FACULTY COLLABORATIVE DYADS:

PROFILES AND PRODUCTIVITY

by

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DEDICATION

This dissertation is dedicated to those in whose footsteps I follow and those who follow mine. To Mom and Dad who are lifelong learners and inspire me with their intelligence, humility, work ethic, and outlook on life. And to my children, Abby, Grace and Brooks, who challenge me to ponder, to question, to think, and to always be open. Thank you.

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TABLE OF CONTENTS

TABLE OF CONTENTS CONTINUED

TABLE OF CONTENTS CONTINUED

LIST OF TABLES

LIST OF FIGURES

ABSTRACT

Collaboration among faculty on research endeavors is becoming more common as the research problems being addressed are more complex and require differing skills and knowledge. Higher education institutions should be interested in understanding these collaborative relationship as a way to support and encourage them and to understand the culture and behavior of faculty. This study seeks to understand those collaborations by looking at the collaborative dyad of two faculty members as the unit of analysis. The purpose of this study is to investigate the relationship between research productivity and the demographic characteristics of faculty collaborative dyads. Using a survey methodology, data was gathered from tenured and tenure-track faculty at two research institutions about their primary research collaboration and the resultant productivity of this collaboration as measured by three outcome variables: (1) Intellectual Contributions – Published, (2) Presentations, and (3) Grants Awarded. The relationship between the demographic characteristics of gender, rank and discipline on the productivity of the dyad were studied with data gathered through an electronic survey to faculty at two institutions. A 34-item survey was distributed to 830 faculty and 207 usable surveys were received. Descriptive statistics and negative binomial regression were used to analyze the data. The results of negative binomial regression analysis of the data indicate that disciplinary homophily is significantly related to all measures of productivity while rank homophily is significantly related to Intellectual Contributions - Published and gender homophily is significantly related to Presentations. Overall, though the research supports the Similarity Attraction Paradigm theory in that homophilous dyads tend to be more productive than their heterophilous counterparts. This study adds to the growing body of knowledge about interdisciplinary collaboration, and specifically the micro-level characteristics of what productive collaborations look like. Recommendations for promoting such collaborations include mentoring of different ranks, and facilitating collaborations across disciplines that are more different from each other than would typically be found in a research collaboration.

CHAPTER ONE

INTRODUCTION

Introduction to the Study

In modern Florence during the Italian Renaissance, the outburst of artistic creativity was stimulated in part by the patronage of the Medici family who brought together sculptors, scientists, artists and philosophers for an exchange of ideas and talents. In higher education today, this same "Medici Effect" can be seen in the convergence of faculty from different disciplines coming together to solve scientific and societal problems through an interdisciplinary approach (Schwieger, Gros, and Barberan, 2010). Interdisciplinary scholarship has become a significant way in which American higher education operates. Not simply a research or educational initiative, interdisciplinary scholarship has permeated the academy in form and content with significant growth in the last 40 years (Brint, Turk-Bicakci, Proctor, & Murphy, 2009). It is seen in the curriculum in majors that cross traditional disciplinary boundaries, in research centers that bring together faculty from various disciplines working toward a common problem and in training where programs like the National Science Foundation IGERT are specifically structured to provide graduate student training across disciplines.

Higher education should be interested in fostering interdisciplinarity for a variety of reasons. Training students to interact and understand more than one discipline better prepares them for the complex world in which they will live and work. Students, in fact, are attracted to interdisciplinary majors. Between 1975-2000, the number of

interdisciplinary programs for undergraduates increased by almost 250% (Brint et al, 2009). Universities may use this as a marketing strategy, highlighting their interdisciplinary offerings and attracting millennial-aged students who have grown up in a global, interactive society. But interdisciplinary education also has a practical application in its goal to foster non-linear thought that is so important with today's complex problems (Elkana, 2009). The interface of disciplines is where one may find solutions to global or societal issues, but simply putting people with different training in a room to solve problems or look at issues is not sufficient. Training students to be open to the perspectives and viewpoints of others with different knowledge and skills is what encourages this non-linear thought.

The curricular structure, the rise of professionalism in academic disciplines, and overall growth of the University organization led to the current structure of most institutions of higher education organized by departments and colleges. This structure has worked as a way to organize knowledge within higher education (Gumport, 2007). The challenge to the existing structure comes when knowledge is created or pursued at the boundaries of existing disciplines, thus being "interdisciplinary" and not fitting neatly into the existing structures of higher education.

Even with all of the attention to interdisciplinary scholarship, the question of "What is interdisciplinary research?" has become more complex in recent years. Attempts to define interdisciplinary research have looked at a continuum of multi-, inter-, and trans-disciplinary research, and disciplinary versus non-disciplinary research in

which faculty may place themselves or their work (Meeth, 1978; van der Besselaar & Heimeriks, 2001).

Interdisciplinarity can be seen across all facets of an institution, from courses, to majors, to research centers each existing independently or in a symbiotic way with each other to support the different missions of the institution. In institutions of higher education that are classified as "very high research activity" (http://carnegieclassifications.iu.edu/), supporting the research mission is a priority, and given the emphasis of federal agencies on interdisciplinary research, supporting efforts at interdisciplinary research is increasingly important (National Academy, 2005). An understanding of the factors and forces associated with the growth of interdisciplinary research can inform the current trend of more interdisciplinary collaboration.

Collaboration is becoming a more common practice among faculty (Etzkowitz, 1998; Jansen, von Gortz, and Heidler, 2010) and one of the motives cited for collaboration is to encourage cross-fertilization across disciplines (Katz & Martin, 1997; Melin, 2000). This cross-fertilization is even being recognized as an effective method to approach problems beyond academia. The US Agency for International Development calls on multidisciplinary approaches between colleges and universities to solve the complex, vexing problems being faced in international development as a way of understanding complex problems and possible solutions (White House Office of Science Technology Policy, 2012). In the research enterprise, this cross-fertilization can lead to sharing knowledge, equipment, and approaches to problems that may lead to publications and grant proposals, which are some of the research productivity metrics used for

promotion and tenure and other merit based evaluations. Faculty who are able to participate in interdisciplinary collaborative research may be more successful in their role in the professoriate, specifically promotion and tenure review and other measures of success (Jansen, von Gortz and Heidler, 2010; Rotolo and Petruzelli, 2013). The productivity of interdisciplinary researchers has been shown to be influenced by a number of factors including environmental/institutional factors, team factors, and individual characteristics of team members (Aboelela, et al., 2007; Feller, 2007). Dietz (2000) argues that the research capacity that interdisciplinarity fosters comes from the social capital that scientists build in networks through their research and collaborations. These networks often give scientists access to new research avenues, expertise, equipment, and knowledge that can grow the research capacity of the scientist and the institution (Bozeman, Dietz, & Gaughan, 2001; Dietz, 2000). This study attempts to contribute to greater understanding the individual characteristics of the team members involved in interdisciplinary collaboration.

Social network theory proposes that resources are available to individuals through a network of connections (Granovetter, 1973). According to Granovetter, the more indirect connections a person has (i.e. weaker ties), the more they are exposed to knowledge outside their immediate circle. In the context of higher education, social network connections can help a faculty member access resources, equipment, expertise and specialized knowledge through collaborations, resulting in research products such as publications, books or grant proposals. If this collaboration is with a single other faculty member from a different discipline, this pair can be called an “interdisciplinary

collaborative dyad". Like the individual faculty member, this dyad has characteristics such as whether or not they are the same gender (gender homophily), or the same rank (rank homophily), and how different their academic disciplines are from one another. Examining the characteristics of these dyads and their research productivity can better help administrators understand the conditions under which faculty are likely to collaborate and be productive.

Most of the research on interdisciplinary research has been conducted at the institutional level, looking at organizational and structural factors that contribute to interdisciplinary success (Butler, 2011) with fewer empirical studies on individuals involved in interdisciplinary research. Kezar and Elrod (2012) proposed three stages of institutionalization through which institutions pass when creating interdiscisplinary environments: 1) mobilization in which the institution prepares for change; 2) implementation where infrastructure is created and the reform is supported, and 3) institutionalization in which innovations are incorporated into the value system, culture, and daily norms of the institution. Institutions that have truly embraced interdisciplinarity have developed ways to institutionalize it across the institution. For example, the University of Michigan has a culture of cluster faculty hires to capitalize on its successful interdisciplinary programs. The National Academy report describes a matrix structure in which departments still exist, but faculty can also self-organize in research clusters, or teaching disciplines that make sense for the problem or issue being addressed (National Academy, 2005).

A major barrier to interdisciplinary collaboration cited in the literature and anecdotally is promotion and tenure policies within specific departments (Feller, 2007; National Academy, 2005). As Aboelela et. al (2007) determined, environmental factors (i.e. size of the university) and individual characteristics are very important factors in fostering interdisciplinary research. With this study, I attempted to better understand the individual characteristics of faculty collaborative dyads by looking at the demographic characteristics of faculty involved in collaboration not only by gender and rank, but also by their disciplinary classification. The method used was a survey that asked about gender, discipline, rank, and research productivity. The sample was faculty at two doctoral granting institutions in Montana, both of which have research expectations of faculty. Results were analyzed using descriptive statistics and negative binomial regression.

Statement of Problem

The decline of traditional sources of funding for higher education is increasing the dependence by many research universities on other sources of income, including external grant funding (Wellman, 2008; Goldstein, 2005). At the same time, the competition for federal research dollars is becoming more intense with a proposal funding rate in 2011 of 18% for the National Institutes of Health and 22% for the National Science Foundation (Kaiser, 2012; NSF, 2012). Attracting and retaining faculty who can successfully garner external funding is becoming increasingly important to institutions of higher education both for alternative funding and maintaining their reputation, such as a Carnegie

Research Tier I classification (Wellman, 2008). While this is an institutional designation, it is primarily based on the activity of the faculty in the institution.

According to Lattuca (2002), the social context of higher education is inseparable from the faculty member role, and is therefore a symbiotic relationship. Better understanding this relationship in the interdisciplinary context can help administrators determine ways to foster and support collaborative interdisciplinary research. Understanding the intrinsic motivators for faculty involved in interdisciplinary research can assist institutions in creating environments and policies at the social and organizational level that will support and recognize the contributions of interdisciplinary researchers. Collaborative work between faculty members allows for resource and expertise sharing that leads to more research products (Bordons et al, 1996; Jha and Welch, 2010; Lee and Bozeman, 2000). Despite institutional efforts, interdisciplinary collaboration between faculty often develops randomly without deliberate effort to match interests and pairings that are productive. Being able to predict the characteristics in rank, gender and discipline that impact research productivity can inform administrators for policies and practices.

Purpose of Study

The purpose of the study was to understand the characteristics of interdisciplinary collaborative dyads involved in research, specifically the relationship of gender, rank, and discipline on the research productivity of the dyad. If we can identify the characteristics of those dyads that are more productive, then we can assist them at different stages of

their career and development and apply more targeted efforts at fostering interdisciplinary collaboration.

Research Questions

The research questions I addressed were:

1. What types of research products are produced by interdisciplinary collaborative dyads?
2. Is there a relationship between gender homophily (i.e. same gender of researchers) and interdisciplinary collaborative research producivity?
3. Is there a relationship between rank homophily (i.e. same rank of researchers) and interdisciplinary collaborative research productivity?
4. Is there a relationship between discipline homophily of the faculty dyad and interdisciplinary collaborative research productivity?
5. What is the relationship among gender, rank, discipline homophily and interdisciplinary collaborative research productivity?

Significance of Study

Higher education institutions should be interested in fostering collaborative interdisciplinary research for a variety of reasons. In times of budget cuts and less funding, many universities look toward the federal money for research centers and initiatives that will build a new research area which could possibly lead to sustainable funding (Feller, 2007). The results of this study can inform administrators and decision makers about the factors that contribute to faculty who are more productive in

interdisciplinary research. Given the opportunities to revise institutional structures and policies to support increased interdisciplinary collaboration, this study can be informative about what those practices and policies should address.

Theoretical/Conceptual Framework

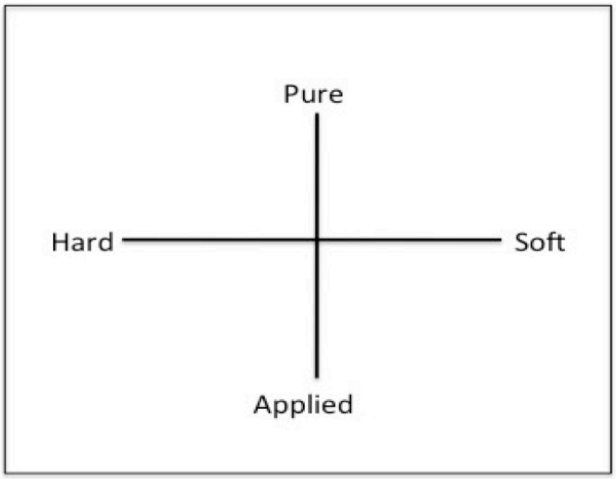
Social Capital Theory

One of the purposes of higher education as an institution is to create new knowledge (Gumport, 2007) which according to Boyer (1990), is a primary role of faculty in higher education. In our increasingly integrated society, one of the most efficient ways to do this is through interactions with others and leveraging the knowledge and resources of each individual. This "social capital" that each person brings to the collaboration can enhance the creation of new knowledge through increased opportunities for access to actual and potential resources (Nahapiet & Ghoshal, 1998). New knowledge is created through this combination and exchange of existing knowledge that the individual faculty members have as their social capital, which would explain why individual members have collaborations with others. The social structure in which one operates is a kind of capital which can give individuals an advantage in their efforts (Burt, 2000). This social network is made of ties with other individuals, which Granovetter (1973) labels strong and weak. It is in the weak ties between groups that individuals are exposed to people different from themselves, thus expanding their social network beyond people who are like them, or more heterophilous to them.

