.

First, this work expects to find that women are funded via reproductive labor mechanisms, primarily teaching assistantships funded via institutional support, at a disproportionately high rate. As well, this work expects to find that women are funded via productive labor mechanisms, primarily research-oriented work funded by “Other U.S. Source” and federal sources, at a disproportionately low rate. The divisions that are expected to be evident in the analysis mirror broader trends in which women are disproportionately employed in teaching college and performing disproportionately high levels of teaching labor (Baker, 2012; Misra et al., 2010; Umbach, 2007; Winslow, 2010). In this way, this research seeks to provide some evidence that women receive socialization for teaching careers at a higher rate than men.

The second component of this research relates to the value of work performed by women and the influence of commercialization for reinforcing gender roles and hierarchies. Slaughter and Metcalf’s (2008; 2011) work suggests that market proximity is an emerging component of perceptions of prestige, relating to the transition toward an academic capitalist regime. Further, scholars argue that the increasingly commercial context in which academic research is being done has resulted in increased commodification of academic research (Irzik, 2013; Jacob, 2009; Radder, 2010; Slaughter & Leslie, 1997; Slaughter & Rhoades, 1996). Because of this, the current work predicts that as commercial influence grows, research labor will increasingly be perceived as masculine, productive labor. Further, this labor will be prioritized over feminine, reproductive labor (most associated with teaching labor) (Acker, 1990, 1992). Through this process, labor undertaken by STEM graduate students is expected to become increasingly gendered. Therefore, women engaged in productive labor may be perceived as resisting gendered norms, which may be associated with consequences. Therefore, disadvantages relating to socialization toward teaching labor may be compounded in highly commercial settings.

The compounded undervaluing of teaching labor in highly commercial settings may be associated with reinforcing and widening gender gaps in the broader academic workforce. Although not investigated in this analysis, such findings may be used to explain women's high representation in academic positions of low prestige, performing less prestigious work like teaching and high representation among part-time, and lower-rank positions (Baker, 2012; Kulis et al., 2002; Misra et al., 2010; Umbach, 2007). Therefore, my study aims at investigating disparities in academic labor pipeline that could help to explain broader gender gaps, as well as why these gender gaps are not decreased simply through increased attainment of doctoral education among women in STEM fields.

Chapter 4: Results

Statistical results are presented in the following sections. I will first present the results for the model predicting gender funding disproportionality among those receiving productive funding mechanisms (P-GFD). This will be followed by a section detailing data and model assumptions, and fit. Next, I will turn to the model predicting gender funding disproportionality among those receiving reproductive funding mechanisms (R-GFD). This will follow the same structure as the previous sections, beginning with a section detailing the model building process, followed by a section discussing data/model assumptions, and fit. Throughout, results are described and interpreted in relation to the research questions guiding this study, outlined in chapter three. The models employed in this analysis utilize a random intercept, multilevel modeling technique, using a full maximum likelihood estimation method.

Modeling Results: P-GFD

The following sections present statistical results for models predicting P-GFD. Furthermore, in this section I will describe the models and interpret results in relationship to corresponding research questions. The process is guided by Raudenbush and Byrk's (2002) work on multilevel modeling, in which they describe optimal model building and selection techniques. Statistical results for all models predicting P-GFD are presented in tables eight a-c.

Model 1. As outlined in the methodology section, the model building process began with a fully unconditional model, or one in which no predictor variables are added. According to Raudenbush and Byrk (2002), the fully unconditional model allows the researcher to assess the proportion of variance that occurs within level two units (among level one units) as well as the proportion of the variance that occurs between level two units. For the current study, this translates to ascertaining the proportion of variation in P-GFD occurring *between* institutions, and the proportion of P-GFD occurring *within* institutions, among STEM departments. One primary purpose of the fully unconditional model is to allow the researcher to test whether or not a multilevel technique is warranted, given the proportion and significance of variance occurring between level two units, or in the case of this study, universities (Raudenbush & Bryk, 2002).

To assess the proportion of variance explained at level one and level two, the intraclass correlation coefficient (ICC) was calculated by dividing the proportion of variance at level two into the total variance between levels one and two for each of the models (Raudenbush & Bryk, 2002). Although the model found very little variance occurring between universities, about 0.01%, this small amount of variance in the outcome was found to be somewhat significant ($p<0.05$). Therefore, while the variance between universities is small, because it is significant, the use of multilevel modeling is justified, and the model building process proceeded.

The rate of P-GFD, however, was found to be approximately zero and non-significant (β_{0j}=0.000, $p>0.05$). This suggests that, on average, P-GFD is not statistically significantly different from zero, representing a lack of gender funding disproportionality. Therefore, returning to research question one, this analysis does not find evidence of average P-GFD in the departments in this study. However, the small amount of variance at level two was significant, thereby justifying the multilevel model.

Model 2a. The next model employed for this analysis addressed the first part of research question two, or what effect do gender disparities have on P-GFD. To address this question, I added two variables to the model simultaneously. The first variable, the department gender disparity, is the ratio of the number of men in a department to the number of women. This variable is indicative of the extent of immediate "male dominance" in the department. The next variable, the field average ratio of men to women, indicates the extent of "male dominance" within the field generally. Taken together, these variables represent two dimensions of male dominance. First, the balance of men to women within a department, and second, the extent of a male dominated culture, demonstrated by the field average ratio of men to women.

The direction of the coefficients, shown in table eight-a, for the department gender disparity and the field average gender disparity were opposite one another (β_{1j}=-0.012, $p>0.05$, β_{2j}=0.022, $p>0.05$, respectively). This would suggest that as the number of men, relative to women, in a department grows P-GFD is expected to decline. However, as a field becomes more "male dominated" on average, P-GFD would be expected to increase. Although these are interesting results, these coefficients were found to be non-significant. Therefore, to address the first part of research question two, there is not evidence suggesting that either dimension of gender disparity is significantly predictive of P-GFD.

The deviance for model two-a decreased very slightly from 6279.661 in model one, to 6278.156 in model two-a. To further analyze this reduction in deviance, the Akaike Information Criterion (AIC), Bayesian Information Criterion (BIC) and

Likelihood Ratio Test (LRT) are reported in table eight-c. Both the AIC and BIC measures indicate an increase in deviance when adjusted for the added variables which increased the complexity of the model. Furthermore, using the LRT method to compare two models, the improvement of model two-a over the fully unconditional model was found to be non-significant ($p>0.10$). However, the main focus of this study is to understand the relationship between variables, and thus, no variables were dropped from the model.

Model 2b. The next model focused on the second aspect of research question two, or the effect of the field average and department ratio of productive funding to reproductive funding mechanisms awarded to students. Therefore, the two variables indicating field-average and department funding ratio were added to the model simultaneously. Once added, the direction of the coefficient for the department funding ratio was found to be opposite of the coefficient for the field average funding ratio ($\beta_{3j}=-0.006$, $p>0.05$, $\beta_{4j}=0.157$, $p<0.05$, respectively), also shown in table eight-a. Although the relationship between the department funding ratio was found to be non-significant, this was not the case for the variable representing the field average funding ratio. According to this model, a one unit increase in the field average funding ratio is associated with a 0.157 increase in P-GFD. Therefore, as a field becomes more reliant on productive funding mechanisms relative to reproductive funding mechanisms, on average, the difference between the proportion of men and women receiving productive funding mechanisms is expected to increase. Therefore, returning to research question two, this suggests field differences in how students are typically funded is somewhat predictive of P-GFD.

For model two-a, analyses of change in deviance IS presented in table eight-c. In this model, the deviance declined 6.383, from 6379.661 in model one, to 6373.278. As with model two-a, the AIC and BIC indicate that the added complexity of associated with the additional variables is not justified by the small reductions in unexplained variance. Interestingly, when comparing the model two-a to model two-e using the LRT method, the model improvement is found to be significant ($p<0.05$). This suggests that variation in department and field funding ratio may be more important for understanding variation P-GFD.

Model 3. In the third model, a variable representing the share of R&D expenditures originating with industry in STEM departments was added to the model using group mean centering, to address research question three. Although the coefficient for the variable was positive, which would indicate that market proximity is associated with increased P-GFD, that relationship was found to be non-significant ($p>0.05$). Therefore, to answer research question three, this analysis does not find evidence to suggest that the share of R&D originating from industry expended within a STEM department is significantly associated with the rate of P-GFD. Furthermore, although the deviance statistic again, decreased somewhat over previous models to 6373.020. However, in a comparison between model two-b and model three, the improvement of the model was found to be non-significant, suggesting that changes in R&D expenditures within a department may not be particularly influential for predicting P-GFD.

Model 4. The level two equations are built in the fourth model, testing whether institutional characteristics are associated with P-GFD, addressing research question four. Level two variables controlling for variation between institutions were added to the model (institution size, institution prestige and institution control) simultaneously using grand mean centering. With the addition of level two control variables, the field average funding ratio lost its significance (β_{4j}=0.118, $p>0.05$). Furthermore, no significant relationships were found between any of the level two variables and any of the level one variables. Although the deviance statistic decreased to 6351.092, this decrease was found to be non-significant when compared with model three ($p>0.10$). Therefore, the level two variables added to the model do not appear to significantly contribute to decreasing unexplained variation P-GFD.

Model 3: Interaction. The first interaction term used to analyze P-GFD, investigated whether or not the relationship between a departments' expenditures on R&D originating from industry and P-GFD, differed in social science fields when compared with non-social science STEM fields, or research question five. To test this, model three was repeated with the addition of a dummy variable indicating whether a field is social science or not, as well as an interaction term between the dummy variable and the share of R&D expenditures originating from industry. The dummy variable was added using group mean centering (Raudenbush & Byrk, 2002), and the interaction term was entered uncentered (Nezlek, 2012).

In this model, the variable indicating the field average funding ratio maintains its significance (β_{4j}=0.181, $p<0.05$). However, the other variables in the model, the share of

R&D expenditures originating from industry, the dummy variable and the interaction term, were all found to be non-significant. This suggests that, while social science fields are conventionally considered to differ significantly from other STEM fields, this analysis does not provide evidence that the effect of the share of R&D originating from industry is different in a social science STEM field, when compared to a non-social science STEM field. Due to the lack of significance, and because analysis of decrease in the deviance statistic showed no significant improvement over model three without an interaction term ($p>0.10$), no further analyses of this interaction term with P-GFD was investigated

Model 5. The purpose of model five is to test whether or not significant covariates' relationships with the outcome variables is significantly different in quantitative STEM fields, when compared with STEM fields that are not so focused on quantitative skill development. In doing so, model five addresses research question six. To begin this process, dichotomous variable indicating whether or not a field is quantitative STEM was added to the model. Once added to the model, although the values of coefficients among covariates changed, these coefficients were not found to be significant ($p>0.05$). Furthermore, the quantitative STEM variable was also found to be non-significant. This is suggestive that P-GFD is not significantly different in quantitative STEM fields, when compared with non-quantitative STEM fields.

The next step for completing model five was to consider whether or not the relationship between a field's average ratio of productive to reproductive funding mechanisms awarded to students is significantly different in quantitative STEM fields when compared with non-quantitative STEM fields. As such, an interaction term was added to the model. As in the previous step of model five, none of the covariates were found to be significantly predictive of the outcome. Furthermore, the interaction term was also found to be non-significant. Therefore, this study does not find evidence that the relationship between the ratio of productive to reproductive funding mechanisms awarded to students and P-GFD is significantly different in quantitative STEM fields when compared with non-quantitative STEM fields.

To assess the appropriateness of the quantitative/non-quantitative STEM field division, models four and five were compared to one another using the LRT method. The decrease in deviance between models four and five was found to be non-significant. This, paired with the non-significant coefficients for both the dummy variable and interaction term, suggests that the quantitative/non-quantitative STEM division may not be the most salient division in STEM fields for understanding variation in P-GFD. This is further suggested in the final chapter of this dissertation.