Disciplinary Classification

One of the most accepted classifications of subject matter was done by Anthony Biglan in the 1970s where he looked at the characteristics of subject matter in different academic areas (1973). While not a faculty theory, specifically, it provides a strong basis

Figure 1.1: Two continuums of Biglan's matrix of disciplines



for understanding the differences in disciplines and faculty within those disciplines. Biglan surveyed faculty at two types of institutions (large research and small liberal arts) about disciplines and their characteristics. The faculty participants at both of the institutions were asked to make judgments and sort different subjects areas on scales in a metric space (Figure 1.1). The results indicated three continuums on which the subjects fell. These were (1) hard-soft; (2) applied-pure; and (3) life-nonlife. Biglan was able to create a two-dimensional matrix for each combination of these pairs, which visually placed each discipline in a different quadrant. For example, one graph might have hard-soft along the x-axis and applied-pure along the y-axis.

Different subjects were graphed according to the data he gathered so that you could see what kinds of disciplines (subjects) were opposite or next to each other on the continuum. Some studies have looked at the research productivity of faculty based on the applied and pure continuum (Abramo. D'Angelo, and DiCasta, 2009; van Rijnsoever and Hessels, 2011; Jansen, von Gortz, and Heidler, 2010) and at least one specifically using Biglan's classification for examining productivity (Shin, 2011). The continued use of this classification testifies to its utility as an organizing theory for disciplines. As interdisciplinary scholarship grows, the collaborations extend across many disciplines and quadrants of Biglan's work. In my study, Biglan's classification provides a framework with which to measure the difference in the disciplines from which the faculty collaborators in the dyad come.

Research Methodology

This study is a quantitative study addressing the research questions through a survey distributed to faculty at the University of Montana and Montana State University. These are the two doctoral granting institutions in the state of Montana and have significant research and sponsored programs activity and an expectation of their faculty to be research active. Tenured and tenure track faculty were surveyed using an instrument administered online. The data analysis techniques used to answer the research questions were descriptive statistics and negative binomial regression.

Operational Definitions

Below are definitions of the variables and constructs examined in this study.

Interdisciplinary

The National Academy of Sciences defines interdisciplinary research as

> "… a mode of research by teams or individuals that integrates information, data, techniques, tools, perspectives, concepts, and/or theories from two or more disciplines or bodies of specialized knowledge to advance fundamental understanding or to solve problems whose solutions are beyond the scope of a single discipline or area of research practice." (2005, p. 2)

For this study, participants were asked to delineate interdisciplinary collaboration based on this definition and whether or not their collaboration is with someone from a discipline that they would not consider their own.

Research Productivity

Research productivity is measured by the products of the collaborative dyad over the previous two years. In this study, research productivity was operationalized to include grant proposals, published works, and conference presentations. The window of two years for faculty productivity has been used in a number of studies looking at faculty and seems to capture this variable as well as a longer time frame (Fairweather, 2002; Porter and Umbach, 2000).

Discipline

The discipline of the faculty member is defined as the field which most closely matches the courses or department in which they teach. Porter and Umbach (2000) found that the teaching field more closely represents the faculty member's discipline than a description of their research.

Academic Rank

Academic Rank is the position in the tenure track which the individual holds at the point in time that they take the survey. This choices are Assistant, Associate or Full Professor.

Gender Homophily

"Homophily" is defined as the tendency of individuals to associate with others of the same kind (McPherson, Smith-Lovin, and Cook, 2001). In my study, gender homophily refers to whether or not the faculty member answering the survey and their identified collaborator are the same gender. This term and variable were used by Jha and Welch (2010) who examined the homophilous and heterophilous contributors to multifaceted collaborative research production by faculty members.

Rank Homophily

Like gender homophily defined above, rank homophily refers to if the faculty member answering the survey and their identified collaborator are the same academic rank. Termed "status homophily" by Jha and Welch (2010), this looks at the similarity or difference in faculty rank of the dyad.

Disciplinary Homophily

Disciplinary homophily in this study refers to the similarity of the two disciplines of the collaborators as categorized by Biglan's subject matter classification discussed earlier in this chapter.

Collaborative Dyad

The faculty member answering the survey and their self-identified collaborator make up the collaborative dyad. Because the study is looking at collaborative research productivity, it requires the study of productivity from at least two individuals. While collaborations can occur between multiple individuals, the direct co-operation between at least two individuals is the fundamental unit of collaboration (Katz and Martin, 1997) and was used for simplicity and ease of data gathering. The characteristics and research productivity of this unit (i.e. dyad) are the subject of the study.

Control Variables

Control variables in this study include the institution of the respondent. Other control variables that contribute to a dyads' productivity include the teaching load of the faculty member, the number of children they have, the years since their doctorate, and their individual productivity, however, these were not examined in this study.

Assumptions

In this study I assume that faculty at the institutions surveyed conduct research that leads to research products. I also assume that if they identify a collaborator in another discipline for the survey, they know that person's gender, academic rank and discipline. I assume that they completed the survey in an honest way and that the results at the point when I conducted the survey are similar to other points in time and therefore generalizable. Research productivity was measured based on self-reported data. Previous studies have found that this is a valid measure of this variable and compares with results

found through other, non-self-reported means (Allison and Stewart, 1974; Fox and Faver, 1985).

Limitations

Limitations of the study include issues with conducting online surveys and gathering responses from people who might be more comfortable with that format, versus those who may not be comfortable with it. This personal preference, which may be age-related, could impose a self-selection on who completes the survey. I surveyed faculty from only two institutions and asked about one collaborative relationship among the faculty members. The survey also looked only at a collaboration between two faculty members, although I acknowledge that collaborations that lead to research products often occur between faculty members and non-faculty members. This is a voluntary study so it could disproportionately represent a certain type of collaboration or discipline. The definition of interdisciplinary is fluid and participants' responses are dependent on their own interpretation.

Delimitations

For the purposes of keeping data collection and analysis manageable, I collected data from two institutions. I also looked at tenured and tenure track faculty only and one interdisciplinary collaborative dyad per faculty member. While faculty may have multiple collaborations, I asked them to focus on one specific collaboration with another tenured or tenure track faculty member about which to answer the survey. This may not

capture the breadth of collaborations a faculty member may have nor the most productive research collaboration.

Chapter Summary

The interface of disciplines is where one may find solutions to global or societal issues and is of interest to institutions of higher education. Since it is at the individual faculty member level where these interactions and collaborations occur, a greater understanding of the characteristics of the faculty dyads that are productive collaborators may allow administrators and decision makers to promote practices and policies that support and encourage interdisciplinary work. This study examined this issue through quantitative survey research methodology.

CHAPTER TWO

REVIEW OF RELATED LITERATURE

Introduction

"Publish or perish" is the mantra of faculty throughout academia. Referring to the need for recognized accomplishments of original scholarly or creative work, this succinct advice still has merit for the faculty member hoping to succeed in academia today. It is not enough just to produce original scholarly work, but the recognition that comes with it through peer-reviewed publication is a requisite to success and often continued employment. In the increasingly tight market for faculty in higher education, the rewards of tenure and promotion, and even attainment of a tenure track position are often determined by the record of scholarly productivity of the individual (Boice, 2000). This emphasis on scholarly productivity as a measure of success is not new in higher education, and is indeed part of a recognized way of evaluating faculty members and their contributions to the creation and dissemination of new knowledge. Factors at the individual, institution, and organizational level influence the productivity of the individual faculty member and studies on many of these components have been conducted. My study attempts to inform and add to our current understanding of the influence of factors on research productivity, particularly interdisciplinary research productivity, with a review of the literature about research productivity following.

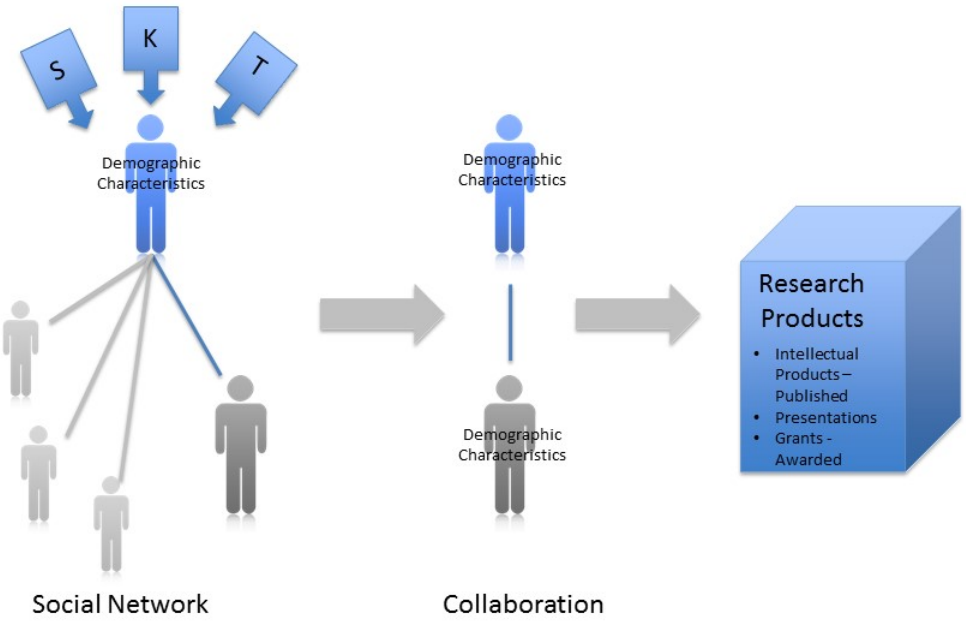
A faculty member's productivity does not occur in a vacuum, but is influenced by disciplinary norms (Fairweather, 2002; Jansen, von Gortz, and Heidler, 2010; Porter &

Umbach, 2000; Baird, 1991), institutional constraints (Fox and Mohapatra, 2007;), and structural opportunities (Leahey, Crockett and Hunter, 2008;Webber, 2011). Another factor that influences productivity is the extent of collaboration in which the researcher engages. According to social network theory, increased productivity through collaboration is possible because of the actual and potential resources embedded in a relationship (Nahapiet and Ghoshal, 1998). Empirical research has come to the same conclusions. Using social network analysis, a number of studies have found that individuals who collaborate have been shown to be more productive than those who work alone (Hou, Kretschmer and Zeyuan, 2008; Defazio, Lockett, and Wright, 2009; Abbasi, Altmann, & Hossain, 2011), perhaps because of the increased access to knowledge, tools, and resources that collaboration brings. Federal agencies have also recognized the benefits of collaboration, particularly across disciplines, that faculty may bring to bear on a research question or problems, by increasing their emphasis on interdisciplinary collaboration in their funding mechanisms and research priorities (Collins, et al, 2014). The relationship between these factors of faculty resources, social network and research productivity is depicted in Figure 2.1.

This chapter will explore the current literature on and the state of interdisciplinary research by faculty in higher education. I will also look at social network theory as it relates to faculty in higher education and how it affects the resources and knowledge the faculty member may have access to which influences their productivity. Finally, I will review the literature and empirical research on factors influencing research productivity of faculty, particularly those variables that I will be addressing in my study: gender, rank,

and discipline.

Figure 2.1: Conceptual framework for the study showing the relationship between the social network of a faculty member, the resulting collaboration and consequent research products. S=Skills, K=Knowledge, and T= Tools.



What is Interdisciplinarity?

The organization of areas of knowledge can be traced back to Aristotle who categorized knowledge into the theoretical, the practical and the productive. While higher education in the United States started out with a generalist model in the colonial period, it moved toward an organization by departments as universities grew and new disciplines emerged. In 1869 the President of Harvard University, Charles Eliot, cemented the predominant structure of higher education when he developed the first curricular major (Thelin, 2004). The curricular structure, the rise of professionalism in academic disciplines, and overall growth of the University organization led to the current structure

of most institutions of higher education organized by departments and colleges. This structure has worked as a way to organize knowledge within higher education (Gumport, 2007). The challenge to the existing structure comes when knowledge is created or pursued at the boundaries of existing disciplines, thus being "interdisciplinary" and not fitting neatly into the existing structures of higher education. The interface of disciplines is where one may find solutions to global or societal issues and indeed, there has been growth over the past few years in the number of departments at higher education institutions and the amount of federal funding awarded for research centers and multi-investigators grants (Brint et al, 2009; National Academy of Sciences, 2005). For example, the NIH Roadmap of 2004 was an initiative aimed at bringing together multiple agencies and disciplines to accelerate medical research. Interdisciplinary research initiatives were part of the original roadmap, and although eventually these were phased out to individual Institutes, this initiative did have the impact of changing the multi-principal investigator policy at NIH, thus emphasizing the role of interdisciplinary research (Collins et al, 2014).

Even with all of this attention on interdisciplinary scholarship in higher education, the question of "What is interdisciplinary research?" has become more complex in recent years. Attempts to define interdisciplinary research have looked at a continuum of multi, inter-, and trans-disciplinary research, and disciplinary versus non-disciplinary research in which faculty may place themselves or their work (Meeth, 1978; van der Besselaar & Heimeriks, 2001). Meeth (1978) defines multi, -inter, and –trans disciplinary based on how the problem is approached. Multidisciplinary involves several disciplines focused

on one problem or issue while a transdisciplinary approach starts with the issue or problem and brings in disciplines as needed to solve it. Like multidisciplinary work, interdisciplinary starts with the disciplines. In an attempt to start from a common definition, the National Academy of Sciences published its own comprehensive definition and report, which drew on interviews and surveys of researchers and administrators across the country.

The National Academy of Science defines interdisciplinary research as

> "… a mode of research by teams or individuals that integrates information, data, techniques, tools, perspectives, concepts, and/or theories from two or more disciplines or bodies of specialized knowledge to advance fundamental understanding or to solve problems whose solutions are beyond the scope of a single discipline or area of research practice." (2005, p. 2).

Many of today's scientific problems are more complex than a single discipline. Those issues at the interface of disciplines are where some of the most compelling research questions are, so it necessitates communication and cross-disciplinary interaction between faculty. The reward for the institution exists as well. In times of budget cuts and leaner funding, many universities look toward the calls for research centers and initiatives that will build a new research area which could possibly lead to sustainable funding (National Academy, 2005; Sa, 2008). The decline of traditional sources of funding for higher education is increasing the dependence by many research universities on other sources of income, including external grant funding (Wellman, 2008; Goldstein, 2005). At the same time, the competition for federal research dollars is becoming more intense with a proposal funding rate in 2011 of 18% for the National Institutes of Health and 22% for the National Science Foundation (Kaiser, 2012; NSF,

2012). Attracting and retaining faculty who can successfully garner external funding is becoming increasingly important to institutions of higher education both for alternative funding and maintaining their reputation, such as a Carnegie Very High Research Activity classification (Wellman, 2008).

Issues Associated with Interdisciplinary Research

The importance of external funding to an institution is important both as a source for additional income, and for institutional prestige (Ali, Bhattacharyya, & Olejniczak, 2010; Ryan, Healy, & Sullivan, 2012). For example, the Carnegie classifications of doctorate-granting Universities include sub-classifications based on the amount of research activity at the institution (http://carnegieclassifications.iu.edu/). The documented drift of more institutions into the doctorate and research granting classification of the Carnegie Classifications from the classifications that don't include awarding doctorates or having a certain level of research funding, indicates the aspirational nature of institutions and the importance of these metrics (Aldersley, 1995). As funding opportunities increase for interdisciplinary research, universities see this as a way to bring in more external funding, thus increasing their resources and prestige as a university known for research.

Ali (2010) found that institutional characteristics (i.e. private vs. public and AAU member vs. non-member) tend to play a significant role in affecting the dollar amount of grants received. Public institutions tended to receive more grants and AAU member institutions received larger amounts than non-member institutions. In the current study, the two institutions under study, The University of Montana and Montana State

University are public, AAU member institutions, so it is expected that receiving grants is a priority of the institutions.

The trend in higher education toward interdisciplinarity is both natural and practical. It allows the universities to respond to changing student interests, and be more appealing to faculty who bring in outside funding. Conn and colleagues described the link between creating a culture of research at one institution and recruiting and retaining faculty who are interested in that culture (Conn, Porter, McDainel, Rantz, & Maas, 2005). They describe the importance of a culture of research built through providing support structures for grant writing, faculty development, and expectations of external funding on recruiting and retaining faculty who could sustain and build this culture. At the same time, this success creates competition for faculty with external funding. In the increasingly tight faculty hiring market, the amount of external funding a faculty member has is one variable that makes them likely to leave an institution (Ryan, Healy, and Sullivan, 2012).

It is the individual faculty member who is engaged in the interdisciplinary research process, bringing their knowledge, skills and resources to the table for collaboration. The National Academy of Science definition of interdisciplinary research asserts that it is a process, not a domain and therefore covers multiple subject areas (Youngblood, 2007). The value of an individual faculty member as a collaborator can be assessed by another faculty member based on the language, tools, and paradigms that they bring to the collaboration. This “social capital” of the faculty member might explain why particular faculty members are valuable as collaborators.

Social Capital and Network Theory

Collaboration has been found to be an effective way to broaden access to resources and expand the knowledge base of individuals. Studies on "social capital" have looked at the value of relationships between individuals and how they may affect such things as productivity in academia. If knowledge is created through combinations and exchanges, which are facilitated through interactions, then those individuals who have more social capital would have more opportunities for knowledge creation (Nahapiet and Ghoshal, 1998). This translates into more productivity for those scientists with greater social capital than their isolated colleagues (Rotolo and Petruzelli, 2013).

Dietz (2000) argues that the research capacity of interdisciplinary collaboration comes from the social capital that scientists build through networks of research and collaboration. These networks often give scientists access to new research avenues, expertise, equipment, and knowledge that can grow the research capacity of the scientist and the institution (Bozeman, Dietz, & Gaughan, 2001; Dietz, 2000), which lead to greater research productivity. The breadth of these networks is described by Granovetter as strong or weak ties (Granovetter, 1973). A network of weak ties expands an individuals' access to people dissimilar to themselves as these people are generally outside of the individual's group (Granovetter, 1973). An individual with strong ties to another who has numerous weak ties therefore has a broad network upon which to draw on for collaborations.

Variables

In an effort to understand the relationship between the variables under study and interdisciplinarity, the following section presents information about the empirical research to date on the relationship of the variables under study and interdisciplinarity.

Research Productivity

The role of faculty in higher education institutions with a research mission generally includes teaching, service and research. Organizational theorists suggest that in institutions such as higher education where there is not a specific product and it is difficult to measure success, goals come from aspiring to emulate other successful institutions (DiMaggio and Powell, 1983; Meyer and Rowan, 1977) and the institutional capacity to achieve these aspirations comes from the faculty who conduct research, teach and serve. Faculty contribute to this institutional capacity by producing the research products that will move an institution toward its more successful exemplar.

Despite its central role in review of faculty, there is no one agreed upon measure for assessing faculty research productivity and measures of productivity vary by discipline (Baird, 1991; Webber 2011), type of institution, and individual characteristics (Ito and Brotheridge, 2007; Stack, 2004). Factors found to influence productivity include gender, academic rank and discipline, but even these are dependent on a variety of influences, and are not simple to parse out into specific effects. There is also the question of the length of time over which to measure research productivity. Some studies use a 5-year window for research productivity, acknowledging that some fields, particularly in the humanities, take longer to produce, but most studies look at a two-year window of

research productivity, which is what I used as well.

Independent and Dependent Variables

Gender

Of the variables I am examining, the relationship of gender on research productivity has the largest body of empirical research. The primary literature on research of gender and research productivity are summarized below in Table 2.1.

Table 2.1 Literature review summary on Gender and Research Productivity

Citation	Research Questions	Findings
Gender Differences in Productivity - Women Lower		
Bellas, M. L., & Toutkoushian, R. K. (1999). Faculty time allocations and research productivity: gender, race, and family effects.	Examined whether faculty differ across gender, racial/ethnic, and family status groups in how they spend their time, and (b) the extent to which any differences help explain intergroup variation in faculty research productivity.	Males have higher levels of productivity than women across a broad definition of productivity - not just publications. More than half to 3/4 explained by other variables in the regression model, such as teaching load and time spent on research. Women are more represented in lower ranks of faculty so also lower ranks of faculty less productive.
Fox, M.F. and Mohapatra, S. (2007). Social-organizational characteristics of work and publication productivity among academic scientists in doctoral granting departments.	What are the effects on publication productivity of 1) team composition 2) collaboration, and 3) work practices.	Male gender positively correlated with higher numbers of articles published in the disciplines studied.
Grapin, S. L., Kranzler, J. H., & Daley, M. L. (2013). Scholarly Productivity and Impact of School Psychology Faculty in APA-Accredited Programs.	A normative study of the research productivity and scholarly impact of faculty in school psychology programs	Men published statistically significantly more publications and had more citations than women in their discipline.
Keim, M. C. (2008). College student affairs preparation program faculty: who publishes and what do they publish?	What is the research productivity of faculty in college student affairs preparation programs and are there differences in gender and rank?	Men in student affairs had statistically significant more publications than women in student affairs

Table 2.1(continued)
Literature review summary on Gender and Research Productivity

Citation	Research Questions	Findings
Long and Fox. (1995). Scientific careers: universalism and particularism.	Purpose was to gain a better understanding of stratification in science by race/ethnicity and sex reviewing a number of studies	Lower publication rates of female scientists compared to male scientists.
Webber, K.L. (2011). Factors related to faculty research productivity and implications for academic planners: planners must align the emphasis on research and scholarly products with overall institutional mission.	What individual factors contribute to research productivity? (rank, gender, marital status, having children, % of time spent on research, & credit hours in teaching). Do differences occur by discipline and type of institution?	Overall females produce fewer non-refereed articles, book reviews and chapter than males, but they produce similar numbers of reviewed articles and scholarly publications. There is some interaction effect, for example, female faculty in physical and life sciences produce less than their male counterparts.
Jha, Y. & Welch, E.W. (2010). Relational mechanisms governing multifaceted collaborative behavior of academic scientists in six fields of science and engineering.	How do relational attributes of social capital within a scientists professional networks predict multifaceted collaboration?	Individuals who produce more grant submission are more likely to be involved in multifaceted collaboration. Gender homophily is negatively related to multifaceted collaboration regardless of whether men or women. Peer status dyads less likely to engage in multifaceted collaboration.
Rhoten, D. and Pfirman, S. 2007. Women in interdisciplinary science: Exploring preferences and consequences.	How do the learning styles, work preferences, and career behaviors affect interdisciplinary collaboration by men and women?	Women have more collaborators than men. Especially when participating in knowledge producing activities such as writing papers, articles and presentations. Women are more likely to engage in interdisciplinary research than men.

The research on gender and productivity shows that in the traditional measures of journal publications males are more productive, however, when other types of productivity are measured, this finding does not necessarily hold up. This was true for studies looking at a broad range of disciplines (Allen, 1997; and Webber, 2011) and for studies that were more discipline-specific. Specifically, studies on productivity by gender and discipline including science, school psychology, sociology and linguistics, and student affairs also supported this with male faculty producing more research

publications (Fox and Mohaptra, 2007; Grapin, Kranz, and Daly, 2013; Keim, 2008; Leahey, Crocket & Hunter, 2008; Long & Fox, 1995; Sonnert & Holton, 1995). Some of these studies were qualified with the affect of gender possibly mediated by something else. For example, there is an effect of rank which cannot by ignored and deeper study of its effect with gender by Joy (2006) showed that males tend to publish more than females pre-tenure, but women increase their publication rates as their career progresses. This historical gender gap may also be shrinking as it did between the 1960's and 1990's (Xie and Schaman, 1998).

With the growth of interdisciplinarity, more recent studies have looked at whether or not there is a relationship between gender and collaboration across disciplines. Some of the psychology of gender literature argues that women may be more inclined toward collaborative work, but the empirical research on rates of scientific collaboration do not show that women are more collaborative than their male colleagues (Corley, 2005; McDowell et al, 2006). It has been suggested that this may be due to the lack of access to formal and informal networks and opportunities that men have. Rhoten and Pfirman (2007) looked specifically at the relationship of gender to interdisciplinary collaboration and proposed four mechanisms of interdisciplinary science. These four include (1) cross-fertilization; (2) team-collaboration; (3) field creation; and (4) problem orientation. Rhoten and Pfirman's research found that women were more likely than men to engage in interdisciplinary collaboration through these mechanisms. While the study didn't look at productivity, it does suggest that gender can play a role in the entrée into interdisciplinary collaboration. One of the studies conducted through a self-reported study, looking at

research productivity and gender of a collaborative team found that whether it was women or men, collaborative pairs of the same gender were less productive than research pairs of different genders (Jha and Welch, 2010). My study built on this research since it looked at the productivity of women and men engaged in interdisciplinary research and the gender profile of the collaborative dyad.

Academic Rank

As mentioned previously, academic rank also has an effect on the research productivity of faculty. Empirical research studies on academic rank and research productivity are summarized below in Table 2.2.

Table 2.2: Literature Summary on Academic Rank and Research Productivity

Citation	Research Questions	Findings
Higher Ranks More Productive		
Bellas, M. L., & Toutkoushian, R. K. (1999). Faculty time allocations and research productivity: Gender, race, and family effects.	Do faculty differ across gender, racial/ethnic, and family status groups in how they spend their time, and (b) what is the extent to which any differences help explain intergroup variation in faculty research productivity?	Faculty with higher rank are more productive.
Bozeman & Corley. (2004). Scientists' collaboration strategies: Implications for scientific and technical human capital.	How does collaboration affect scientists science and technology human capital?	Longer tenured researchers have developed more scientific and human capital that makes them attractive as collaborators.
Byrnes and McNamara. (2001). Evaluating doctoral programs in the developmental sciences.	What is the productivity of the faculty associated with a given program?	In the developmental sciences, asstistant professor publish mean of 0.81 publications per year; associate 1.19 and full 2.31.
Dundar & Lewis (1998). Determinants of research productivity in higher education.	What are the individual, institutional and departmental attributes that contribute to research productivity? Aggregated data by field clusters of disciplines not specific departments	Departments with higher percentage of full professors were more productive.