P-GFD Model Fit Summary

In sum, only model two-b demonstrates significant improvement over model two-a and thus, this model demonstrates the best fit for predicting P-GFD. However, when compared with model one, we again find that the improvement of model two-b is not significant when compared with the fully unconditional model. This suggests that, while a model including gender disparity and funding ratio variables is better than a model including only gender disparity variables, the funding ratio variables appear to be more important for understanding variation in P-GFD. Although assessments of model fit, and comparisons between two models inform the analysis and interpretation of these results, the true intent of this study is to understand relationships between the covariates and P-GFD. Therefore, analysis of data assumptions consider model three, which includes the main independent variable of interest for this research.

Figure five demonstrates various ways that the data and model were assessed. First, the outcome variable, shown in the first graph, demonstrates an approximately normal distribution. Next, the relationship between the outcome variable and the main independent variable of interest was analyzed, shown in graph two. Although the fitted line on this graph shows only a small amount of incline, it does demonstrate a roughly linear relationship. The next graph is used to analyze the assumption of normality. Data conforming to this assumption will align along a forty-five-degree angle extending from the lower right-hand corner to the upper left-hand corner. As graph three shows, there is some degree of violation of the normality assumption. However, given the robustness of multilevel models against violations of assumptions, this was noted but did not stop the model building process. Finally, graph four indicates no clear pattern, demonstrating that the homogeneity of variances assumption is also upheld.

Modeling Results: R-GFD

The following sections report results from the models predicting R-GFD. Full statistical results are presented in tables nine a-c. In this section, discussion and interpretation of results throughout focus on the way these results provide insight into the research questions in chapter three. Further analysis, and contextualized interpretations are discussed in the final chapter of this dissertation.

Model 1. As in the previous section, the model building process for predicting R-GFD began with a fully unconditional model containing no predictors, in order to assess the proportion of variance described at levels one and two (Raudenbush & Bryk, 2002). The fully unconditional model was also used to answer the primary focus of research question one, whether or not R-GFD is detectable on average among departments included in the sample.

The ICC was calculated to assess the proportion of variance at levels one and two. Although the proportion of variance occurring between universities in this model is small, approximately 2.3%, this variance is much larger than in the model predicting P-GFD. Furthermore, while the variance among universities in the model predicting P-GFD was somewhat significant, the variance in the current model is highly significant ($p<0.001$). Because of the significance of this variance, the multilevel analysis is justified, and the model building process continued.

Turning now to the primary focus of research question one; whether R-GFD exists, on average, across departments. The direction of the intercept suggests that men outnumber women on average, among those receiving reproductive funding mechanisms. However, as in the previous model, this relationship is non-significant. Therefore, to answer research question one, R-GFD is not detectable, on average, among departments included in this analysis ($\beta_{0j}=0.003$, $p>0.05$) but there does exist significant variation between universities. Therefore, the use the multilevel modeling technique is justified.

Model 2a. The next model employed in this analysis aimed to address research question two and its associated sub questions. To do this, four variables were added to the model over two steps (model two-a and model two-b). In the first step, the department gender disparity and field average gender disparity variables are entered into the model to analyze the effect of being in fields and departments with more or less "male dominance." Both the department and gender disparity variables were both found to be significant (β_{1j}=-0.071, $p<0.001$, β_{2j}=0.067, $p<0.005$, respectively). Interestingly, the direction of the relationship of these variables to the outcome is opposite one another. As such, an increase in the department's number of men, relative to women, is associated with a decrease in R-GFD, or the difference between the proportion of men and women receiving reproductive funding mechanisms is expected to decrease. On the contrary, increases in a field's average rate of men, relative to women, are associated with increased R-GFD or, the difference in the proportion between men and women receiving reproductive funding mechanisms would increase.

The deviance in model two-a decreased 36.901 to 6338.853, when compared with the fully unconditional model. The adjustments made using the AIC and BIC methods, considering the additional complexity added to the model, indicate an increased deviance. However, when comparing the fully unconditional model to the current model using the LRT, the reduction in deviance was found to be non-significant ($p>0.005$). However, as mentioned in the previous sections, while this indicates that the complexity of the model is not justified due to the decreased unexplained variance, the focus of this study is not to predict the outcome. Instead, the focus remains to analyze the relationships between the variables used in this analysis. However, change in deviance through the model building process is considered and reported throughout this analysis

Model 2b. The next step in model two is to add the variables considering two dimensions of the conditions of funding available to students. The first variable simply represents the ratio of productive funding to reproductive funding within each of the departments included in the study. The next variable indicates the field average ratio of productive funding to reproductive funding mechanism granted to students. Together, these variables represent both the "local" department funding conditions, as well as the "typical" department within each of the fields.

As with the gender disparity variables, the direction of the two new variables added to the model was again opposite one another. However, while the department funding ratio was found to be non-significant (β_{3j}=0.010, $p>0.05$), the field average ratio of productive to reproductive funding mechanisms was found to be highly significant (β_{4j}=-0.258, $p<0.005$). Therefore, to answer research question two, these results indicate that as a field becomes more reliant on productive funding mechanisms to fund students, on average, the rate of R-GFD declines, or the rate of men receiving reproductive funding mechanisms minus the rate of women, decreases.

Taken together, models two-a and two-b indicate that field differences are important for understanding variation in R-GFD. Both the field attribute variables were found to be highly predictive of R-GFD. Therefore, the current analysis finds support that field differences, both in terms of "male dominance" and reliance on productive funding mechanisms, are significantly associated with R-GFD. However, as a field becomes more reliant on productive funding mechanisms relative to reproductive funding mechanisms, the model predicts that R-GFD will decrease. R-GFD also decreases as a department becomes more male dominated, although this relationship is weaker than those with the field attribute variables. On the contrary, as a field becomes more "male dominated," R-GFD is expected to increase. This result is discussed further in the concluding chapter.

Models two-a and two-b were also compared to one another using the LRT method. In doing so, the reduction in deviance between the two models was found to be non-significant ($p>0.10$). This indicates that the department and field average dimensions of gender disparity are likely more important for predicting R-GFD than variation in funding ratios.

Model 3. The third model to predict R-GFD, aims to address research question three, or to what extent a department's share of R&D expenditures originating from industry is associated with R-GFD. As such, a variable indicating the share of R&D expenditures originating from industry was added to the model using group mean centering. The results indicate that the department and field average gender disparity variables, as well as the field average funding ratio all maintain their significance. Furthermore, the new variable added to the model was also found to be somewhat significant (β_{5j}=-0.367, $p<0.05$). This suggests that departments with a high proportion of R&D expenditures originating with industry are associated with decreased R-GFD, or the difference between the proportion of men and women receiving reproductive funding mechanisms decreases. This result, contrary the expectations is discussed further in the discussion sections in the concluding chapter.

Model 3: Interaction. In order to understand the extent to which the relationship between R-GFD and a department's share of R&D expenditures originating from industry differs in social science STEM fields when compared with non-social science STEM fields, two additional variables were added to model three. The first variable, a dummy variable indicating whether or not a field is a social science or not, was entered using group mean centering (Raudenbush & Byrk, 2002), and then an interaction term between the dummy variable and a department's share of R&D expenditures originating from industry was entered uncentered (Nezlek, 2012).

In this model, the department's gender disparity and the field average funding ratio were both found to be highly significant (β_{1j}=-0.077, $p<0.001$, β_{4j}=-0.286 $p<0.001$), and the field average gender disparity was also found to be somewhat significant (β_{3j}=0.075, $p<0.005$). Importantly, neither the interaction term, nor the dummy variable indicating whether a field is social science or non-social science, were found to be significant predictors. Therefore, as in the model predicting P-GFD, although the social science STEM fields are conventionally considered very different, this model does not find significant differences between social science STEM fields and non-social science STEM fields and R-GFD.

To further assess this interaction term, the LRT method of comparing models was used to compare model three without interaction terms to model three *with* interaction terms. However, the reduced deviance between the current and previous model was found to be non-significant. Thus, these results suggest that while social sciences and non-social science STEM fields are considered to be very different from one another, the relationship between R-GFD and change in R&D expenditures originating from industry is not significantly different in social science fields when compared with other STEM fields. Given these results, no further analysis of this interaction term was done.

Model 4. In the fourth model, level two variables were added using grant mean centering in order to analyze research question four, pertaining to the effects of institutional characteristics on R-GFD. Once level two variables are added to the model, the coefficient for the field average gender disparity become non-significant and the field average funding ratio coefficient decreased in significance ($p<0.05$). Furthermore, compared with model three, the decreased unexplained variance relating to the addition of level two variables was found to be non-significant when compared model four to model three using the LRT method ($p>0.10$). As such, these results suggest that the increased complexity due to the additional variables is not justified by the decrease in unexplained variance in the outcome.

Model 5. The final models used in this analysis aimed to address research question six, or the extent which the relationships between the significant covariates in the model are significantly different in quantitative STEM fields, when compared with non-quantitative STEM fields. The first step for doing this involved adding a dummy variable indicating whether or not a field is a quantitative STEM field or not, followed by adding interaction terms for each of the significant covariates from the previous models.

In the first step for model five, there was little change to the model. As had been the case in model four, the department gender disparity variable was still negative and highly significant (β_{1j}=-0.069, $p<0.001$), while the coefficients for the field average gender disparity and the field average funding ratio were both found to be somewhat significant (β_{2j}=0.057, $p<0.05$, β_{4j}=-0.243, $p<0.05$, respectively). Interestingly, the dummy variable indicating whether a field is quantitative STEM or not was found to be non-significant, which indicates that variation in R-GFD is not significantly different in quantitative STEM fields when compared with non-quantitative STEM fields.

The next step for model five involved adding in an interaction term for each of the significant covariates from previous models. As such, variables indicating an interaction between field average and department gender disparity, and field average funding ratio were created and added to the model. Interestingly, once these terms were added to the model, both the department and field average gender disparity were found to be non-significant ($p>0.05$). However, the field average funding ratio coefficient continued to be somewhat significant (β_{4j}=-0.254, $p<0.05$). Furthermore, none of the interaction terms were significant, which suggests that the relationship between the significant covariates and the outcome variable are not significantly different in quantitative STEM fields when compared with non-quantitative STEM fields.

To analyze change in deviance, the first step in model five was compared with the second step using the LRT method of comparing models. As such, the reduction in deviance between the first and second steps for building model five was found to be non-significant. This suggests that the added complexity in this model relating to the interaction terms is not justified by the decrease in deviance. Further analysis of this model as well as previous models discussed in final chapter of this dissertation.

R-GFD Model Fit Summary

In contrast with the model predicting P-GFD, the model predicting R-GFD found significant relationships with many of the variables, including both the department and field average gender disparity, the field average funding ratio, and the main independent variable of interest, the share of R&D expenditures originating from industry, in some models. The fourth model run for this analysis demonstrated the most complete model for this study. This, combined with the fact that analyses of interaction terms found no significance, lead me to select model four as the best fit model for this analysis. Although the central focus of this study is not to create a predictive model for R-GFD, this section will describe analysis of data model and assumptions for the best fit model.

Figure six shows the various analyses carried out to assess whether or not the model assumptions were upheld. First, as graph one indicates, the outcome variable demonstrates a roughly normal distribution. Next, graph two shows that the relationship between the outcome variable and the main independent variable of interest, the share of R&D expenditures originating from industry, is roughly linear, and negative. This suggests that, overall, increased share in R&D expenditures originating from industry is associated with decreased R-GFD.

The final two graphs depicted in figure six allow the researcher to analyze the linearity and homogeneity of variances assumptions. In graph three, while there is some variation toward the upper left hand of the graph, the data generally aligns along a 45-degree angle extending from the lower left-hand corner, to the upper right-and corner of the graph. As in the previous model, this suggests some amount of violation of the normality assumption. However, as the fourth graph shows, the data does not demonstrate any apparent pattern. Therefore, the homogeneity of variances assumption is upheld for this analysis.

In total, the model predicting R-GFD generally conforms to model specifications and assumptions. Furthermore, analyses of model improvement indicate that each of the progressive models built for this analysis demonstrate significant improvement over the null model. Therefore, although not the primary focus of this analysis, these results indicate that the model predicting R-GFD is a more effect model for prediction than the P-GFD model described in the previous sections.