Table 2.2 (continued):
Literature Summary on Academic Rank and Research Productivity

Citation	Research Questions	Findings
Keim, M. C. (2008). College student affairs preparation program faculty: Who publishes and what do they publish?	What is the research productivity of faculty in college student affairs preparation programs and are there differences in gender and rank?	Professors in student affairs had statistically significant more publications than other faculty ranks in student affairs.
Tien, F. F., & Blackburn, R. T. (1996). Faculty rank system, research motivation, and faculty research productivity: Measure refinement and theory testing.	Does promotion and to what extent, motivate faculty research behavior?	Full professors publish more research than assistant and associate, but associate professors do not produce more than assistant. Asst professors show least variation in productivity. Avg. number of publications was 1.83 for asst. 1.79 for associate and 2.27 for full
Webber, K.L. (2011). Factors related to faculty research productivity and implications for academic planners: planners must align the emphasis on research and scholarly products with overall institutional mission.	What individual factors contribute to research productivity? (rank, gender, marital status, having children, % of time spent on research, & credit hours in teaching).	Full professors are more productive across all measures of productivity (referred journal articles, books, textbooks, presentations, non-refereed articles).
Other Ranks Higher Productivity		
Baldwin, R. G., Lunceford, C. J., & Vanderlinden, K. E. (2005). Faculty in the Middle Years: Illuminating an Overlooked Phase of Academic Life.	Do faculty in mid-career differ from colleagues at other career stages? Do some characteristics of faculty in mid-career define them more than others?	Faculty productivity varies by faculty career stage - high productivity in midlife and lower in late career and early career. faculty in hard disciplines publish more articles, faculty in soft disciplines publish more books
No Difference Based on Rank		
Grapin, S. L, Kranzler, J.H. and Daley, M. L. (2013). Scholarly Productivity and Impact of School Psychology Faculty in APA-Accredited Programs.	A normative assessment of research productivity of faculty in school psychology programs	Average school psychology faculty member published one publication per year and the most prolific published up to 8 per year. No differences in rank.

A comprehensive study of faculty from research, doctoral granting and comprehensive institutions showed that full professors are the most productive, followed

by assistant professors and then associate professors (Tien & Blackburn, 1996). This study examined data from a national survey of over 2500 faculty and used a two-year reporting period to measure the research productivity of faculty. The average number of publications was 1.83 for assistant professors, 1.79 for associate professors and 2.27 for full professors. Publication rates for assistant professors had the least variability among the ranks. The dip in productivity in the associate professor rank may be due to the attainment of tenure, since the academic reinforcement goal the faculty aspired to was achieved (Tien, 2007). However, other studies have not necessarily seen this dip in the associate professor rank but have shown a linear increase in research productivity as rank increases (Bellas & Toutkoushian, 1999; Dundar & Lewis, 1998). For example, a 2001 study by Byrnes and McNamara of faculty in the developmental sciences found that full professors were the most productive, followed by associate and then assistant professors (Byrnes and McNamara, 2001). This study was limited to faculty in graduate programs of developmental sciences (developmental psychology and human development) and found that the average number of publications for assistant professors was 0.81, for associate professors was 1.19 and for full professors was 2.31. These results were obtained by looking at citations in databases by faculty in the 97 identified graduate programs over a seven-year period. The longer time frame examined may account for the differences in results between the two studies.

Other studies have produced contradictory results regarding research productivity and rank with a number pointing to the negative effects of age, that is, the older you get the less you publish (Levin & Stephan, 2001; Porter & Umbach, 2001; Smeby & Try,

2005; Baldwin, Lunceford and Vanderlinden, 2005) and others saying there is not a linear relationship between research productivity and rank (Grapin, Kranz, and Daley, 2013), although this particular study was limited to one discispline. One study on Psychology faculty did find that while there was no difference in productivity based on rank, the productivity of the individual was consistent, suggesting that it isn't the rank that makes a difference in productivity, but intrinsic motivators of the individual (Joy, 2006).

The above review suggests that the empirical research generally supports that the higher the rank, the greater the research productivity. It seems, however, to be influenced by other factors such as gender and discipline, which I am also considering. Jha and Welch (2010) examined the rank of a research dyad on multifaceted research collaboration and found that dyads of the same rank were the least productive. Their study was based on a two-year time frame and used a self-reported survey on products of the dyad for data gathering. My study is similar to this research, but included the interdisciplinary component on the research productivity of the dyad, thus providing some useful information on the question of if the rank of a pair of researchers impacts research productivity.

Discipline

That the research productivity of faculty varies by academic discipline is consistently borne out in empirical research (see Table 2.3). Some disciplines tend to produce more peer refereed journal articles or presentations, while others produce more books or chapters and it is within this social context that a faculty member works. The literature on discipline and research productivity is summarized in Table 2.3

Table 2.3 Literature Summary on Discipline and Research Productivity

Citation	Research Questions	Findings
Empirical Evidence Showing Differences in Research Productivity		
Baird, L. L. (1991). Publication productivity in doctoral research departments: Interdisciplinary and intradisciplinary factors.	What mix of people and resources leads to high productivity in a discipline?	Some disciplines had much higher publications rates than others. There were significant differences in mean publications and range of publications by discipline.
Dundar and Lewis. (1998). Determinants of research productivity in higher education.	What are individual, institutional and departmental attributes that contribute to research productivity?	Considerable productivity differences in the fields examined (biological sciences, engineering, physical sciences & mathematics, social sciences). Measure of research productivity was journal articles only, which is a limitation.
Specific Disciplinary Differences		
van Rijnsoever and Hessels. (2011). Factors associated with disciplinary and interdisciplinary research collaboration.	Which characteristics of researchers are associated with disciplinary and interdisciplinary research collaborations and which type of research collaborations are most rewarding in different scientific discipline?	Researchers in basic discipline (i.e. pure - in Biglan) engage less in IDR than researchers in strategic (applied) disciplines.
Baldwin, R. G., Lunceford, C. J., & Vanderlinden, K. E. (2005). Faculty in the middle years: Illuminating an overlooked phase of academic life.	Do faculty in mid-career differ from colleagues at other career stages? Do some characteristics of faculty in mid-career define them more than others?	Faculty in hard disciplines publish more articles, faculty in soft disciplines publish more books.
Jansen, D., von Gortz, R. & Heidler, R. (2010). Knowledge production and the structure of collaboration networks in two scientific fields.	Is scientific productivity in new and/or established scientific fields dependent on different types of underlying research collaboration networks?	The advantage of types of networks (i.e. closed or not depends on the discipline. Closed networks are better for paradigmatic (i.e. pure) disciplines. Applied disciplines benefit more from networks with more holes where they can access other knowledge.

Table 2.3 (continued) Literature Summary on Discipline and Research Productivity

Citation	Research Questions	Findings
Webber, K.L. (2011). Factors related to faculty research productivity and implications for academic planners: planners must align the emphasis on research and scholarly products with overall institutional mission.	What individual factors contribute to research productivity? (rank, gender, marital status, having children, % of time spent on research, & credit hours in teaching).	Life and physical sciences produce twice as many refereed articles as faculty in other disciplines and one-third as many presentations. There are differences across disciplines in types of products produced and numbers.

The academic discipline of a faculty member is an important contributing factor in a faculty member's research productivity as Porter and Umbach (2000) argue that faculty within an academic discipline more closely resemble each other than faculty in other disciplines. Differences in the nature of research in academic disciplines inevitably will result in differences in research productivity measures. There is some research on interdisciplinary research that indicates applied fields are more likely to engage in interdisciplinary research (van Rijnsoerver and Hessels, 2011) but in a study of Italian higher education systems, Abramo, G., D'Angelo, C.A. and Di Costa, F. (2009) found the opposite – basic research is more collaborative than applied.

According to Biglan's classification of discisplines, the applied versus pure dichotomy of disciplines would indicate that subjects such as Engineering and Education are more likely to participate in interdisciplinary research than pure fields such as Geology and Philosophy. For the hard-soft dichotomy, Biglan described the 'hard' fields as having a paradigm (i.e. Chemistry or Physics) versus those without a paradigm such as History or English. Biglan conducted a follow up study and found that social connectedness was higher in hard, pure subjects and applied, soft subjects (Biglan,

1973b). The implications from this research indicate that in certain subjects interdisciplinarity is a more natural way of doing research.

In their study of astrophysics and nanoscience researchers, Jansen, von Gortz and Heidler (2010) examined the social networks of these two fields which differ in their age, modes of knowledge production, and approach. Their study consisted of a citation index study and social network analysis of researchers in astrophysics and nanoscience, two fields at opposite ends of the pure-applied, or paradigmatic, non-paradigmatic spectrum. By analyzing the numbers of international papers and the social networks of researchers in these fields, they found that the applied field (nanoscience) benefited more from the interdisciplinary collaborative network.

Empirical studies have shown that research collaboration is positively associated with productivity (Abbasi, Altmann, and Hossain; 2011; Cimenler, Reeves, and Skvoretz, 2014). Looking at one discipline across five institutions, Abbasi and colleagues (2011) found that research performance of scholars who collaborated, particularly multiple times with a few people was greater than that of scholars who did not. Following up on this study, Cimenler, Reeves and Skvoretz (2014) looked at the impact of the social network of researchers on not only citations, but patents and grant proposals and affirmed the results of Abbasi, Altmann and Hossain with this expanded measure. One of the motives cited for collaboration is to encourage cross-fertilization across disciplines (Katz & Martin, 1997; Melin, 2000). Indeed, Salaran (2010) found that research productivity could be predicted through regression analysis from social interactions of individuals. Using a survey administered to academics in five Australian universities, Salaran looked

at research productivity as measured by publications over the previous three years and the amount of time they spent per week with their social networks. A standard regression analysis showed that the independent variable of social interaction contributed significantly to the dependent variable of research productivity in this study.

The empirical research described above shows that discipline does indeed make a difference in research productivity. Whether or not interdisciplinary collaboration makes a difference is less studied and shows mixed results. My study can add to this body of knowledge by specifically categorizing the discipline of the faculty member responding to the survey according to Biglan's dichotomies.

Collaboration

The effect of collaboration on research productivity has been studied generally by looking at the publications or co-authorships of faculty involved in a collaboration. In science disciplines, collaboration leads to higher productivity of the researcher, and indeed is a predictor of research productivity (Lee & Bozeman, 2000). Lee and Bozeman's study looked at the curriculum vitae of faculty in addition to a survey of faculty to determine the extent of collaboration and research productivity over a two-year period and measured both the normal count of publications by a faculty member and a fractional count (dividing each paper by the number of co-authors). The normal count was significantly higher for faculty who collaborated, but the fractional count was not, indicating that there may be types of collaborations that are more productive than others. Specifically in neurosciences, gastroenterology and cardiovascular systems collaboration is positively correlated with increased productivity (Bordons, M., Gomez, I., Fernandez,

M.T., Zulueta, M.A., and Mendez, A. 1996). Collaboration with those outside of academia also leads to increased research productivity (Landry, Traore, and Godin; 1996).

However, empirical studies on the impact of disciplinary or interdisciplinary collaboration on research productivity have shown mixed results. Van Rijnsoever and Hessels (2011) found that disciplinary collaboration rather than interdisciplinary contributes more to career development and that there was no advantage in terms of citation frequency in a multidisciplinary field (Bartuch & Hie, 2010). Porac et al (2004) looked at disciplinary homophilous and heterophilous collaborative groups. In comparing publication outcomes of these two groups, they found that the heterophilous groups had greater productivity. Another study looking at a different outcome had contradictory results. Pull et al (2015) examined the completion rate of PhD students and found that heterogeneity in natural sciences led to less productivity (i.e. PhDs finishing) than a more homophilous group in the computational sciences. One explanation may be that while departments are necessary for tools, techniques and trainings, interdisciplinary work often creates its own vocabulary, organizations and language, which can hinder productivity (Jacobs, 2009).

Chapter Summary

The growth of interdisciplinarity in higher education is not likely to diminish given the factors that are influencing the increase in new disciplines and new areas of study. This growth naturally leads to interactions of faculty from different disciplines and an interest in examining questions and problems at the interface of these disciplines. These

collaborations may lead to research products, which are generally measured by publication counts. The literature on research productivity points to a number of factors than can influence it including gender, rank, and discipline. An examination of these factors and the collaborations between faculty of different disciplines on the research productivity of the faculty member is the goal of this study, which has been designed and informed by the literature reviewed above.

CHAPTER THREE

METHODOLOGY

Introduction

In higher education, interdisciplinary collaboration between faculty members is becoming more common as funding opportunities and societal problems present themselves at the interface of traditional disciplines. There has been growth over the past few years in the number of departments at higher education institutions and the amount of federal funding awarded for research centers and multi-investigators grants, suggesting that higher education institutions have responded to this interest and need (Brint et al, 2009; National Academy of Sciences, 2005).

The growth in interdisciplinarity includes research collaboration between researchers, which can lead to publications, presentations, and grant proposals. Indeed, some empirical research has shown that faculty who collaborate tend to be more productive as measured by the number of publications they produce (Jansen, von Gortz and Heidler, 2010; Rotolo and Petruzelli, 2013). At its roots, this trend toward interdisciplinarity is both natural and practical. It allows the universities to respond to changing student interests, and on the research side, faculty can examine problems that are at the interface of disciplines where there are many interesting and unanswered questions.

Most of the research on interdisciplinary research has been conducted at the institutional level, looking at organizational and structural factors that contribute to

interdisciplinary success (Butler, 2011; Sa, 2008). A better understanding of the individual characteristics of faculty involved in interdisciplinary research can inform administrators about policies and practices that might encourage this practice. With this study, I attempt to address that gap by examining the characteristics of a collaborative faculty dyad on the productivity of the dyad.

The factors I studied (gender, rank and discipline) have been shown to have an influence on various measures of productivity by faculty. Women and men have different patterns of productivity depending on factors such as their rank, number of children, and discipline (Grapin, Kranz, and Daley, 2013; Long & Fox, 1995; Sonnert & Holton, 1995; Fox & Mohapatra, 2007; Leahy, Crockett & Hunter, 2008; Grapin, Kranz, and Daly, 2013; Keim, 2008). Most empirical research shows that faculty at the more senior rank (i.e. full professor) produce more than their junior level colleagues (Tien & Blackburn, 1996; Bellas & Toutkoushian, 1999; Dundar & Lewis, 1998). Applied disciplines tend to publish more than pure suggesting that certain disciplines will demonstrate more research productivity than others (Jansen, von Gortz and Heidler, 2010; van Rijnsoerver and Hessels, 2011). Considering the combination of these variables within a faculty dyad doing collaborative research broadly across disciplines has not been done and this study attempts to address that gap. This study also uses the home institution of the faculty member responding to the survey as a control variable.

From a research study of this type I would expect to determine the variables that influence interdisciplinary collaborative research productivity. That is, is there a particular profile of faculty dyads (i.e. research collaborators) that are more productive in

interdisciplinary collaborative research, and if so, institutions can use this information to be more purposeful in supporting interdisciplinary scholarship based on faculty needs and interests.

The research questions I address in this study are:

1. What types of research products are produced by interdisciplinary collaborative dyads of tenure track faculty?
2. Is there a relationship between gender homophily (i.e. same gender of researchers) and interdisciplinary collaborative research productivity for tenure track faculty dyads?
3. Is there a relationship between rank homophily (i.e. same rank of researchers) and interdisciplinary collaborative research productivity for tenure track faculty dyads?
4. Is there a relationship between discipline homophily of the dyad and interdisciplinary collaborative research productivity for tenure track faculty dyads?
5. What is the relationship among gender, rank, discipline and interdisciplinary collaborative research productivity for tenure track faculty dyads?

Research Design and Rationale

Quantitative survey research was used to investigate the productivity of faculty collaborative dyads and the demographic characteristics of that dyad including gender homophily, rank homophily, and disciplinary homophily. Research products examined were Intellectual Contributions – Published, Presentations, and Grants - Awarded. Data

were gathered through a survey of tenured and tenure track (T/TT) faculty at two similar research universities, the University of Montana and Montana State University. In the survey, faculty answered demographic questions about themselves, and then were asked to identify a primary research collaborator and answer the same demographic questions about that collaborator. Dependent variables of research productivity were then asked about this faculty dyad (the faculty member responding to the survey, and the collaborator they identified). The dependent variables were the types of research products such as grant proposals, publications, and presentations, and the count of research products. An experimental design was not possible given the relationship of the collaborations I studied and the necessity for the relationship to pre-exist.

Population, Sampling and Sampling Technique

The population for this study was tenured and tenure track faculty in all except the fine arts at Montana State University (MSU) and the University of Montana (UM) in the fall of 2015. The fine arts departments were excluded, as these disciplines were not included in Biglan's classification model of disciplines, which was the basis in this study for disciplinary classification (Biglan, 1973a, 1973b). Tenured and tenure track faculty are the group of faculty whose role description at doctoral granting institutions generally contains an expectation of research, so they are the individuals who were surveyed. After obtaining Institutional Review Board approval, email lists of the applicable faculty were obtained from the Office of Planning and Analysis (MSU) and the Office of Planning, Budgeting, and Analysis (UM).

The University of Montana and Montana State University were selected as the institutions from which to gather information because they are similar in that both are doctoral granting research institutions of similar size and demographic profile. Table 3.1 provides information about the two institutions and their student and faculty demographics. Montana State University is the land grant institution in the state with an undergraduate enrollment in the Fall 2015 of 13,707 and graduate student enrollment of 1981 students across eight different academic colleges (MSU Planning and Analysis website, www.montana.edu/opa/). With an expectation of research or creative experience for every undergraduate, there is a strong research influence on the campus. The student body is predominantly white (84%), male (54%) and from Montana (56%). As the land grant institution in the state, it has a more agricultural and engineering focus than the University of Montana, which has professional schools of journalism, law and pharmacology. The University of Montana student population is similar in size with a fall 2015 enrollment of 10,777 undergraduates and 2267 graduate and professional students. UM is predominantly white (75%), female (55%), and from Montana (71.8%) (Office of Planning, Budgeting and Analysis website, http://www.umt.edu/plan/documents/201570Census.pdf). Both schools offer undergraduate degrees in a variety of liberal arts disciplines. Tenure track faculty at both institutions are expected to participate in research, teaching and service.

Table 3.1 Comparison of the two institutions in the study

	Montana State University – Fall 2015	University of Montana – Fall 2015
Total Number of Students	15,688	13,044
Male	54%	45%
White	84%	75%
Total Number of Tenured/Tenure Track Faculty	565*	556**
Male	61%*	61%**
White	87%*	89%**
Research Expenditures	$87,806,094	$64,572,795

* 2014 – most recent year data available
** 2013 – most recent year data available

The total number of email addresses received from the two institutions was 830 with 436 from Montana State University and 394 from the University of Montana. A link to a Qualtrics© survey was sent to all of these email addresses with a cover email explaining IRB messages and the purpose of the survey. Four individuals responded that they were neither tenure-track faculty nor research active, so these were eliminated from the sample, making the total possible survey responses 826.

Sample Size and Characteristics

I used a census survey to gather data, which meant the survey was sent out to all eligible participants at the two institutions. The advantage of this type of sampling is that it gives all members of the population an equal chance of being sampled, therefore reducing the chance of bias in the sample. Eight hundred and thirty emails were sent out, with 266 responding for a 32.0% response rate. The response rate from the University of Montana was 22.1% and 34.4% from Montana State University. According to Sax, Gilmartin, and Bryant (2003), this is above average for a web-based survey with no

incentive for response. Since the survey was based on faculty dyads, it was possible that two individuals would report on the same collaborative faculty dyad. Two such cases were confirmed, so responses from one of the pair were randomly eliminated from the final sample. In addition, systematic incomplete survey responses were eliminated leaving the final complete survey sample at 207, for a usable response rate of 25 %. Table 3.2 shows the demographic characteristics of the sample.

Table 3.2 Characteristics of Survey Participants

	N	Frequency – MSU	Percent of Respondents – MSU	Frequency - UM	Percent of Respondents - UM	Pearson Chi-Squared test sig.
Gender	207	133	64.2	74	35.7	0.245
Male	129	79	59.4	50	67.6	
Female	78	54	40.6	24	32.4	
Rank	207	133	64.2	74	35.7	0.096
Full Prof	81	45	33.8	36	48.6	
Associate Prof	58	39	29.3	19	25.7	
Assistant Prof	68	49	36.8	19	25.7	
Discipline	207	133	64.2	74	35.7	0.028
Applied, Hard	26	23	17.3	3	4.1	
Applied, Soft	41	27	20.3	14	18.9	
Pure, Soft	48	31	23.3	17	23.0	
Pure, Hard	92	52	39.1	40	54.1	

As the only doctoral granting institutions in Montana, the two universities are similar in many ways, as seen in the similar demographics from Tables 3.1 and 3.2. The most significant difference is in the disciplines at each institution, as Montana State University is the land grant institution with an engineering and agricultural focus and the University of Montana has more liberal arts degrees. However, both are the doctoral – granting, research-focused institutions in the state. The focus of the study was to look at the research productivity of the faculty collaborative dyads, not the differences in the institutions, so the data were aggregated across the institutions. A chi-square analysis

was performed to determine whether respondents from Montana State University and the University of Montana were similarly represented across all ranks, disciplinary categories and both genders. The analysis produced a nonsignificant chi-square value for rank (χ^2 = 4.697, *df* = 2, *ns*) and gender (χ^2 = 2.070, *df* = 1, *ns*) indicating that neither Montana State University nor the University of Montana were overrepresented in either of the gender categories nor the three rank categories. In the distribution of responses by institution of the disciplinary quadrants, chi-square analysis produced a significant result (χ^2 = 9.076, *df* = 3, $p < 0.05$). As mentioned previously, it is disciplinary areas in which the two institutions were expected to differ. In the analysis, discisplines were aggregated along the soft-hard dichotomy, rather than having classifications along the soft-hard and pure-applied quadrants. This was done because of the low number of responses in some of the quadrants (*n* = 8) that made data analysis impractical. This data aggregation resulted in three disciplinary homophily categories (soft-soft, hard-hard, or opposite) rather than six categories (soft-applied, soft-pure, hard-applied, hard-pure, opposite, same) (See Chapter 4, analysis).

Instrument

A 34-question survey was administered to address the research questions (Appendix A). The survey consisted of four parts and was adapted from a previous study which examined research productivity of faculty dyads (Jha and Welch, 2002). The first series of questions addressed demographic information about the respondent and their research productivity. The second part of the survey asked the respondent to consider a single individual with whom they have collaborated in the last two years and answer the

same demographic questions. The third part was a list of research products and asked the respondent to indicate the numbers of the various products that have been produced with the individual they identified in part two of the survey. Part four of the survey contained descriptive questions about the reasons for collaborating and definitions of disciplinary collaboration. The independent variables of gender, rank and discipline were asked in the first and second parts and the dependent variables of research products and research productivity were gathered in the third part of the survey, where the respondent answered questions about their productivity as part of a faculty dyad. The survey was open for three weeks, with two email reminders sent to those that had not yet completed the survey at the beginning of weeks two and three in which it was open.

A pilot survey was conducted with three faculty at Montana State University in the Fall 2014 using a response processes interview design (Presser et al, 2004). They were given the instrument in a paper form and sat with the researcher providing feedback on the questions as they answered them. This allowed for timely and immediate feedback on the survey, which led to adjustments in the order of the questions, the wording of specific questions and addition and deletion of questions for clarity.

Table 3.3 lists the items on the survey that addressed the research questions. This table of specifications increases the internal validity of the survey in that it shows the link between the questions asked and the data gathered. The full survey is included in Appendix A.

Variables and Constructs

The variables used in this study are defined below. The dependent variables (DV) of Intellectual Contributions – Published, Presentations, and Grants – Awarded were count data. The independent variables (IV) are the gender homophily, rank homophily, and disciplinary homophily of the faculty members who make up the research dyad. Table 3.4 describes the coding used in analysis.

Collaborative Dyad

The faculty member answering the survey and their self-identified collaborator make up the collaborative dyad. Because the study is looking at collaborative research productivity, it requires the study of productivity from at least two individuals. While collaborations can occur between multiple individuals, the direct co-operation between at least two individuals is the fundamental unit of collaboration (Katz and Martin, 1997) and was used for simplicity and ease of data gathering.

Table 3.3 Table of Specifications

Research Question	Survey Questions to address this
1. What are the types of research products produced by an interdisciplinary collaborative dyad?	25-30. Questions about the number of research products produced by the interdisciplinary collaborative dyad (grant proposals, articles, publications, artistic exhibitions)
2. Is there a relationship between gender homophily of an interdisciplinary collaborative dyad (i.e. same gender of researchers) and research productivity of the dyad?	4. What is your gender? 21. What is the gender of your most significant interdisciplinary faculty collaborator? 27, 28 and 31. Questions about the number of research products produced by the interdisciplinary collaborative dyad (Intellectual Contributions Published, Presentations, Sponsored Research Awarded).

Table 3.3 (continued)

3. Is there a relationship between rank homophily (i.e. same rank of researchers) and interdisciplinary collaborative research?	2. What is your rank? 20. What is the relative rank of your most significant interdisciplinary faculty collaborator? 27, 28 and 31. Questions about the number of research products produced by the interdisciplinary collaborative dyad (Intellectual Contributions Published, Presentations, Sponsored Research Awarded).
4. Is there a relationship between discipline homophily and interdisciplinary collaborative research?	1. What is your primary academic discipline? 19. What is the primary academic discipline of your most significant interdisciplinary faculty collaborator? 27, 28 and 31. Questions about the number of research products produced by the interdisciplinary collaborative dyad (Intellectual Contributions Published, Presentations, Sponsored Research Awarded).
5. What is the relationship among gender, rank, discipline and interdisciplinary collaborative research?	1. What is your primary academic discipline? 2. What is your rank? 4. What is your gender? 19. What is the primary academic discipline of your most significant interdisciplinary faculty collaborator? 20. What is the relative rank of your most significant interdisciplinary faculty collaborator? 21. What is the gender of your most significant interdisciplinary faculty collaborator? 27, 28 and 31. Questions about the number of research products produced by the interdisciplinary collaborative dyad (Intellectual Contributions Published, Presentations, Sponsored Research Awarded).

Research Products (DV)

The dependent variable of research products was the types of products that are produced as evidence of scholarship or creativity. These products include (1) Intellectual Contributions – Published, which includes books, book chapters, conference proceedings, journal articles, technical reports; (2) Presentations, defined as paper, poster, reading of

creative work, exhibit, keynote, plenary address; and (3) Contracts, Fellowship, Grants and Sponsored Research – Awarded, which is abbreviated as Grants – Awarded. These specific products were measured because they are used in faculty annual reviews. Additionally, the Intellectual Contributions – Published constitutes a common metric of bibliometrics used to measure productivity among faculty (Borgman & Furner, 2002; Milesi, Brown, Hawkley and Dropkin, 2014).

Research Productivity (DV)

Research productivity was measured by the products of the interdisciplinary collaborative dyad over the past two years. The three types of research productivity used as measures in this study were those listed and defined above, that is, the number of Intellectual Contributions – Published, the number of Presentations, and the number of Grants – Awarded. The window of two years for faculty productivity has been used in a number of studies looking at faculty productivity and seems to capture this variable as adequately as a longer time frame (Fairweather, 2002; Porter and Umbach, 2000).

Missing cases on the dependent variable were assigned zeros based on imputation methods and after considering the patterns of responses and the survey design (Groves, Singer and Corning, 2000; Little, 1988).