Results Summary and Conclusion

In the above sections, statistical results presented provide some insight into variation in both P-GFD and R-GFD, and address each of the research questions laid out in chapter three of this dissertation. First, neither model demonstrated significant gender funding disproportionality for either those receiving productive nor reproductive funding mechanisms, on average among departments studied. However, the ICC for each of the models does demonstrate significant variation between institutions, thereby justifying the use of the multilevel modeling technique in both cases. Together, these findings address research question one.

Research question two and its' sub-question controlled for department variation in the ratio of productive funding mechanisms to reproductive funding mechanisms as well as the ratio of men to women students, while investigating how the field averages of each of these measures affects the outcome variables. In both the P-GFD and R-GFD models, the field average ratio of productive funding to reproductive funding was found to be significant. The results indicate that as a field becomes more reliant on productive funding mechanisms, relative to reproductive funding mechanisms, the proportion of men receiving productive funding mechanisms minus the proportion of women, will increase. Alternatively, this funding ratio increase is also associated with a decrease in the difference between the proportions of men and women receiving reproductive funding mechanisms.

Furthermore, both the department and field average gender disparity variables were also found to be significantly predictive of R-GFD. These relationships were such that an increase in a field's average gender disparity, indicating increased male dominance in the field, was also associated with an increase in R-GFD, or a larger difference between the proportion of men and women receiving reproductive funding mechanisms. However, larger gender disparities at the department level were associated with a reduction in the difference between the proportion of men and women receiving reproductive funding mechanisms.

One interesting result associated with the field attribute variables is that one can compare fields based on their attributes. For example, while the ratio productive funding to reproductive funding in Civil Engineering is 1.11, it is only 0.11 and Sociology.

Therefore, when compared with Sociology, these models predict that the difference between the proportion of men and women receiving reproductive funding mechanisms will be smaller by 0.235, on average, in Civil Engineering departments when compared with sociology departments. However, this would also be associated with an increased difference over sociology departments, on average, between the proportion of men and women receiving productive funding mechanisms of about 0.163. As this demonstrates, due to the increased reliance on productive funding mechanisms relative to reproductive funding mechanisms in Civil Engineering, these results suggest that the effect on P-GFD and R-GFD is about one-time larger than in Sociology.

In terms of field attributes related to a field's "male dominance," it is also helpful to consider how this connects to differences between fields. Again, comparing Civil Engineering with Sociology, we find that men outnumber women approximately six to one in Civil Engineering on average. Therefore, we can expect that R-GFD is likely much larger in Civil Engineering fields than in sociology fields. Field attributes appear to be important for understanding variation in both P-GFD and R-GFD. However, while field average gender disparities are significantly predictive of R-GFD, they do not appear to be significant predictors for P-GFD. This is discussed further in the following chapter.

The third research question investigated the relationship between the main independent variable of interest, the share of R&D expenditures originating from industry and the outcome variables. The results demonstrate that as the share of R&D expenditures originating from industry increases, R-GFD decreases. This suggests that as a field is closer to the market, as demonstrated by a higher share of R&D expenditures originating from industry, the difference between the proportion of men and women receiving reproductive funding mechanisms decreases. This is contrary to the predictions outlined in chapter three, and thus, will be discussed as a key finding in the following chapter. Additionally, no significant relationship was found between the main independent variable of interest and P-GFD.

The next questions considered interaction effects within the previous models. First, question five analyzed whether or not variation in a department's market proximity, or share of R&D originating with industry, had a significantly different relationship with the outcome variables in STEM social science fields, compared with those that are non-social science. For both outcome variables, coefficients for both the dummy variables indicating whether or not a field is social science, as well as the interaction terms, were found to be non-significant. Therefore, these results suggest that, although social sciences and STEM fields are conventionally considered to be very different, the relationship between GFD and a field's market proximity appears to be similar in both social science and non-social science STEM fields.

In research question six, further analyses of interactions were considered. Specifically, research question six focused on another division within STEM fields, quantitative vs. non-quantitative STEM fields. As such, a dummy variable indicating whether a field was quantitative or non-quantitative was entered into the model, as were interaction terms for each of the covariates found to significantly predict either P-GFD or R-GFD. For the model predicting P-GFD, the only interaction term included interacted the quantitative/non-quantitative STEM field dummy variable with the field average funding ratio. However, in the model predicting R-GFD, three interaction terms were included: department gender disparity*quantitative/non-quantitative STEM, field gender disparity*quantitative/non-quantitative STEM, and field funding ratio*quantitative/non-quantitative STEM. However, neither model found significantly relationships between either the dummy variable or any of the interaction terms. Therefore, the current analysis did not find evidence that the relationship between any of the significant covariates and the outcome variables were significantly different in quantitative STEM fields, compare with non-quantitative STEM fields.

In total, the results outlined here contribute four primary findings. First, both P-GFD and R-GFD were found to be significantly related to field's average ratio of productive to reproductive funding mechanisms awarded to students. Second, while the gender disparity variables were not found to significantly predict P-GFD, both variables were significant predictors of R-GFD. Furthermore, the relationship between R-GFD and the gender disparity variables were opposite one another. Third, the main independent variable of interest for this, the share of R&D expenditures originating with industry, was found to significantly predict R-GFD, but not P-GFD. Finally, the fourth primary finding is not so much a finding, as much as an absence of findings. Although both the division between social science and non-social science fields, as well as the division between quantitative and non-quantitative STEM fields appears to be profound, the current work did not find evidenced that the variables used in the analyses had significantly different relationships with the outcome variables in social science fields when compared with non-social science fields, or in quantitative fields when compared with non-quantitative fields. Further discussion and analyses of these results continued in the next chapter of this dissertation.

Chapter 5. Conclusion

In the previous chapter, full statistical results and interpretation related to corresponding research questions were presented. In this chapter, I will critically analyze and discuss the results more broadly, as they relate to the theoretical and scholarly work informing this study. The first section of this chapter will critically discuss the concept of gender funding disproportionality and the way it is used in this study. This will be followed by a section detailing this study's four primary findings, their limitations, and implications for theory and practice. The next section will outline recommendations for future research and the final section will provide a brief conclusion for this work.

Critical Analysis of Gender Funding Disproportionality

As was outlined in the literature review section of this study, women tend to be overrepresented as faculty in teaching institutions and they also tend to spend disproportionate amount of time teaching when compared to men in the same departments (Baker, 2012; Misra et al., 2010; Winslow, 2010). Furthermore, this elevated time spent teaching is not rewarded. On the contrary, studies demonstrate that increased time spent on teaching tasks was associated with pay decreases (Umbach, 2007), while increased time spent on research tasks was associated with pay increases (Misra et al., 2010; O'Meara & Bloomgarden, 2011; Winslow, 2010). From this scholarly work, we conclude that women are disproportionately associated with teaching, reproductive labor and, this association with reproductive labor disadvantages women due to the relatively lower value of teaching, relative to research labor. Given this background, the current work used critical perspectives to design a statistical model to detect evidence of this type of gender segregation in graduate student labor, which would help to explain multidimensional gender gaps occurring among STEM doctorate holders.

First, neither model detected gender funding disproportionality (GFD), on average, among either those receiving productive (P-GFD) or reproductive (R-GFD) funding mechanisms. This contradicts works informing this study, somewhat, which found women were more likely to receive paid teaching positions, while men were more likely to receive paid researcher positions (F. Ampaw, 2010). However, Ampaw's (2010) work went beyond STEM fields and attributed these findings, at least to some extent, to women's overrepresentation in fields with higher rates of teaching assistantships. Furthermore, Ampaw and Jaegar (2011) found that in science fields specifically, men were more likely than women to receive paid researcher positions. Therefore, one may expect disproportionately high rates of men receiving productive funding mechanisms, relative to women. Thus, the current study's "negative" finding requires further interpretation and explanation, in light of the work informing this research.

The dependent variables used in this analysis represent a variety of concepts. First, the embeddedness of gender in academic labor is interpreted through the productive/reproductive dichotomy in which research work is associated with masculine, productive work and teaching work is associated with feminine, reproductive work. However, one limitation of the data set used for this study is that data is not disaggregated by funding mechanism type (teaching assistantship, research assistantship, etc.) and gender. Instead, data is disaggregated by gender and funding mechanism source. Therefore, institutional funding sources served as an indicator of reproductive labor, due to the high correlation between institutional funding and teaching assistantships, and funding from federal or industry sources served as an indicator of productive labor, due to the high correlation between those funding sources and paid, researcher positions. While these operationalizations are consistent with the theoretical frameworks used in this analysis, they do have limitations. For example, institutions likely do provide some funding for fellowships or other research assistantships, and thus, not all students receiving institutional support may be engaged in reproductive labor, defined as teaching labor. Furthermore, while unlikely, it is possible that outside funding is used to fund teaching assistantships in certain cases.

Although the current definitions of productive and reproductive labor are imprecise, the use of sources of funding mechanisms does provide an additional dimension to the metrics. Specifically, the current work can analyze and consider, does source of funding matter? Further research in this area may consider marginal cases, such as institutionally funded researcher positions, or industry/federally funded teaching assistantships. In doing so, one may consider whether or not traditional "productive labor" funded by institutions provides reproductive benefit for the institution. Alternatively, does teaching labor funded by non-institutional sources play a less reproductive role for the survival of an institution. However, while the use of the source of funds provides an additional dimension to this analysis, it also may "muddy the water" so to say.

In addition to "muddying the waters" as it relates to the productive/reproductive labor concepts, the use of disproportionality among departments with significant variation in the representation of men relative to women may also mask inequalities, other than disproportionality. In a department with ten men and two women, equality between men and women would mean that one woman receives a research assistantship, while five men would. Although this would mean that the proportion of men and women are equal to one another, it masks inequality stemming from women's initial underrepresentation in the department. Therefore, while the current work identifies gender inequality as the *disproportionate* amount of men/women receiving productive/reproductive funding mechanisms, within the same department, the broader inequality may instead stem from unequal resource distribution, providing additional paid researcher positions for students, between STEM fields where women are more- or less-underrepresented.

One concern about women who are dramatically underrepresented in certain fields, is the danger of tokenism (King, Hebl, George, & Matusik, 2010). According to King et al. (2010), individuals from underrepresented groups tend to be disadvantaged when they are the single representation of their social group in a workplace due to increased social isolation and visibility. Furthermore, scholarly work has shown that representation of women in fields matters, demonstrating fields with significant overrepresentation of men are associated with increased "gender-science" bias related to stereotyping (Banchefsky & Park, 2018; Miller, Eagly, & Linn, 2015; Sax, 1996). Therefore, while the current work demonstrates a lack of disproportionality in the way men and women graduate students in STEM are funded, the significant underrepresentation of women between STEM fields may be of more importance for understanding broader gender inequality and segregation within the academic labor force.

One final consideration for these results, which may be compounded by the effects of tokenism, is that the population being studied is one that has been exposed to academic culture for many years of their life. By the time a student graduates with their doctorate, they have likely spent 24+ years in academic environments. Therefore, it is possible that the lack of disproportionality evident in this analysis stems from the fact that individuals who are being funded in a STEM doctorate program have already been socially and culturally shaped into the individuals they need to be in order to be successful in their field. Thus, it is possible that women “selected” for STEM doctorate programs are already those who 1) conform to gender roles in order to most effectively navigate their field, and/or 2) developed effective skills and strategies for resisting gender roles and norms in order to be successful. As such, further analysis considering these differences in culture between fields would greatly inform future research in this area.

Although these results do not shed light on disproportionality between men and women in the way they are funded, it does reinforce research demonstrating that the gender gap problem is intimately related to between field differences. Two attempts were made in the current work to distill between-field differences to a single, important element, first whether or not a field was social science, and second whether or not a field was focused on quantitative skills. Although these divisions are intuitive, the study did not find evidence that these dichotomies are adequate for understanding between field variation. Therefore, future studies should more fully consider differences between fields. Further discussion of specific techniques and suggestions for analysis continued in the next section.