Discipline (IV)

The discipline of the faculty member is defined as the field that most closely matches the courses or department in which they teach. Porter and Umbach (2000) found that the teaching field more closely represents the faculty member's discipline than a description of their research. Many research areas are specialized and faculty may see

themselves as being in more than one particular field, but the university structure is still generally siloed with academic departments reflecting the teaching area of the faculty member. The discipline was then categorized according to Biglan's disciplinary classification along the soft-hard axis (Biglan, 1973a). For disciplines that were not specifically named by Biglan, classification of disciplines was determined based on a follow-up study to Biglan's work in which more disciplines were classified (Drees, 1982). Three cases had no collaborator discipline listed and eight individual cases had disciplines that were not listed in either Biglan or Drees. Seven of these were able to be classified based on similarity to listed disciplines.

Academic Rank (IV)

Academic Rank is the position in the tenure track that the individual holds at the point in time that they take the survey and is one of Assistant, Associate or Full Professor.

Gender Homophily (IV)

"Homophily" is defined as the tendency of individuals to associate with others of the same kind. In my study, gender homophily refers to whether or not the faculty member answering the survey and their identified collaborator are the same gender. This term and variable were used in Jha and Welch (2010) who examined the homophilous and heterophilous contributors to multifaceted collaborative research production by faculty members. The gender homophily variable is "different gender", "male-male dyad", or "female-female dyad" which refers to the gender of the individual answering the questions and their chosen collaborator.

Rank Homophily

Like gender homophily defined above, rank homophily refers to if the faculty member answering the survey and their identified collaborator are the same academic rank. Termed "status homophily" by Jha and Welch (2010), this looks at the similarity or difference in faculty rank of the dyad. In my study, the rank homophily categories are "Same rank", "Jr. to me", and "Sr. to me".

Control Variables

Control variables in this study were the institution of the respondent, either Montana State University of the University of Montana.

Coding of Variables

My study was looking at the characteristics of the collaborative faculty dyad, so variables were created and coded by analyzing the data for both members of the dyad (Table 3.4). For instance, a "gender homophily" variable was created by comparing the subjects' responses to "What is your gender?" (Question #5) to "What is [the gender of your collaborator]" (Question #17). The Gender homophily category was a nominal variable of 0 = Different Gender, 1 = Male-Male Dyad, 2=Female-Female Dyad. Such coding was not necessary for Rank Homophily, since the question regarding rank homophily was "What is the relative rank of [your collaborator]?" (Question #16) with the response choices being "Jr. to me" = 2, "Sr. to me" = 1, "same rank" = 0. For disciplinary homophily, I had hoped to categorize the faculty dyad according to one of six categories based on Biglans' soft-hard, and pure-applied disciplinary categorization. However, there were fewer than 10 responses in some cells (n = 8), so the data were

aggregated instead to the Soft-Hard dichotomy, leaving three categories for disciplinary homophily: 1= Hard-Hard, 2 = Soft-Soft, 3 = Opposite. These codes were assigned based on the coding of the subjects response to the open-ended question of "What is your primary academic discipline?" (Question #1) and my coding of that based on Biglan's (1973a) and Drees (1982), and the response to Question #20 about their collaborators discipline "What is the primary academic discipline [of your collaborator]" and a similar coding strategy.

Data Collection Procedures

The survey was designed and administered using Qualtrics © online software and emailed to the list of tenured and tenure-track faculty at UM and MSU identified and gathered from institutional offices. Reminder emails were sent one week and two weeks after the initial survey invitation was sent.

External Validity

Attempts to ensure external validity were made by gathering responses from as many faculty in the sample as possible. An initial email invitation was sent from the researcher, with follow up emails one and two weeks later to those who had not yet responded to the survey. MSU and UM are both doctoral granting research institutions, so it is anticipated that results can be generalized to similar institutions but are both however, in the same state, which is rural and does not have a large industrial base or population diversity, which may affect the type of people that are attracted to faculty positions in these institutions, and therefore the generalizability of the data.

Table 3.4 Coding Table of Variables

Variable	Operational Definition	Scale	Measurement
Independent Variables			
Gender	Male or Female	Nominal	0-Man 1-Woman
Academic Rank	Level of tenured or tenure track position	Nominal	0 - Assistant Professor 1 – Associate Professor 2 – Full Professor
Discipline	One of Biglan's four categories of disciplines (listed in survey)	Nominal	0 – Quadrant 1 – applied, hard 1 – Quadrant 2 – applied, soft 2 – Quadrant 3 – pure, soft 3 – Quadrant 4 – pure, hard
Gender homophily	Gender similarity of identified collaborator	Nominal	0 – different gender 1 – male-male dyad 2 – female-female dyad
Academic Rank homophily	Academic rank similarity of identified collaborator	Nominal	0 – same rank as subject 1 – senior to subject 2 – junior to subject
Discipline homophily	Identification of collaborators primary discipline and relationship to subject's disciplinary classification	Nominal	0 – Homophily on Hard Axis 1 – Homophily on Soft Axis 2 – Opposite axes
Institution	Institution where subject is a faculty member	Nominal	0 – University of Montana 1 – Montana State University
Dependent Variables			
Research Productivity Count and Research Products	Number of grant proposals awarded; number of journal articles/book chapters published, number of presentations	Scale	

Internal Validity

Internal validity was ensured by satisfying the three criteria for internal validity that are 1) temporal precedence; 2) relatedness; and 3) attempts to minimize other explanations are made. In this study, the interdisciplinary collaborative dyad that was studied was established before the research products were produced by the dyad, meeting the temporal precedence condition. There is a relationship between the two components

of the study (homophily of faculty dyad and research productivity) in that the research productivity of the interdisciplinary dyad is what is being measured (relatedness). Attempts to minimize other explanations of the relationship of the dyad and research products are attempted by asking about control variables on the survey and the survey design. The two institutions may differ in their emphasis on promotion and tenure review and resources available for research, so institution was a control variable. Finally, it is difficult to determine cause and effect because the survey is not longitudinal.

Data Analysis

The data was analyzed using descriptive statistics and negative binomial regression because the dependent variable measure was count data which violates the assumptions of ordinary least squares regression, particularly that the predictor variables are linearly related to the outcome variables and that the data are normally distributed. Poisson regression was also not appropriate because the variance exceeded the mean for the dependent variables, indicating overdispersion. This is often the case when there a high number of zeros in the count data, as there were in my data. The zero-inflated model was not appropriate, however, because there was no separate mechanism at work which may have influenced the number of zeros in the count data (Cameron and Triverdi, 2015).

The assumptions of negative binomial regression including independence of responses, lack of homoskedasicity, and linearity were met. The first assumption, independence of responses, is that each of the responses of the outcome variable is independent of the others. In my data, the response about a dyad's productivity was not

affected by the responses of other dyads. Each of the dyads in the final analysis were independent from each other. The second assumption of negative binomial regression is that there is not homoskedasicity in the variance. In OLS regression, the variance around the regression line is the same for all values of the predictor. In this data, the variance is a function of the mean, so varied with the predictors (independent variables). The assumption of linearity in OLS is also not assumed in negative binomial regression because the expected response is not linearly related to the parameters. And finally, the distribution of the data is more general than that in OLS and from the exponential family of distributions (Gardner, Mulvey and Shaw, 1995).

Based on literature review of factors affecting faculty productivity, four models were tested using negative binomial regression as described above. The control used was the subject's institution.

Model 1: Gender Homophily and Research Productivity

Model 2: Rank Homophily and Research Productivity

Model 3: Disciplinary Homophily and Research Productivity

Model 4: Gender Homophily + Rank Homophily + Disciplinary Homophily + Home Institution of subject

This modeling approach was used to determine the effect of each predictor variable individually on the outcome variable and then the effect of the full model of all predictor variables on the outcome variable. My study involves models of research productivity based on different variables of a research dyad, and isolates them each

before running a full model of all of the variables. However, I recognize that in reality these variables are not isolated, but work together to affect the outcome.

Chapter Summary

This study attempts to fill the gap in the literature on characteristics of faculty involved in interdisciplinary research. Specifically, this study examined the demographic characteristics of gender, rank, and discipline of a collaborative faculty dyad on the research productivity of the dyad. A 31-item survey was administered to faculty at the University of Montana and Montana State University asking about their research productivity and research collaborations. It was distributed to 830 tenured and tenure track individuals with 266 returned for a response rate of 32%. After data cleaning, 207 useable cases were used for analysis for a response rate of 25%. Data was determined to be not overly dispersed between the two institutions, so data was aggregated for further analysis as reported in Chapter 4.

CHAPTER FOUR

RESULTS

Introduction

This chapter contains the results of the study on the characteristics of faculty dyads on their research productivity. In this chapter, I provide the results of the survey administered to faculty at Montana State University and the University of Montana in the fall of 2015. The unit of analysis is the faculty dyad and its' characteristics including the gender homophily, rank homophily and disciplinary homophily of the dyad. The dependent variables studied are the types of collaborative research products produced by the dyad, specifically Intellectual Contributions – Published, Presentations, and Grants-Awarded. The first part of the chapter contains descriptive statistics about the respondents and the faculty dyads. Following this is an analysis using negative binomial regression tapping the characteristics of faculty dyads on the outcome variables. The third part of the chapter contains descriptive statistics of some of the other variables gathered regarding the faculty member's perceptions of interdisciplinary collaboration. These include whether they view their research as disciplinary, multidisciplinary, interdisciplinary or transdisciplinary, and the reasons that they participate in research collaboration. The last section of the chapter is a summary and overview of results.

Descriptive Data Results

The collaborative research process can result in a variety of types of tangible products, and my first research question was concerned with what types of products were produced by the collaborative faculty dyads being studied. Survey respondents were asked to provide the number of products produced in three different types of research products. These three types of products were based on the information gathered at an institutional level for faculty annual reviews and was intended to capture the breadth of scholarly activity by faculty. The results of this analysis can be found in Table 4.1. The product that was most commonly produced by these dyads was Presentations with a mean of 1.62 (*SD* = 2.08). Contracts, Grants, and Fellowships Awarded was the product least likely to be produced with a mean of 0.69 (*SD* = 1.21). The other product I examined in further analysis with inferential statistics was Intellectual Contributions – Published (*M* = 1.42, *SD* = 1.93).

Table 4.1 Descriptive Statistics of the Dependent Variables

	N	Mean	SD	Minimum	Maximum
Intellectual Contributions Published	207	1.42	1.93	0	12
Presentations	207	1.62	2.08	0	15
Contracts, Grants, and Fellowships Awarded	207	0.69	1.21	0	8

The scholarly products in Table 4.1 were the outcome variables in which I was interested for further analysis. The predictor variables in the study were the characteristics of the faculty dyad. Specifically, gender homophily (male-male dyad, female-female dyad, or different gender); rank homophily (same rank, junior to subject,

senior to subject), and disciplinary homophily (both disciplines of dyad members classified as hard, both classified as soft, or opposite).

The characteristics and research productivity of this unit (i.e. dyad) are the subject of the study and descriptive data about the dyads in the sample are found in Table 4.2. Because the number of dyads in some of the Biglan quadrants was low, data was aggregated based on the soft-hard dichotomy of disciplines, rather than a combination of

Table 4.2 Characteristics of the Collaborative Dyads

	N	Frequency – MSU	Percent of Respondents – MSU	Frequency - UM	Percent of Respondents - UM	Pearson Chi-Squared test sig.
Gender Homophily	207	133	64.3	74	35.7	0.131
Diff Gender	85	52	39.1	33	44.6	
Male-Male	88	54	40.6	34	45.9	
Female-Female	34	27	20.3	7	9.5	
Rank	207	133	64.3	74	35.7	0.232
Same Rank	85	49	36.8	36	48.6	
Junior to subj.	51	34	25.6	17	23.0	
Senior to subj.	71	50	37.6	21	28.4	
Discipline Homophily	207	133	64.3	74	35.7	0.973
Hard-Hard	101	65	48.9	36	48.6	
Soft-Soft	57	36	27.1	21	28.4	
Soft-Hard	49	32	24.1	17	23.0	

soft-hard and applied-pure descriptions. Pearson Chi Square analysis shows that there was no significant difference in the homophily characteristics of gender (1.40, df =1, *ns),* rank (2.92, df = 2, *ns*) and soft-hard discipline (0.05, df = 2, *ns)* based on the two institutions.

The dependent variables examined were the number of Intellectual Contributions – Published by the dyad, the number of Presentations by the dyad, and the number of

Grants - Awarded to the dyad. Missing cases were assigned zeros based on imputation methods and participant motivation for eliciting a response (Groves, Singer and Corning, 2000). A summary of descriptive data results of the research productivity variables by the independent variable characteristics can be found in Table 4.3 including the mean and standard deviation for each of these dependent variables by each of the independent variables. Because the research productivity variables were count data, the percentage of zero responses in each category is included in the table.