Overview of Primary Findings

Although the current work did not find evidence of either P-GFD or R-GFD, on average, the models did demonstrate significant relationships between some covariates and the outcome variables. These findings can be concentrated into four primary areas. The first finding discussed here relates to the relationship between the field average funding ratio with both outcome variables which indicates the importance of between field differences for understanding variation in GFD. The next findings that I will discuss are be the relationships between gender disparity variables, both at the department and the field-average level, and R-GFD. The third finding that I will discuss in this section relates to the relationship between R-GFD and the main independent variable of interest, the share of R&D expenditures originating with industry representing market proximity. Finally, I will discuss the results from models utilizing interaction terms.

As was demonstrated in the previous chapter, few variables appeared to be predictive of P-GFD, while many of the variables that were entered into the model predicting R-GFD did demonstrate a significant relationship. However, the variable representing the field average ratio of productive funding mechanisms to reproductive funding mechanisms demonstrated a significant relationship with *both* R-GFD and P-GFD in some models, although the direction of this relationship is opposite one another.

According to these models, as a field's average ratio of productive to reproductive funding mechanisms increases, R-GFD will decrease, while P-GFD increased.

The relationships between the field average funding ratio, as well as its opposite effect on R-GFD and P-GFD, are somewhat intuitive. First, one would expect that a field's average funding ratio translates to a typical department within that field and it is intuitive that as the availability of different types of funding changes, disparities between men and women may also shift somewhat. Second, because the outcome variables represent proportions of students receiving particular types of funding mechanisms, it is also intuitive that as P-GFD increases, R-GFD is likely, although may not necessarily, decrease. However, what is not intuitive is that the local, department funding ratio was not found to significantly predict either P-GFD or R-GFD.

This finding suggests that differences between fields, particularly as it relates to broad trends (not local ones) in the way students are typically funded, are important for understanding both types of gender funding considered in this analysis. However, while the field average gender disparity variable was also found to significantly predict R-GFD, it did not significantly predict P-GFD. Therefore, as it relates to P-GFD, it appears that field differences, specifically related to the typical conditions of funding available to students, affects gender funding disproportionality. For R-GFD, although the field average gender disparity variable was found to be significant, so too was the department gender disparity variable and thus, this suggests that field variation is important, but that both department and field gender disparities are important for understanding change in R-GFD. However, as identified in the previous chapter, the direction of the relationship for these two variables was opposite one another. Therefore, as field becomes more "male dominated," demonstrated by an increase in a field's average ratio of men to women, the difference between proportion of men and women receiving reproductive funding mechanisms decreases. Alternatively, as a department's ratio of men to women increases, the disparity also increases.

Additionally, the main independent variable of interest in this study, the share of R&D expenditures originating from industry, was found to significantly predict R-GFD but not P-GFD. Furthermore, in models predicting R-GFD that did find this variable to be significant, the level was just below the traditional threshold for significance ($p<0.05$). Therefore, while variation between departments in the share of R&D expenditures originating from industry is significantly associated with variation with R-GFD, this relationship is somewhat weak. Furthermore, given that this variable does not demonstrate a significant relationship with P-GFD, this study finds only little evidence that market proximity, demonstrated via department reliance on business/industry funding for R&D, is associated with variation in gender funding disproportionality. Of particular interest and relating to the main independent variable of interest is that its relationship with R-GFD, although weak, is opposite the prediction outlined in chapter three of this dissertation. In chapter three, it is predicted that as the share of R&D expenditures originating from industry increases in a department, R-GFD would increase. However, the findings suggest that this relationship is opposite, with growth in the share of R&D expenditures originating from industry associated with decreased R-GFD.

In addition to the above findings, interaction terms were investigated in order to identify salient divisions within STEM fields. The first division considered was between socials science and non-social science STEM fields and investigated whether the relationship between GFD and market proximity differed in social science STEM fields when compared with non-social science STEM fields. The next division considered, was between quantitative and non-quantitative STEM fields. These analyses considered interactions between each of the significant covariates from previous model, considering whether or not relationships between the covariates differed significantly in quantitative STEM fields. However, neither the social science/non-social science nor the quantitative/non-quantitative division demonstrated significant relationships. Thus, although the divisions considered are typically used to disaggregate STEM fields, further disaggregation of fields may be necessary in order to adequately model between field variation.

To summarize, the major findings of this study fall into four general categories. First, results suggest that between field variation is important for understanding gender funding disproportionality. Second, the degree of “male dominance” at the field level, as well as the local conditions related to gender disparity are also important for understanding variation in R-GFD. Third, there is a relationship between the main independent variable of interest, the share of R&D expenditures originating with industry, and R-GFD but not with P-GFD. Fourth, the relationships between the covariates investigated and outcome variables did not demonstrate significantly different relationships in either social science vs. non-social science STEM fields, or quantitative vs. non-quantitative STEM fields. Implications of these findings are discussed in the following section.

Discussion of Findings and Limitations

In this study, Acker's (1990; 1992) theory of gendered organizations was used to interpret the embeddedness of gender in graduate student funding mechanisms. As such, I identified reproductive funding mechanisms, institutionally funded labor, primarily teaching-oriented, as labor that conforms to traditional feminine gender roles. Furthermore, productive funding mechanisms, primarily research-oriented funded by external sources including business/industry as well as state and federal sources, conforms more to traditional masculine gender roles. However, these representations of gender embedded in labor are not without limitations, as described in chapter three. In this section, I will discuss the results as they relate to the broader questions of multidimensional gender gap in STEM fields. Furthermore, I critically discuss the shortcomings of the current approaches and suggest future strategies for furthering analysis in this area of research.

Field Attributes. The first finding, that field averaged funding ratios were significantly associated with both P-GFD and R-GFD, but department funding ratios were not, suggests that differences between fields are likely important for understanding variation in gender funding disproportionality. Furthermore, the relationships indicate that, in a field more reliant on productive funding mechanisms, thereby demonstrating a culture of research-oriented funding for students (as well as an ability to provide such positions for students), the difference between the proportions of men and women receiving productive funding mechanisms increases, while the difference between the proportions of men and women receiving reproductive funding mechanisms decreases.

Interestingly, while the funding ratio variable was found to significantly predict both P-GFD and R-GFD, the field average gender disparity was only predictive of R-GFD. To further analyze between field differences, figure seven depicts the distribution of the funding ratio variable across the 25^{th}-99^{th} percentiles for broad fields (social science, life science, physical science, and engineering). This figure demonstrates stratification of funding ratios by broad fields. It shows that fields in engineering tend to have a higher proportion of students receiving productive funding mechanisms, relative to reproductive funding mechanisms, than the other fields (descriptive data for funding ratio variable by field available in table ten). Furthermore, while the single largest funding ratio value in this dataset occurred within a social science field (34.5), social science fields generally have a lower rate of students funded via productive funding relative to reproductive funding.

Taken alongside the study's finding that the field average funding ratio significantly predicts both outcomes, one would expect that engineering departments would to be those likely to experience the lowest levels of R-GFD, and the highest levels P-GFD, while social science fields would be the most likely to experience the opposite. However, as the standard deviations for each broad field indicates, there is considerable variation within broad fields and thus, further analysis between specific fields is still necessary for understanding between field differences. These results point to the importance of between field differences. Thus, further investigation may consider within field analyses, or focus on ascertaining salient between field differences for understanding differences in P-GFD and R-GFD.

One reason that fields with high reliance on productive funding mechanisms, relative to reproductive funding mechanisms may relate to the way that outside funding opportunities are often awarded. As the productive funding mechanism variable includes federal and business/industry sources of funding for students, it is likely that these sources are used primarily, if not entirely, for research-oriented activities. However, due to the success of undergraduate research programs for increasing persistence among undergraduate underrepresented minorities, including women, in STEM fields (Gilmore, Vieyra, Timmerman, Feldon, & Maher, 2015; Russell, Hancock, & McCullough, 2007; Vieyra, Gilmore, & Timmerman, 2011), outside funding sources are often open only to URM students, or heavily encourage URM students to apply. Therefore, the increased availability of productive funding mechanisms, on average in a field, may be associated with increased equity between the proportion of men and women receiving productive funding mechanisms specifically because many of these funding opportunities are aimed at “diversifying” STEM fields. Further analysis is needed, but these results are suggestive that funding aimed at URM students may be associated with decreased P-GFD. However, given that increased reliance on productive funding mechanisms is associated with an increase in R-GFD, there is not enough evidence to say that gender disparities are inherently improved in fields with greater reliance on productive funding mechanisms.

Gender Disparities. Unlike in the models predicting P-GFD, models predicting R-GFD, found both the department and field average gender disparity variables to be significant. Taken together, this suggests that variation in gender composition is highly associated with disparities between men and women receiving reproductive funding mechanisms, while P-GFD appears to be affected little by changes in gender compositions. However, the difference between the proportion of men and women receiving reproductive funding mechanisms is increased in fields with a higher average gender disparity, but departments with higher rates of men, relative to women, are associated with a reduced difference between the proportions of men and women receiving reproductive funding mechanisms.

As with the funding ratio variable, department gender disparities across broad fields are somewhat stratified, as demonstrated in figure eight, with engineering fields tending to have the highest levels of gender disparities (descriptive in table eleven). The seemingly contradictory finding, that fields with high average gender disparities increase R-GFD while departments with high gender disparities decrease R-GFD, may simply result from the fact that, as men account for a higher proportion of students in a department, then the needs of the department may dictate that many of those men take on reproductive funding mechanisms, requiring somewhat high proportions of men graduate students to take on reproductive funding mechanisms in engineering fields. Importantly, this finding suggests that, even when controlling for between department differences, field average gender disparities continue to significantly predict R-GFD, again reinforcing the importance of differences between fields.

Therefore, these findings are puzzling in that gender disparities appear to be very important for predicting change in R-GFD, but not P-GFD. Why would the difference between men and women receiving reproductive funding mechanisms be affected by both immediate and field average gender disparities, while the difference between men and women receiving productive funding mechanisms does not? One way to explain this finding may be that reproductive funding mechanisms may be a better operationalization of feminized labor among graduate students. Furthermore, differences in sources of productive funding mechanism may affect the way productive work is conceived. For example, is research funded by federal sources commodified in the same way that one would expect research funded by business or industry to be? Given that increased industry influence is associated with increased commodification of research (Irzik, 2013; Jacob, 2009; Radder, 2010; Slaughter & Leslie, 1997; Slaughter & Rhoads, 2004), and increased masculinization of research labor (Acker, 1990, 1992), further analysis is needed to better ascertain the extent to which research is increasingly conceived of as commodified and/or masculinized.

Influence of Market Proximity. The final finding reviewed here, that higher shares of R&D expenditures originating from industry were associated with reduced differences between the proportion of men and women receiving reproductive funding mechanisms, speaks to a primary focus of this study; the effect of industry. Again, this finding appears to be somewhat contradictory with expectations. According to the theoretical works informing this study, as a field becomes more closely associated with the market, as demonstrated by a higher share of R&D expenditures originating from industry, one would expect research to be considered increasingly commodified (Pestre, 2005; Radder, 2010; Slaughter & Rhoads, 2004), and thus, increasingly masculinized (Acker, 1990, 1992). Given this framework, the following two predictions were outlined in the theory section of chapter one:

1) As commercial influence increases, gender funding disproportionality among those receiving productive funding mechanisms will increase
2) As commercial influence increases, gender funding disproportionality among those receiving reproductive funding mechanisms will increase

However, the results of this analysis found no relationship between the share of R&D expenditures originating from industry and P-GFD. Further, the relationship between the share of R&D expenditures originating from industry and R-GFD decreases, contrary to the above prediction. This unexpected result, in the case of R-GFD, may not immediately disprove the assumptions underlying this analysis. For example, in a field where women are very overrepresented, a corresponding decrease in the number of women receiving reproductive funding mechanisms in a department with higher rate of R&D expenditures originating from industry, may be high in terms of numbers, say ten out of thirty students, or 33.3%. However, if the department has only ten graduate student men, then to match the same number of women no longer receiving reproductive funding mechanisms, 0% of men in the department would receive reproductive funding mechanisms. This illustrates how using disproportionality, while informative in studies attempting to control for differences in representation, it can also mask inequalities, particularly when women or men are severely over-/underrepresented.