Table 4.3 Descriptive Statistics of the research productivity variables by faculty dyad characteristics

	Total N	Intellectual Contributions -Published			Presentations			Grants Awarded		
	N	Mean	SD	%0	Mean	SD	%0	Mean	SD	%0
Gender	207			42.5			40.6			63.3
Male-Male	88	1.69	2.16	37.5	1.64	2.37	45.5	0.81	1.50	63.6
Fem-Fem	34	0.91	1.38	50.0	2.15	1.79	17.6	0.59	0.96	64.7
Diff. Gender	85	1.34	1.84	44.7	1.40	1.85	44.7	0.60	0.93	62.4
Rank	207			42.5			40.6			63.3
Same	85	1.74	2.24	36.4	1.51	1.68	36.5	0.59	0.93	64.7
Jr to subj.	51	1.02	1.41	47.0	1.76	2.76	45.1	0.67	1.11	64.7
Sr to subj.	71	1.32	1.83	46.5	1.66	1.98	40.8	0.78	1.51	60.6
Disc	207			42.5			40.6			63.3
Hard-Hard	101	1.74	2.12	33.7	1.86	2.46	40.6	0.88	1.26	51.5
Soft-Soft	57	1.26	1.73	45.6	1.56	1.72	35.1	0.49	1.28	78.9
Soft-Hard	49	0.94	1.65	57.1	1.20	1.50	46.9	0.51	0.94	69.4

Table 4.3 is organized in blocks by gender, rank, and disciplinary homophily categories. For the dependent variable of Intellectual Contributions – Published, same rank dyads and those from Hard-Hard disciplines had the highest mean (M = 1.69, SD= 2.24 and SD = 2.12, respectively). The smallest mean was for female-female gender dyads (M = 0.91, SD = 1.38). All three of the dyad profiles had a high percentage of zeros

for the dependent count variables. The Intellectual Contributions - Published variable percentage of zeros ranged from 33.7% (hard-hard disciplinary homophily) to 57.1% (opposite disciplines).

For the outcome variable of Presentations, the range of zeros in all of the homophily categories was 17.6% (female-female disciplinary homophily) to 46.9% (opposite disciplines). The largest mean for the outcome variable of Presentations was in the female-female dyad with a mean of 2.15 (*SD* = 1.79). The smallest mean for this variable was by opposite disciplinary dyads (soft-hard) (*M*= 1.20, *SD* = 1.50).

The dependent variable of Grants - Awarded had zero percentages from 51.5% (hard-hard disciplinary homophily) to 78.9% (opposite disciplines). Soft-soft disciplinary dyads had the smallest mean for this variable (*M*=0.49, *SD* = 1.28) and Hard-Hard disciplinary dyads had the largest mean (*M*=0.88, *SD*= 1.26).

Analysis

Negative Binomial Regression Analysis

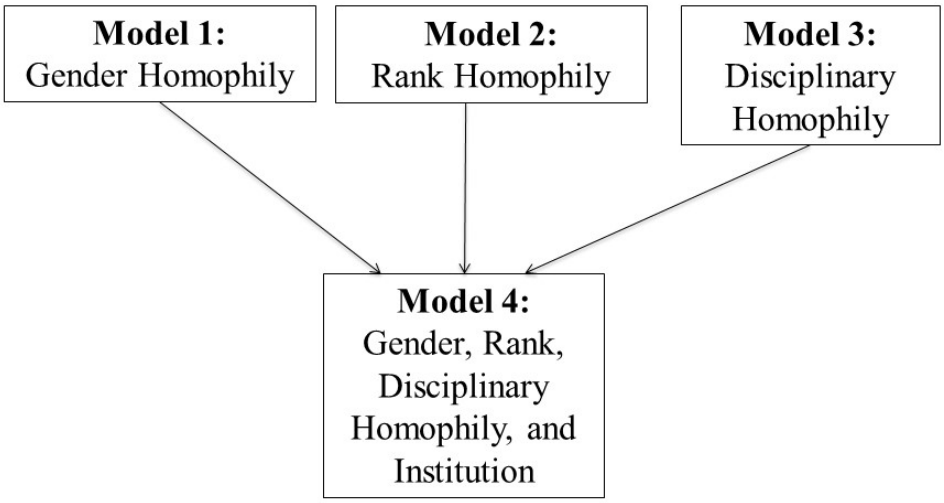
Each dependent variable is a count measure of productivity, which results in a non-negative integer for all outcomes. Count variables violate the assumptions of ordinary least squares regression, necessitating a different inferential statistical method. As seen in Table 4.3, the variance exceeds the mean for the each of the dependent variables, indicating overdispersion of the dependent variables. Because of this non-normal distribution and high percentage of zeros in the count data responses, negative binomial regression was used as the inferential statistical method of analysis to evaluate the relationship between the characteristics of the faculty dyad and their research

productivity. A zero-inflated equation was not used because there was no reason to assume that a separate, predictable process was generating excessive zeros; rather faculty dyads simply did not produce any products in those instances (Cameron and Trivedi, 2015).

I employed a model building strategy to estimate the baseline unadjusted and saturated adjusted relationship between each predictor variable and each outcome variable (Figure 4.1). Models 1-3 examined the unadjusted relationship of each of the predictor variables alone on the dependent variables of interest. That is, the baseline relationship of gender homophily (Model 1), rank homophily (Model 2) and disciplinary homophily (Model 3) each singly on the three outcome variables of (1) Intellectual Contributions - Published, (2) Presentations, and (3) Grants - Awarded. As described previously, the disciplinary homophily variable was determined based on the homophily along Biglan's Soft-Hard axis of the subject's discipline and their collaborator's discipline. The soft-hard axis was chosen because of a gap in the literature about the productivity outcomes of this dichotomy. Model 4 was the saturated model that included all of the homophily categories as well as the institutional indicator. This model estimated the adjusted relationships between the predictor and outcome variables. Further, Model 4 provided the most conservative estimates of the influence of each predictor as the other predictors were also in the regression equation. A summary of the

model building steps is shown in Figure 4.1.

Figure 4.1 Model Building Strategy for Data Analysis



A practical interpretation of the negative binomial coefficients was not plausible given that the coefficients represented the difference between logs of the expected counts for each unit change in the independent variables. To simplify interpretation, I transformed the coefficients into Incidence Rate Ratios (IRR) that measure the multiplicative effects on the odds of being productive for each one-unit change in the independent variables (Sedgwick, 2010). Given that all independent variables were dichotomous, these IRR values represented the differences of being coded "1" versus being coded "0". These incidence rate ratios (IRR) found in Tables 4.4-4.6 represent the odds of a change in the research productivity outcome variable for every one-unit change in the predictor variable.

Table 4.4 Incidence Rate Ratios from the Negative Binomial Regression Coefficients for Research Productivity: Products Published

Variables	Model 1	Model 2	Model 3	Model 4
Gender				
Diff. Gender (reference)	-----	-----	-----	
Male-Male	1.26			1.15
	(0.20)			(0.30)
Female-Female	0.68			0.76
	(0.30)			(0.21)
Rank				
Same Rank (reference)	----	-----	-----	
Senior		0.76		0.83
		(0.21)		(0.22)
Junior		0.59**		0.67
		(0.24)		(0.25)
Discipline				
Hard-Hard (reference)	-----	-----	-----	
Soft-Soft			0.73	0.82
			(0.22)	(0.23)
Opposite			0.54**	0.66*
			(0.28)	(0.26)
Institution				
UM (reference)	-----	-----	-----	
MSU				1.32
				(0.20)
Model Fit Statistics				
Log Likelihood	-337.14	-337.03	-336.06	-332.57
LR p-value	0.08	0.07	0.03	0.05

*p< 0.10, **p< 0.05, ***p<0.01
Note: Standard errors are in parentheses

The dependent variable of "Intellectual Contributions – Published" was described on the survey as "book, book chapter, conference proceedings, journal articles, technical report". The results of Model 1 shown in Table 4.4 show that there was no significant relationship between gender homophily of the dyad and Intellectual Contributions – Published. That is, same gender or different gender dyads was not a significant predictor

of the outcome variable of Intellectual Contributions – Published. In Model 2, there was a significant relationship between the predictor variable of rank homophily and the Intellectual Contributions-Published by the collaborative faculty dyad. Specifically, dyads in which the collaborator was junior in rank to the subject had expected counts of Intellectual Contributions – Published that were reduced by a factor of 0.59 or 41% lower than those dyads that contained faculty of the same rank (p=0.02). There was also a significant relationship between the predictor variables of discipline homophily on the outcome variable of Intellectual Contributions – Published (Model 3). A collaborative dyad made of one member from a soft discipline and one from a hard discipline had expected counts of Intellectual Contributions – Published that were reduced by a factor of 0.54 or 46% lower than a collaborative dyad made up of members from hard-hard disciplines (p=0.03). In Model 4, which included all of the predictor variables as well as the control variable of institution on Intellectual Contributions – Published, the significance in rank did not persist, but the significance of disciplinary homophily did with a collaborative dyad of soft-hard disciplines having expected counts of Intellectual Contributions – Published reduced by a factor of 0.66 or 34% lower than those hard-hard discipline dyad (p=0.10). There was non-significance of rank in the full model (Model 4) indicating that the other variables may be accounting for its influence on the number of products published. The addition of the control variable of institution in Model 4 was also not a significant predictor of Intellectual Contributions - Published.

The second outcome variable examined was the number of Presentations produced by the faculty dyad (Table 4.5). The same model building strategy was

employed with this variable as in the previous outcome variable. The IRR coefficients seen in Table 4.5 indicate significance in Models 1 and 3 as well as the full model (Model 4). In Model 1, which is the relationship of gender homophily and Presentations, female-female collaborative dyads had expected counts of Presentations that were increased by a factor of 1.53 or 53% higher than different gendered dyads (p=0.03). There was no significance in the number of Presentations by male-male gender dyads compared to different gendered dyads.

Table 4.5 Incidence Rate Ratios from the Negative Binomial Regression Coefficients for Research Productivity: Presentations

Variables	Model 1	Model 2	Model 3	Model 4
Gender				
Diff. Gender (reference)	-----	-----	-----	-----
Male-Male	1.17			1.08
	(0.21)			(0.20)
Female-Female	1.53**			1.55*
	(0.20)			(0.26)
Rank				
Same Rank (reference)	----	-----	-----	-----
Senior		1.10		1.14
		(0.18)		(0.21)
Junior		1.17		1.16
		(0.25)		(0.23)
Discipline				
Hard-Hard (reference)	-----	-----	-----	-----
Soft-Soft			0.84	0.76
			(0.20)	(0.23)
Opposite			0.65**	0.59**
			(0.22)	(0.24)
Institution				
UM (reference)	-----	-----	-----	-----
MSU				1.22
				(0.19)
Model Fit Statistics				
Log Likelihood	-359.43	-360.64	-359.08	-355.50
LR P-value	0.23	0.76	0.16	0.15

*p< 0.10, **p< 0.05, ***p<0.01
Note: Standard errors are in parentheses

Model 2, which is the relationship between the predictor variables of rank and the outcome variable of Presentations had no significance in any of the categories of rank homophily. In Model 3, faculty dyads from different disciplines (one soft, one hard) had expected counts of presentations that were reduced by 0.65 or 35% lower than those of dyads from hard-hard disciplines (p=0.05). In Model 4, which includes all of the predictor variables, the gender and disciplinary homophily significance relationship remained, although the significance level weakened for the gender homophily category. In Model 4, collaborative dyads made up of one faculty member from a hard discipline and one from a soft discipline had expected counts of presentations that were reduced by a factor of 0.59 or 41% lower than a dyad made of collaborators from two hard disciplines (p=0.03). Like Model 2 in which it was considered solely, rank homophily was not a significant predictor of presentations in Model 4 which was the full model of all of the predictor variables. The control variable of institution was not significant in Model 4. The model fit statistics for the dependent variable of Presentations are not significant at the 95% confidence level, however individual variables within those models are significant.

Table 4.6 shows the results of the analysis for the outcome variable of Grants-Awarded. In Model 1 of the negative binomial regression analysis predicting Grants - Awarded to the faculty dyad, gender homophily was not significantly related to the productivity of the dyad. Model 2 also did not have any significance. This indicates that neither the gender homophily of the dyad, nor the rank homophily of the dyad is a predictor of Grants-Awarded to collaborative dyads. Model 3, which is the relationship

of discipline homophily and Grants-Awarded did show significance for a dyad made of opposite disciplinary groups. A soft-hard disciplinary dyad had expected counts of Grants-Awarded that were reduced by a factor of 0.58 or 42% lower than dyads of hard-hard disciplines.

Table 4.6 Incidence Rate Ratios from the Negative Binomial Regression Coefficients for Research Productivity: Grants Awarded

Variables	Model 1	Model 2	Model 3	Model 4
Gender				
Diff. Gender (reference)	-----	-----	-----	
Male-Male	1.35			1.19
	(0.26)			(0.25)
Female-Female	0.98			0.87
	(0.32)			(0.35)
Rank				
Same Rank (reference)	----	-----	-----	
Senior		1.39		1.45
		(0.28)		(0.26)
Junior		1.13		1.24
		(0.29)		(0.30)
Discipline				
Hard-Hard (reference)	-----	-----	-----	
Soft-Soft			0.56	0.62*
			(0.37)	(0.28)
Opposite			0.58*	0.54**
			(0.30)	(0.30)
Institution				
UM (reference)	-----	-----	-----	
MSU				2.02**
				(0.26)
Model Fit Statistics				
Log Likelihood	-234.87	-234.95	-232.52	-227.10
LR p-value	0.39	0.42	0.03	0.02

*p< 0.10, **p< 0.05, ***p<0.01
Note: Standard errors are in parentheses

In Model 4, which is the full model incorporating all of the predictor variables, disciplinary homophily was a significant predictor for dyads from opposite disciplines as compared to hard-hard disciplinary dyads, with those from opposite disciplines having expected counts of Grants Awarded that were reduced by a factor of 0.54 or 46% fewer Grants – Awarded (p=0.04). There was also significance with dyads from soft-soft disciplines having expected counts of Grants Awarded that were reduced by a factor of 0.62 or 38% lower Grants Awarded than those from hard-hard disciplines (p=0.09). In the full model (Model 4), the subject's institution was also a significant predictor of the number of grants awarded with MSU faculty having expected counts of Grants Awarded increased by a factor of 2.02 or twice that of UM faculty (p=0.007).