Given the above findings, further analysis of the relationship between differences in the share of R&D expenditures originating from industry and the funding opportunities available to students, could help to further understand the influence of market proximity on gender funding disproportionality. For example, are departments with higher shares of R&D expenditures originating from industry likely to be those with a higher proportion of students receiving productive funding mechanisms? Interestingly, these two variables correlate at a very low rate (8%). Therefore, the link between the share of R&D expenditures and the conditions of student funding are still somewhat unclear. Further analysis in this area would be informative to the current study and may provide insight into better operationalizations of industry influence for the purposes of understanding patterns in graduate students funding mechanisms.

Interaction terms. The interaction terms used in this analysis focused on two key divisions commonly identified within STEM fields, social science vs. non-social science and quantitative vs. non-quantitative. However, none of the models showed significant evidence for either of these divisions being salient for understanding variation in GFD. Although the lack of results does not lead us to a specific conclusion, it does suggest that the divisions considered in this study do not adequately describe the between STEM field variation in GFD.

Because of this, the most significant limitation related to the interactions investigated in this study is that the divisions identified were an attempt to distill divisions within STEM fields down to a single, important factor, either social science/non-social science or the primacy of quantitative work within that field. What the current work shows is that the two divisions considered do not speak to the primary divisions that predict GFD. Given this finding, or lack thereof, the current work is suggestive that simple dichotomous variables may not be effective for predicting GFD. Therefore, further work in this area may consider disaggregation of STEM fields into more than two categories, in order to identify the most salient divisions within STEM fields.

Implications for Theory and Practice

In the following section, implications of the current results are discussed. I will first discuss implications as they relate to the theoretical perspectives informing this study. In doing so, I will also describe on the extent to which the current work has implications for STEM gender gap researchers in the future. This will be followed by a brief discussion of the implication of the results for practitioners, working to reduce the gender gap in STEM.

Theoretical Implications. The current work builds on three different areas of theory. First academic capitalism and resource dependence theory were used to describe why one would expect industry influence to command power within institutions and departments. Furthermore, this is expected to vary based on the extent of a departments' reliance upon industry funding, as operationalized through the share of R&D expenditures originating from industry. New institutional theory and feminist institutional theory were used to describe how this relates to reinforcing gender roles and norms and, finally, Acker's (1990; 1992) theory of gendered organizations was used to interpret the embeddedness of gender in graduate student labor mechanisms.

First, the results provide little evidence for the academic capitalism framework. Although the framework provides little in the way of predictions, the proxy used in this analysis for industry influence, the share of R&D expenditures originating from industry, was not found to significantly predict P-GFD, and the direction of the effect for R-GFD was opposite of what was expected. This lack of evidence does not imply that the academic capitalism framework is irrelevant; however, it does not necessarily provide support for it. Furthermore, given that the field average funding ratio variable was found to significantly affect both P-GFD and R-GFD, this provides some support for a resource dependence framework. As more students receive productive funding, or funding from non-institutional sources, fewer students may take on reproductive funding mechanisms. This suggests that outside funders' needs for student researchers may be being prioritized over institutional needs for teachers, requiring institutions to rely on other contingent labor to fulfill its teaching responsibilities. Therefore, increased reliance upon productive funding mechanisms may represent outside funders increased command of power to shape institutional goals and priorities. Although further analysis is needed to validate this theory, the current results do provide some support for resource dependence.

Given the lack of gender funding disproportionality, on average, detectable among those receiving reproductive funding mechanisms, this analysis does not provide support for its' use of feminist institutionalism or gendered organizations. However, the implication of this finding, again does not suggest an absence of gendered inequality occurring, or that these concepts are not relevant for understanding P-GFD or R-GFD. Instead, the implication of this negative finding is that further theorizing and research is needed to develop more precise measures and indicators of theoretically important concepts such as industry influence as well as productive and reproductive labor. Multidimensional gender gaps, identified throughout the literature informing this study, exist and show little or no indication of improvement. Thus, despite these negative findings, further work considering the interrelationships between power, gender and labor is necessary for understanding how and why multidimensional gender gaps in STEM fields persist.

Additionally, the current work points to the importance of between field differences for understanding gender inequality in STEM fields. As is shown in Figure four, women's rate of participation between STEM fields is incredibly varied. Therefore, further analysis and theorizing about this topic may consider unequal distribution of resources between fields. Furthermore, by analyzing women's increased representation in fields with relatively lower resources for student funding or for the funding of research-oriented funding mechanisms, this may represent gender inequality that is not evident through this analysis of disproportionality. Further theorizing and analyses that makes between field differences in STEM the primary focus may be better equipped to identify gendered inequality within graduate student labor mechanisms.

Practical Implications. Due to the negative, and sometimes contradictory results in relation to the theoretical frameworks used in this analysis, few practical implications emerge from this research. However, what the current work does emphasize is the multidimensional nature of inequality facing women in STEM fields currently.

Therefore, practitioners should match this problem with multidimensional approaches for both understanding and addressing inequality.

First, practitioners should consider ways in which inequality may occur. As this current work argues, the way that graduate students are funded is not simply a neutral source of income. On the contrary, graduate student funding mechanism are part of the process of socialization for the postdoctoral career (Austin, 2002; Austin et al., 2009; Blume-Kohout, 2014). Therefore, practitioners should take care to ensure that both men and women graduate students are able to access funding opportunities, particularly highly prestigious, research-oriented funding mechanism, at about the same rate as men in the department. Furthermore, consistent evaluation and assessment considering gaps in the way STEM graduate students are funded, in an effort to reduce potential inequality stemming from these gender gaps.

Second, practitioners should take careful notice of gender inequality occurring between STEM fields. As is demonstrated in figure four, women's representation between STEM fields is varied. Therefore, taking a critical perspective, a practitioner may come to realize that fields with more women are also fields that tend to be less prestigious (Weeden et al., 2017) or heavily emphasize teaching (Baker, 2012; Misra et al., 2010; Winslow, 2010). These observations may in fact be from whence gender gaps emerge. As a result, practitioners may take a proactive stance on the matter, creating programming focused on developing research skills and experience in fields with high rates of women's participation, with lower rates of funded research opportunities.

Alternatively, practitioners may also consider ways for increasing the prestige of teaching-oriented work through developing teaching programs, awards or fellowships.

In all, practitioners should take a critical approach for understanding gender inequality. Although the numbers of men and women in a particular department, a particular institution may be equal to one another, this does not mean that gender equality has been achieved. Taking a critical approach to challenge normative notions of equality can help pracitioners to identify multiple dimensions of gendered inequality, as well as to develop proactive strategies for reducing multidimensional gender gap in STEM.

Recommendations for Future Research

Throughout the previous section, limitations of the current work are identified, and areas of future study are suggested. In this section, I will outline the three areas in which further analysis would help to better our understanding of gender funding disproportionality among STEM graduate students. Furthermore, I will address some of the data limitations of the current study, and the need for intersectional data and approaches for understanding inequality in labor mechanisms for STEM graduate students.

Although the current work is certainly suggestive of the importance of fields for understanding differences in gender funding disproportionality, more research is needed in this area. One approach to this may be to conceive of the structure of the data as departments nested within fields, instead of departments nested within institutions, due to the small but significant differences between institutions. Alternatively, a three level, multilevel analysis may also be attempted in order to test whether department, institution and field levels all significantly vary across P-GFD and R-GFD. Another approach would be to develop within field analyses, potentially compared over time. While such studies would be limited in terms of comparing one field to another, they may help researchers to best tease out the important factors for predicting gender funding disproportionality.

The next area, the process of commodification of research, likely requires qualitative inquiries. One of the key assumptions underlying the current work is that industry influence restructures the workplace (Slaughter & Leslie, 1997; Slaughter & Rhoads, 2004), a consequence of which is the commodification of academic research (Irzik, 2013; Jacob, 2009; Radder, 2010) thereby reinforcing gender norms (Acker, 1992, 1992). However, further analyses aimed at understanding the processes and mechanisms by which industry influence results in the commodification of academic research may help researchers to find a better operationalization of the concept of industry influence. For example, while the share of R&D expenditures originating from industry speak to a dimension of industry influence, it may not necessarily reflect more or less degree of commodification of academic research. It's possible that commodification does not occur on a spectrum, but instead is conceived of as a dichotomy. Therefore, further understanding of this process could help quantitative researchers to select variables that better reflect change in commodification of academic research.

Another weakness of the main independent variable of interest relates to the third area of future research. Although the main independent variable of interest, the share of

R&D expenditures originating from industry certainly speaks to a dimension of industry influence, its low correlation with the department funding ratio suggests that this variable may not adequately address industry's influence on graduate students specifically. As with the commodification of research, further analysis of the ways that industry influence within a department affect graduate students would also greatly inform research int his area. One example of an approach that would be informative would be considering an interaction between type and source of funding. For example, does productive funding from federal sources affect gender funding disproportionality differently than productive funding from private/industry sources?

The current work represents preliminary steps into investigating gender funding disproportionately among graduate students in STEM fields. However, it is severely limited by the structure of the publicly available NSF datasets. Specifically, the primary survey used in this analysis, the Survey of Graduate Students and Postdoctorates in Science and Engineering, disaggregates data by either gender *or* race, making an intersectional approach to this study impossible. Although this purpose for this structure of data may relate to privacy concerns, it nonetheless affects how analyses must be carried out. Furthermore, the inability to consider the intersecting oppressions stemming from identities, particularly race alongside gender, in the current analysis is a major limitation. Thus further work which takes intersectional approaches, and future efforts to collect data, should be greatly informed by critical quantitative works on data collection/surveys (H. E. Metcalf, 2014), as well as intersectionality theoretical frameworks (Crenshaw, 1990).

Conclusion

The primary motivator for this research was to understand whether disparities exist in the way that men and women graduate students are funded in STEM fields. Furthermore, this research took on an additional layer by critically evaluating the role that industry influence plays for changing how research is conceived, and thereby affecting the gendered perception of labor among graduate students. Given this theoretical framework, drawing on academic capitalism and resource dependence, one would expect to find a restructuring of the workplace as departments become more reliant on industry sources of funding (Pfeffer & Salancik, 2003; Slaughter & Rhoades, 1996; Slaughter & Rhoads, 2004). As such, using feminist institutionalism (Kenny, 2007; Mackay et al., 2010) and the theory of gendered organizations (Acker, 1990, 1992), I theorized that existing gender dichotomies apparent in graduate student funding mechanisms, would likely be reinforced as marked influence increased.

Of particular importance for the current work is to analyze the extent to which patterns in men and women's funding mechanisms in STEM departments, aligned with the predictions of the critical theories used in this analysis. However, the statistical did not provide evidence that increased commercialization leading to increased commodification of research was associated with increased P-GFD. Furthermore, this study found evidence that increased commercialization, leading to increased commodification of research, was associated with decreased R-GFD. These findings, while contrary to the theoretical perspectives used, point to the need for further analysis of the assumptions used in for this study. As detailed in the discussion section, further work is needed to better understand the process of commodification of academic research, as well as the extent to which the used of proportions in this analysis may mask inequalities that are evident when analyzing the raw numbers of students.

As is identified throughout this work, gender gaps in STEM are multidimensional and persistent. The use of critical theories to develop this model, and critical perspectives used to analyze the results, requires of researchers to consider such multidimensional approaches to understanding inequality. Although the current work failed to find support for its' predicted outcomes, the results do provide rich insight into the interrelationships between the various variables used in this analysis. As such, this work represents a jumping off place of sorts for future analyses of gender funding disproportionality among STEM graduate students.

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List of Figures

Figure 1. Rates of Doctorates Awarded to Males and Females in STEM, 1986-2016

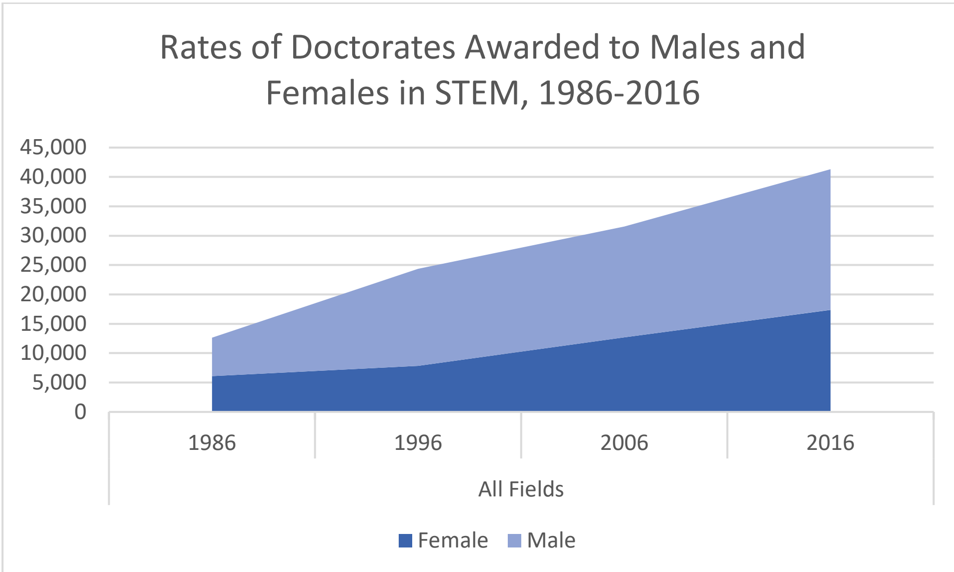


Figure 2. Doctorates Awarded by Field and Sex, 1986 & 2016

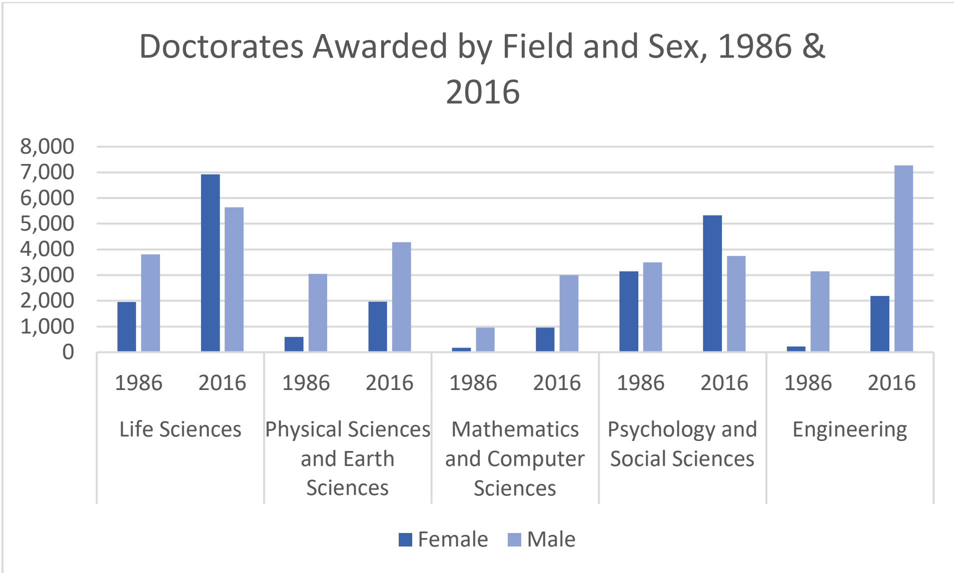


Figure 3. Map of Theoretical Perspectives and Predictions

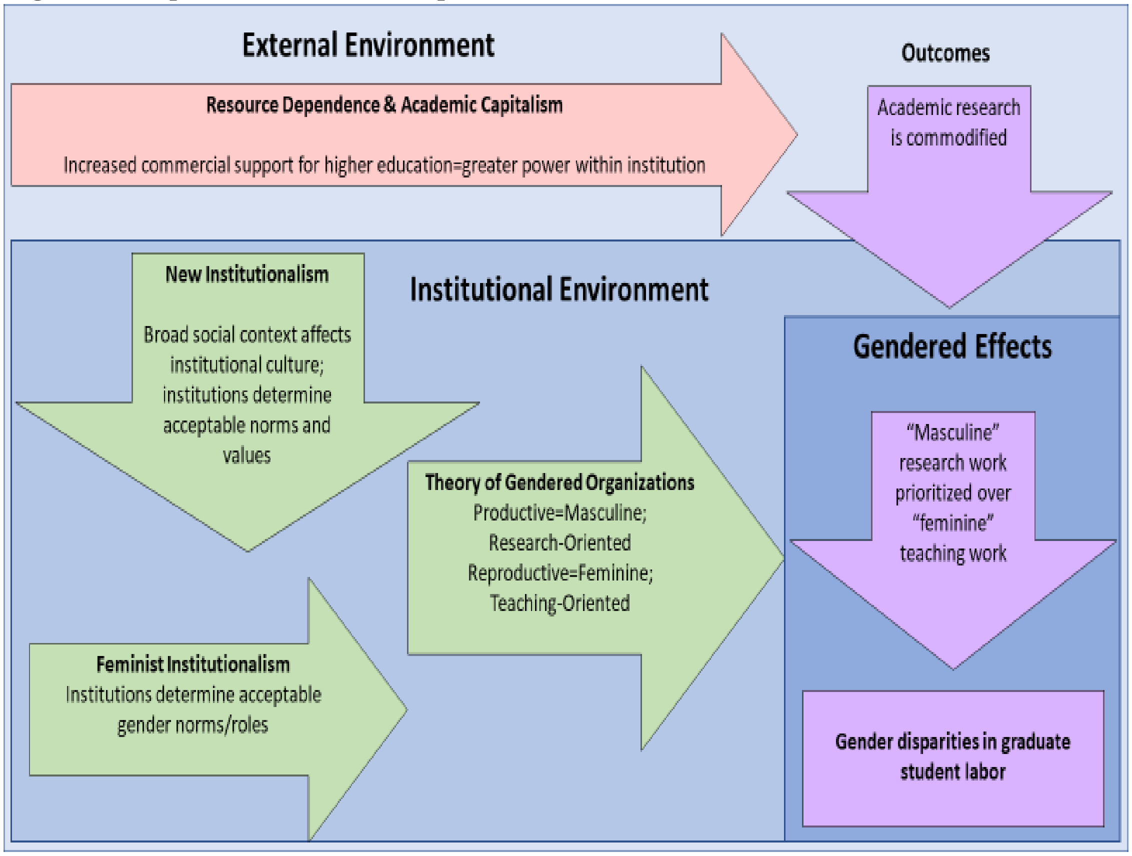
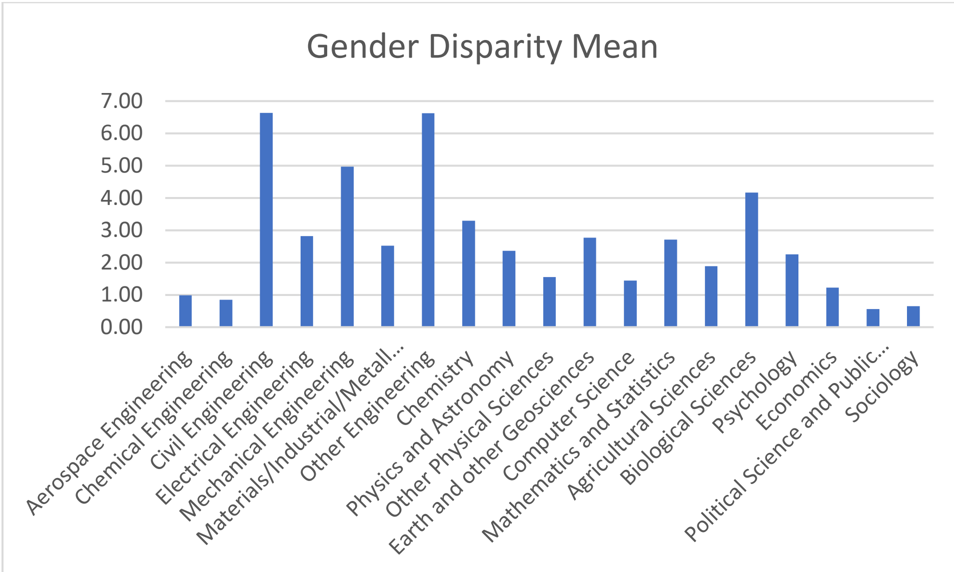


Figure 4. Graphs of Field Gender Disparity and Funding Ratio Averages



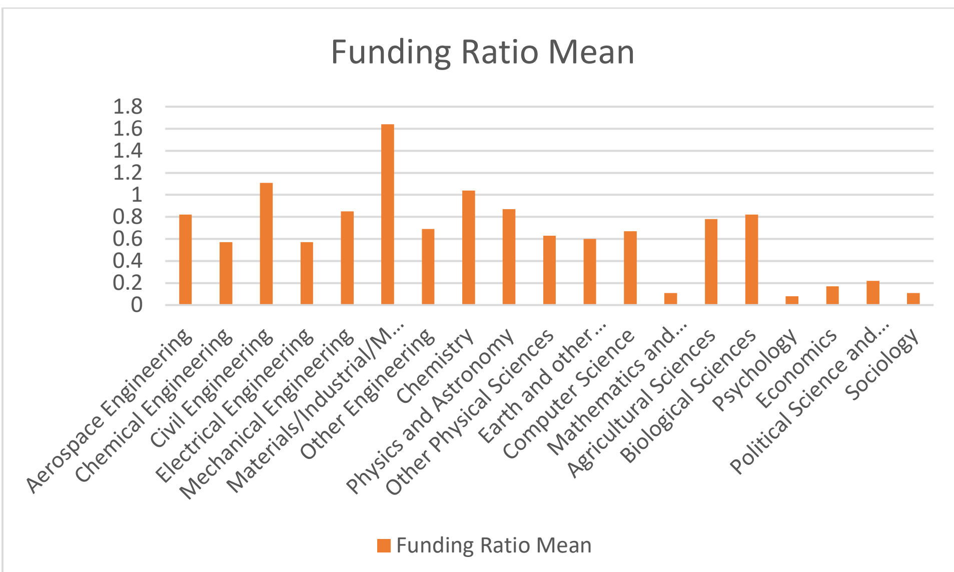


Figure 5. Analysis of P-GFD Data and Model Assumptions

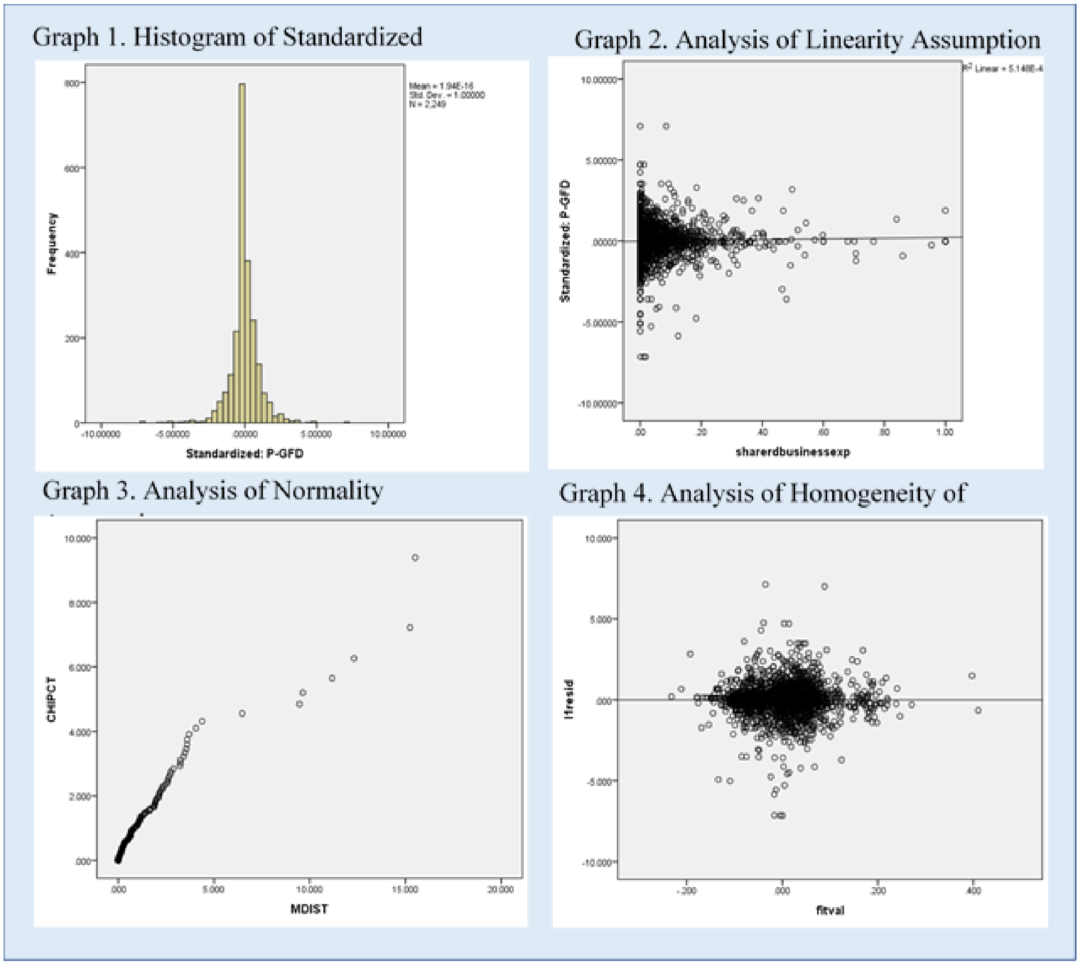


Figure 6. Analysis of R-GFD Data and Model Assumptions

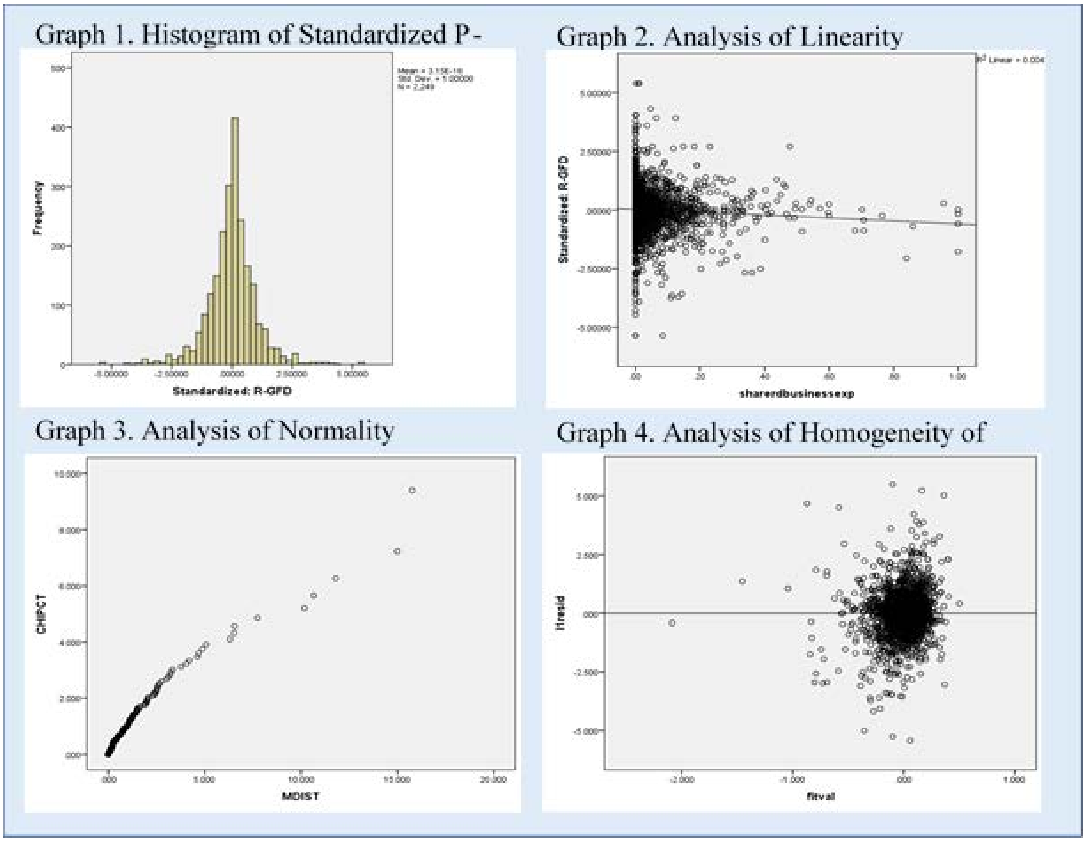


Figure 7. Funding Ratio Percentiles by Broad Field

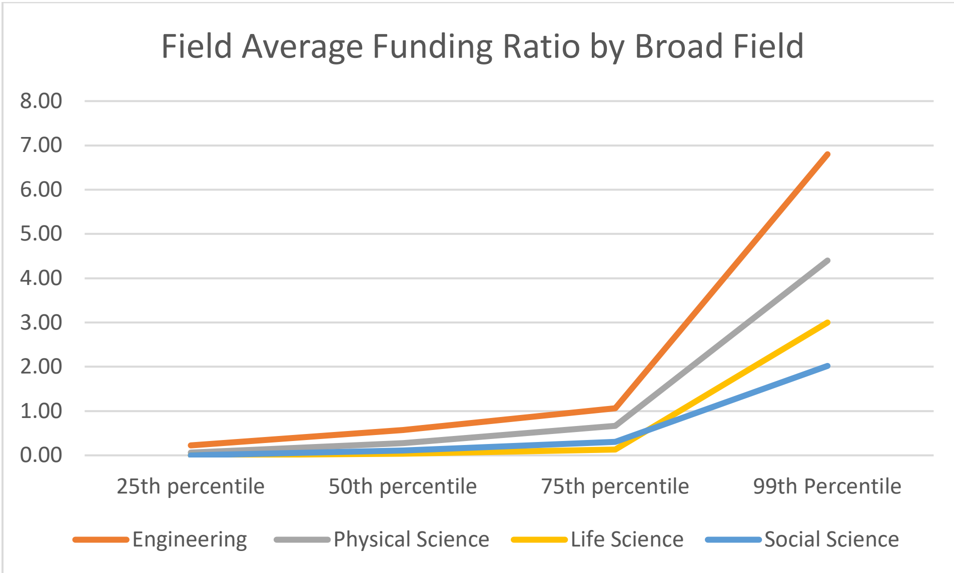
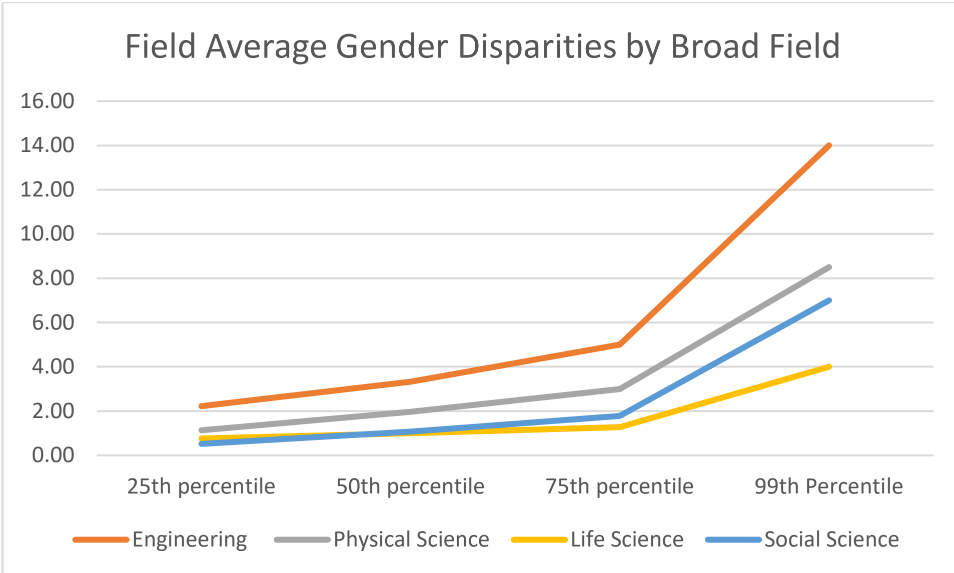


Figure 8. Gender Disparity Percentiles by Broad Field



List of Tables

Table 1. Combined Fields

GSS Survey Fields	Broad Field Used in Analysis to Match HERD Survey
Industrial and Manufacturing Engineering	Metallurgical and Materials Engineering
Metallurgical and Materials Engineering	
Chemical Engineering	Chemical Engineering
Petroleum Engineering	
Agricultural Engineering	Biological and Biomedical Engineering
Biomedical Engineering	
Biological and Biosystems Engineering	
Engineering Science and Engineering Physics	Other Engineering
Mining Engineering	
Nuclear Engineering	
Mathematical Sciences	Mathematic Sciences
Statistics	
Physics	Physics and Astronomy
Astronomy	
Biochemsitry	Biological Sciences
Biology	
Biometry and epidemiology	
Biophysics	
Botany	
Cell and Molecular Biology	
Ecology	
Entomology and Parasitology	
Genetics	
Microbology, Immunology and Virology	
Nutrition	
Pathology	
Pharmacology	
Zoology	
Biological Sciences	
Atmospheric Sciences	Earth Sciences
Geosciences	
Oceanic Sciences	
Earth, Atmospheric and Ocean Sciences not e	
Psychology, except clinical	Psychology
Clinical Psychology	

Table 2. Other Fields Included

GSS Survey Fields	Fields Used in Analysis Matching HERD Survey
Aerospace Engineering	Aeronautical and Astronautical
Civil Engineering	Civil Engineering
Electrical Engineering	Electrical Engineering
Mechanical Engineering	Mechanical Engineering
Chemistry	Chemistry
Agricultural Sciences	Agricultural Sciences
Economics	Economics
Political Science	Political Science
Sociology	Sociology
Computer Science	Computer Science

Table 3. Frequencies of each field included in the sample (across all institutions)

Field	**Frequency in Sample**
Aerospace Engineering	31
Chemical Engineering	111
Civil Engineering	139
Electrical Engineering	155
Mechanical Engineering	145
Materials/Industrial/Metallurgical/Manufacturing Engineering	61
Other Engineering	66
Chemistry	195
Physics and Astronomy	169
Other Physical Sciences	6
Earth and other Geosciences	130
Computer Science	177
Mathematics and Statistics	185
Agricultural Sciences	71
Biological Sciences	95
Psychology	108
Economics	131
Political Science and Public Administration	149
Sociology	125
Total	**2249**

Table 4. Descriptive Statistics for Outcome Variables

Outcome Variables	N	Minimum	Maximum	Mean	Standard Deviation
Proportion of men minus proportion of women receiving reproductive funding mechanisms (R-GFD)	2249	-5.353	5.382	0	1
Proportion of men minus proportion of women receiving productive funding mechanisms (P-GFD)	2249	-7.155	7.091	0	1

Table 5. Field Attribute Variables

Field Attribute Variables	**Gender Disparity Mean**	**Funding Ratio Mean**
Aerospace Engineering	6.64	1.11
Chemical Engineering	2.36	0.87
Civil Engineering	2.82	0.57
Electrical Engineering	4.97	0.85
Mechanical Engineering	6.63	0.69
Materials/Industrial/Metallurgical/Manufacturing Engineering	2.52	1.64
Other Engineering	3.30	1.04
Chemistry	1.56	0.63
Physics and Astronomy	4.17	0.82
Other Physical Sciences	1.88	0.78
Earth and other Geosciences	1.44	0.67
Computer Science	2.77	0.6
Mathematics and Statistics	2.71	0.11
Agricultural Sciences	0.98	0.82
Biological Sciences	0.84	0.57
Psychology	0.56	0.22
Economics	2.25	0.08
Political Science and Public Administration	1.23	0.17
Sociology	0.65	0.11

Table 6. Independent Variable Descriptive Statistics

Level 1 Independent Variables	**N**	**Minimum**	**Maximum**	**Mean**	**Standard Deviation**
Gender Disparity	2249	0.111	32.000	2.567	2.338
Funding Ratio (department)	2249	0.000	34.500	0.542	1.137
Gender disparity (field	2249	0.556	6.639	2.636	1.672
Funding Ratio (field average)	2249	0.080	1.640	0.568	0.345
Share of R&D Expenditures	2249	0.000	1.000	0.051	0.100
Interaction Term	2249	0.000	1.000	0.046	0.094
	Social Science	**Non-Social Science**			
Social Science/Non-Social Science	513	1736			
Level 2 Independent Variables	**N**	**Minimum**	**Maximum**	**Mean**	**Standard Deviation**
Institutional Size (number of graduate students)	210	521	25077	5965.32	4253.98
Prestige (US News and World Report Ranking)	**Top 50**	**50-100**	**100-150**	**150-200**	**Unranked**
	46	38	34	34	58
Public/Private	**Public**	**Private**			
	151	59			

Table 7. U.S. News and World Report Ranking Bands used to Indicate Institutional Prestige

US News and World Report Ranking Bands	**Number of Institutions**	**Number of Observations**
Ranks 1-10	12	147
Ranks 11-20	8	93
Ranks 21-30	10	114
Ranks 31-40	8	90
Ranks 41-50	8	116
Ranks 51-60	7	105
Ranks 61-70	8	107
Ranks 71-80	8	96
Ranks 81-90	10	100
Ranks 91-100	5	55
Ranks 101-110	7	86
Ranks 111-120	4	37
Ranks 121-130	9	107
Ranks 131-140	9	98
Ranks 141-150	5	55
Ranks 151-160	5	49
Ranks 161-170	11	124
Ranks 171-180	5	51
Ranks 181-190	8	94
Ranks 191-204	5	41
Ranks 204-264	42	365
Unranked	16	119
Total	210	2249

Table 8 a. Statistical Results for Model Predicting P-GFD: Fixed Effects: Departments

	Model 1	**Model 2a**	**Model 2b**	**Model 3**	**Model 3: Interaction**	**Model 4**	**Model 5**	**Model 5: Interaction**
Fixed effects: Departments (Within Institutions)								
Intercept	0.000	0.000	0.000	0.000	0.007	-0.003	0.000	0.025
Department Gender Disparity		-0.012	-0.012	-0.012	-0.012	-0.016	-0.016	-0.016
Field Average Gender Disparity		0.022	0.007	0.006	0.007	0.014	0.017	0.018
Department Funding Ratio			-0.006	-0.006	-0.006	-0.009	0.000	0.000
Field Average Funding Ratio			0.157*	0.163*	0.181*	0.118	0.142	0.185
Share of R&D Originating from Industry				0.272	0.235	0.029	0.086	0.087
Social Science/Non-Social Science					-0.039			
Interaction: Share of R&D*Social Science/Non-Social Science Field					-0.149			
SQ/Non-SQ							-0.001	0.029
SQ*Funding Ratio								-0.066

*p<0.05 **p<0.05 *** p<0.001

Table 8 b. Statistical Results for Model Predicting P-GFD: Fixed Effect Universities (Between Institutions)

		Model 1	Model 2a	Model 2b	Model 3	Model 3: Interaction	Model 4	Model 5	Model 5: Interaction
Fixed effects: Universities (Between Institutions)									
Intercept	Institution Size						0.000	0.000	0.000
	Institutional Prestige						0.005	0.005	0.010
	Institutional control						0.018	0.019	0.003
Department Gender Disparity	Institutional Size						0.000	0.000	0.000
	Institutional Prestige						-0.004	-0.004	-0.004
	Institutional control						-0.570	-0.055	-0.054
Field Average Gender Disparity	Institution Size						0.000	0.000	0.000
	Institutional Prestige						0.007	0.004	0.004
	Institutional control						0.100	0.111	0.114
Department Funding Ratio	Institution Size						0.000	0.000	0.000
	Institutional Prestige						0.007	0.007	0.007
	Institutional control						0.122	0.121	0.113
Field Average Funding Ratio	Institution Size						0.000	0.000	0.000
	Institutional Prestige						-0.022	-0.250	-0.016
	Institutional control						-0.447	-0.421	-0.248
Share of R&D Originating from Industry	Institution Size						0.000	0.000	0.000
	Institutional Prestige						-0.091	-0.089	-0.088
	Institutional control						-0.343	-0.345	-0.331
STEM Quant	Institution Size							0.000	0.000
	Institutional Prestige							0.014	0.021
	Institutional control							-0.085	0.310
SQ* Mean Funding Ratio	Institution Size								0.000
	Institutional Prestige								-0.014
	Institutional control								-0.257

Table 8 c. Statistical Results for Model Predicting P-GFD: Random Effects & Model Fit Criteria

	Model 1	**Model 2a**	**Model 2b**	**Model 3**	**Model 3: Interaction**	**Model 4**	**Model 5**	**Model 5: Interaction**
Random Effects								
ICC	0.001							
Intercept	0.001*	0.001*	0.001*	0.001*	0.001*	0.001*	0.001*	0.001*
Level-1	0.999	0.998	0.995	0.996	0.994	0.986	0.985	0.984
	Model 1	**Model 2a**	**Model 2b**	**Model 3**	**Model 3: Interaction**	**Model 4**	**Model 5**	**Model 5: Interaction**
Model Fit Criteria								
Deviance Statistic	6379.661	6378.156	6373.278	6373.02	6368.645	6351.092	6347.087	6345.417
AIC	6385.661	6392.156	6387.278	6389.02	6388.645	6403.092	6399.087	6397.417
BIC	6386.627	6404.892	6410.708	6415.797	6422.116	6490.117	6507.5	6527.219
LRT Significance		p>0.10	p <0.05	p >0.10	p > 0.10	p > 0.10	p > 0.10	p > 0.10

*p<0.05

**p<0.05

*** p<0.001

Table 9 a. Statistical Results for Model Predicting R-GFD: Fixed Effects: Departments (Within Institutions)

	Model 1	**Model 2a**	**Model 2b**	**Model 3**	**Model 3: Interaction**	**Model 4**	**Model 5**	**Model 5: Interaction**
Fixes effects: Departments (Within Institutions)								
Intercept	0.003	0.002	0.002	0.002	-0.002	0.004	0.002	0.001
Department Gender Disparity		-0.071***	-0.071***	-0.071***	-0.077***	-0.069***	-0.078***	-0.095
Field Average Gender Disparity		0.067*	0.067*	0.069*	0.075**	0.062*	0.057*	0.075
Department Funding Ratio			0.010	0.010	0.011	0.012	0.007	0.007
Field Average Funding Ratio			-0.258***	-0.235***	-0.286***	-0.190*	-0.243*	-0.254*
Share of R&D Originating from Industry				-0.367*	-0.495	-0.417	-0.453	-0.457
Social Science/Non Social Science					0.031			
Interaction: Share of R&D*Social Science/Non-Social Science					0.100			
Field SQ/Non-SQ							0.078	0.078
SQ*Mean Gender Disparity								-0.021
SQ* Dept. Gender Disparity								0.018
SQ*Average Funding Ratio								0.024

*p<0.05 **p<0.05 *** p<0.001

Table 9 b. Statistical Results for Model Predicting R-GFD: Fixed Effects: Universities (Between Institutions)

		Model 1	**Model 2a**	**Model 2b**	**Model 3**	**Model 3: Interaction**	**Model 4**	**Model 5**	**Model 5: Interaction**
Fixed effects: Universities (Between Institutions									
Intercept	Institution Size						0.000	0.000	0.000
	Institutional Prestige						0.000	0.001	-0.007
	Institutional Control						0.580	0.078	-0.130
Department Gender Disparity	Institution Size						0.000	0.000	0.000
	Institutional Prestige						-0.005	-0.005	-0.007
	Institutional Control						0.027	0.028	-0.445
Field Average Gender Disparity	Institution Size						0.000	0.000	0.000
	Institutional Prestige						0.002	0.007	0.007
	Institutional Control						-0.080	-0.088	-0.073
Department Funding Ratio	Institution Size						0.000	0.000	0.000
	Institutional Prestige						0.000	0.002	0.003
	Institutional Control						0.021	0.005	0.017
Field Average Funding Ratio	Institution Size						0.000	0.000	0.000
	Institutional Prestige						0.010	0.007	-0.003
	Institutional Control						0.020	-0.045	-0.221
Share of R&D Originating from Industry	Institution Size						0.000	0.000	0.000
	Institutional Prestige						0.008	0.021	0.019
	Institutional Control						0.060	0.444	0.419
Social Science/Non Social Science	Institution Size						0.000		
	Institutional Prestige						0.010		
	Institutional Control						0.020		
Interaction: Share of R&D*Social Science/Non-Social Science Field	Institution Size						0.000		
	Institutional Prestige						0.008		
	Institutional Control						0.060		
SQ/Non SQ	Institution Size							0.000	0.000
	Institutional Prestige							-0.022	-0.030
	Institutional Control							-0.019	-0.405
SQ*Department gender disparity	Institution Size								0.000
	Institutional Prestige								0.002
	Institutional Control								0.077
SQ*Mean Gender Disparity	Institution Size								0.000
	Institutional Prestige								-0.001
	Institutional Control								-0.021
SQ*Funding Ratio	Institution Size								0.000
	Institutional Prestige								0.015
	Institutional Control								0.273

Table 9 c. Statistical Results for Model Predicting R-GFD

	Model 1	**Model 2a**	**Model 2b**	**Model 3**	**Model 3: Interaction**	**Model 4**	**Model 5**	**Model 5: Interaction**
Random Effects								
ICC	0.023							
Intercept (between variance)	0.023***	0.026***	0.027***	0.027***	0.028***	0.028***	0.026***	0.029***
Level-1 (within variance)	0.977	0.96	0.953	0.952	0.952	0.949	0.937	0.931
	Model 1	**Model 2a**	**Model 2b**	**Model 3**	**Model 3: Interaction**	**Model 4**	**Model 5**	**Model 5: Interaction**
Model Fit Criteria								
Deviance Statistic	6375.754	6338.853	6321.888	6318.697	6318.358	6294.675	6288.377	6281.962
AIC	6381.754	6352.853	6335.888	6334.697	6338.358	6346.675	6340.377	6333.962
BIC	6391.796	6365.589	6359.318	6361.474	6371.829	6433.7	6448.79	6506.541
LRT significance		p<0.001	p<0.01	p >0.05	p >0.20	p> 0.10	p > 0.10	p > 0.10

*p<0.05

**p<0.05

*** p<0.001

Table 10. Descriptive Statistics for Funding Ratio Variable by Broad Field

	25th percentile	50th percentile	75th percentile	99th Percentile	Standard Deviation	Mean
Full Sample	***0.05***	***0.25***	***0.69***	***4.14***	***1.14***	***0.54***
Engineering	0.23	0.57	1.07	6.8	**1.04**	**0.83**
Physical Science	0.06	0.27	0.67	4.4	**0.93**	**0.53**
Life Science	0	0.04	0.13	3	**0.47**	**0.16**
Social Science	0	0.11	0.3	2.02	**1.58**	**0.32**

- Darker yellow indicates largest value across fields

Table 11. Descriptive Statistics for Gender Disparity Variable by Broad Field

	25th Percentile	**50th Percentile**	**75th Percentile**	**99th Percentile**	**Standard Deviation**	**Mean**
Full Sample	***1.07***	***1.96***	***3.25***	***11***	***2.34***	***2.57***
Engineering	2.22	3.33	5	14	2.94	4.14
Physical Science	1.13	1.97	3	8.5	1.78	2.36
Life Science	0.76	1	1.27	4	0.7	1.13
Social Science	0.52	1.07	1.78	7	1.21	1.34

- Darker yellow indicates largest value across fields