Other Descriptive Statistics

As the definition of interdisciplinary collaboration continues to evolve, it is informative to determine how faculty perceive their own scholarship collaboration, as this might influence policies and procedures to encourage collaboration. The survey administered contained a question regarding the spectrum of definitions of disciplinary collaboration and asked the faculty members to categorize themselves based on the definitions given. The terms were Disciplinary, Multidisciplinary, Interdisciplinary and Transdisciplinary which are becoming increasingly common in the literature on collaboration. Results were analyzed according to the disciplinary homophily categories of the dyad, since this predictor variable was significant on all of the outcome variables. Descriptive statistics results of this analysis are in Table 4.7.

As seen in Table 4.7, the highest percentage of respondents in a Hard-Hard disciplinary dyad classify their research as Interdisciplinary (36%), which is the same for those who are in a Hard-Soft dyad (38.8%). For the Soft-Soft dyad, the highest definition of disciplinary collaboration identified is "disciplinary" (29.8%). The lowest percentage overall was Transdisciplinary (20.8%), which was also the lowest definition chosen for those from Hard-Hard disciplinary categories (19.0%). Soft-Hard disciplinary dyads had "disciplinary" and "transdisciplinary" at the bottom of the definitions chosen, with both at 20.4%. The lowest for the Soft-Soft dyads was "Interdisciplinary" (21.1%).

Table 4.7: Disciplinary Collaboration Definitions

Definition	N	Overall %	Hard-Hard %	Soft-Soft %	Opposite %
Disciplinary: I approach research questions using the paradigms, tools, and methods specific to my discipline and if I collaborate, it is with others form my discipline.	48	23.3	21.0	29.8	20.4
Multidisciplinary: My research draws on the knowledge from different disciplines, but stays within the boundaries of those disciplines.	48	23.3	24.0	24.6	20.4
Interdisciplinary: My research analyzes, synthesizes, and harmonizes links between disciplines into a coordinated and coherent whole.	67	32.5	36.0	21.1	38.8
Transdisciplinary: My research cuts across disciplines, integrating content, theory and methodology from any disciplinary area that will shed light on the research questions.	43	20.9	19.0	24.6	20.4
TOTAL	206	100%	100%	100%	100%

Similarly, understanding the mechanisms by which faculty engage in collaboration can help explain how collaborations were formed and how they might be promoted among

faculty. Table 4.8 presents responses to the question "Why do you collaborate?" and was again analyzed by the soft-hard categories in the disciplinary homophily variable. These responses were taken from Rhoten and Pfirman (2007), who examined patterns of interdiscisplinary and disciplinary collaboration by gender. The largest percentage of respondents indicated that they collaborate for "Problem Orientation" (31.6%), which was also the highest response for each of the disciplinary categories (Hard-Hard – 29.8%, Soft-Soft – 33.3%, Soft-Hard – 31.7%). The smallest reason for collaborating chosen by respondents was "Field Creation". The overall response for this choice was 16.3% with the Soft-Soft category choosing it less frequently than the other disciplinary categories (8.3%). Just under eighteen percent of Hard-Hard dyads selected this choice (17.9%) making it the lowest for that category as well. Only 19.1% of dyads made up of a soft-hard discipline chose "Field Creation" as their reason for collaborating, which was not the lowest category for this group (Cross-fertilization of ideas – 17.0%).

Table 4.8 – Why Collaborate? By Disciplinary Homophily Categories

Response	Frequency	Overall %	Hard-Hard %	Soft-Soft %	Opposite %
Cross-fertilization of ideas – to use the tools, concepts, data or methods of another field or discipline	42	24.6	28.6	27.8	17.0
Team Collaboration – to collaborate as a team or network	47	27.4	23.8	30.6	29.8
Field Creation – to engage in research in domains that are at the intersection of multiple fields of disciplines	28	16.3	17.9	8.3	19.1
Problem Orientation – to engage in topics that not only draw on multiple fields or disciplines, but also serve multiple stakeholders and broader missions outside academics.	54	31.6	29.8	33.3	31.7
TOTAL	171	100%	100%	100%	100%

Another area of interest for practical reasons is how these collaborations under study came to be formed. The survey included the question "Which of the following most accurately describes how this person came to be your collaborator?" Table 4.9 shows the percentage of responses to each of the choices in aggregate and by disciplinary categories.

The descriptive results show that Professional Networking was the most common method of forming collaborations (34.2% overall), followed closely by "intentionally sought out this person" with an overall response rate of 32.1%. What is useful for institutions is that in this sample, "institutional efforts to facilitate the collaboration" was much lower as a reason to collaborate that the top two reasons (19.0% overall).

Table 4.9 – How did this person become collaborator?

Response	Frequency	Overall %	Hard-Hard %	Soft-Soft %	Opposite %
Colleague from graduate school or post-doc	27	14.7	11.0	23.5	11.9
Professional Networking	63	34.2	37.4	29.4	33.3
Intentionally sought out this person because of skill set, knowledge or expertise	59	32.1	33.0	27.5	35.7
Institutional efforts to facilitate this collaboration	35	19.0	18.7	19.6	19.0
TOTAL	184	100%	100%	100%	100%

Chapter Summary

The purpose of this study is to examine the relationship between research productivity and the characteristics of the collaborative faculty dyad producing the research. An electronic survey was sent to faculty at the University of Montana and Montana State University in the fall of 2015 and had a response rate of 26% for a total of

207 usable surveys. Descriptive statistics of the count data for each of the dependent variables indicated that Presentations had the highest mean with Grants-Awarded the smallest mean. In all cases, the variance exceeded the mean indicating the need for a non-normal distribution inferential statistical analysis method.

Negative binomial regression was used to analyze the count data of the dependent variables of Intellectual Contributions – Published, Presentations, and Grants-Awarded. This analysis showed a significant relationship in each of the outcome variables and at least one of the predictor variables. In the case of Intellectual Contributions- Published it was the rank homophily category of junior to the subject that produced significantly fewer products than a same rank dyad. Opposite disciplinary dyads (soft-hard) also produced significantly fewer products than the hard-hard disciplinary dyads. For Presentations, the gender homophily category of female-female produced significantly more presentations than an opposite gender dyad, and again a faculty dyad of opposite disciplines produced significantly fewer presentations than a hard-hard disciplinary collaborative dyad. The opposite disciplinary dyad also produced significantly fewer Grants- Awarded than hard-hard disciplines, a finding which did not persist when the full model of all variables was run. For the Intellectual Contributions -Published outcome variable, the significance of rank weakened in the full model, but was still present. The statistically significant relationship of a female-female dyad on presentations outcome also held up in the full model with all of the variables, as well as the significance of disciplinary homophily and individual productivity.

In summary, the data indicate the homophily of faculty dyads does have a significant relationship with the outcome variables of Intellectual Contributions – Published, Presentations, and Grants - Awarded. The same set of characteristics of the dyad does not necessarily persist across all outcome variables. Descriptive data demonstrated that faculty collaborations result in a variety of products and that faculty view their scholarship not simply in one category of disciplinary collaboration, but across a spectrum of definitions. Further interpretation and recommendations based on these findings are in Chapter 5.

CHAPTER FIVE

CONCLUSIONS

Introduction

The purpose of this study was to investigate the relationship between research productivity and the demographic characteristics of faculty collaborative dyads. Using a survey methodology, I gathered data from tenured and tenure-track faculty at two research institutions about their primary research collaboration and the resultant productivity of this collaboration as measured by three outcome variables: (1) Intellectual Contributions – Published, (2) Presentations, and (3) Grants Awarded. The results of negative binomial regression analysis of the data indicate that disciplinary homophily is significantly related to all measures of productivity while rank homophily is significantly related to Intellectual Contributions - Published and gender homophily is significantly related to Presentations. This chapter includes an overview of the study, methodology, and a discussion of the results. It also discusses the limitations of the study and offers recommendations for practice and future research.

Overview of the Study

Interdisciplinary collaboration among faculty is becoming a common practice in higher education (Brint, Turk-Bicakci, Proctor, & Murphy, 2009;). This has been attributed to a number of factors including the incentive for funding which is increasingly more interdisciplinary related, and the nature of research problems that often are at the

interfaces of disciplines and require expertise from more than one discipline (Elkana, 2009; Katz & Martin, 1997; Melin, 2000). While some efforts have been made at individual institutions to increase their acceptance of interdisciplinary work through the tenure and promotion process, most higher education institutions are still siloed in the traditional college and departmental structure (Feller, 2007; National Academy, 2005). It is within these structures that individual faculty members operate, with the expectation of productivity as a measure of success.

An individual faculty member may seek out a collaborator based on their research needs or the expertise of the other person, and if the collaboration is fruitful, there are research products that are the outcomes of the collaboration. As in any relationship, both parties bring expertise, background and personal characteristics to the collaboration that may impact the "fit" of the collaboration, and ultimately its productivity. Because this study examined collaborative research productivity, it requires the study of productivity from at least two individuals. While collaborations can occur between multiple individuals, the direct cooperation between at least two individuals is the fundamental unit of collaboration (Katz and Martin, 1997). Understanding the micro-level characteristics of a collaborative dyad was the motivation for this study, so that some of these "fit" characteristics can be better understood. The three characteristics I examined in this study were gender, rank, and discipline.

Much research has been done on the role of gender in the professoriate, and specifically productivity (see Chapter 2). Male and female faculty have different patterns of productivity based on factors such as their professional status, discipline, and

measurements of the types of products produced (Cole and Singer, 1991; Stack, 2004; Webber, 2011). This study examined this demographic characteristic at the dyad level, considering whether or not the collaborative pair was of different genders, both male or both female.

The rank of the faculty member conducting research has also been studied extensively with mixed results on whether or not faculty become more productive as they become more senior, or less productive (Baldwin, Lunceford, and Vanderlinden, 2001; Byrnes and McNamara, 2001; Tien and Blackburn, 1996). This variable was examined in my study by determining whether the collaborative dyad was of the same rank, or whether or not the respondent was senior or junior to their collaborator. The productivity from these differing rank categories may underscore previous empirical results about the productivity of faculty as they move from Assistant to Associate to Full professor, or whether they are most productive pre-tenure.

While there are a number of different factors that can be considered when categorizing disciplines, Biglan's classification (1973a, 1973b) has persisted as a robust classification of disciplines along three different dichotomies. These dichotomies of Soft-Hard, Pure-Applied, and Life-Nonlife were used in the original research to classify 35 different disciplines. Further study by Drees (1982) classified an additional 38 disciplines. I used this classification system to look at homophily between collaborators in a faculty dyad. The Soft-Hard dichotomy was used based on the dearth of other empirical studies along this dichotomy. Chapter 2 traces the literature on these three variables and research productivity by faculty.

This study examined the relationship between these three characteristics of a faculty dyad and their research productivity. In Chapter 3, I described the methodology used for the study, including sampling, and research questions. Chapter 4 explained the descriptive and inferential statistics results from the study. Following in this chapter, I provide a brief discussion of the method used and a discussion of the results.

Methodology

This study was conducted through an electronic survey administered to 830 faculty at MSU and UM. The survey was based on one used previously to examine multifaceted collaboration (Jha and Welch, 2010). It consisted of 34 questions covering four areas. The first was demographic information about the respondent and their productivity as a faculty member. The second part asked them to consider a collaborator and answer the same demographic questions about that person. The answers to these questions and the respondent's demographics, allowed for variables of homophily about the dyad to be created. The respondent then answered about the productivity of the research collaboration. The three dependent variables examined in the analysis were Intellectual Contributions – Published, Presentations, and Grants – Awarded. The fourth part of the survey asked more qualitative questions regarding definitions of disciplinarity, motivation about collaborating, and how the person came to be a collaborator.

The data was analyzed using SPSS software. The dependent variables for the analysis were the number of Intellectual Contributions - Published, the number of Presentations, and the number of Grants - Awarded. After running Chi-square analysis to determine there was not unreasonable skewness or kurtosis among the variables,

descriptive statistics for each of the aggregated variables and by institution were obtained. Negative binomial regression was the inferential statistical method used to answer the following five research questions:

1. What types of research products are produced by interdisciplinary collaborative dyads of tenure track faculty?
2. Is there a relationship between gender homophily (i.e. same gender of researchers) and interdisciplinary collaborative research productivity for tenure track faculty dyads?
3. Is there a relationship between rank homophily (i.e. same rank of researchers) and interdisciplinary collaborative research productivity for tenure track faculty dyads?
4. Is there a relationship between discipline homophily and interdisciplinary collaborative research productivity for tenure track faculty dyads?
5. What is the relationship between gender, rank, discipline and interdisciplinary collaborative research productivity for tenure track faculty dyads?

Discussion of Research Results

Research Question #1

What types of research products are produced by interdisciplinary collaborative dyads of tenure track faculty?

This research question was analyzed with descriptive statistics from the result of the survey. "Presentations" was the collaborative product with the highest mean (M=1.62, SD = 2.08), while Contracts, Grants, and Fellowships Awarded had the lowest

mean of the three variables studied ($M = 0.69$, $SD = 1.21$). The third outcome variable studied, Intellectual Contributions – Published, had a mean of 1.42 ($SD = 1.93$). The standard deviation for each of the dependent variables was higher than the mean, indicating overdispersion of the data, in part due to the high number of zeros in each category.

Most empirical research on productivity has looked at publications or citations of individuals as the measure of productivity. The mean for the Intellectual Contributions – Published in my study was lower than previous empirical research on this variable (Byrnes and McNamara, 2001; Tien and Blackburn; 1996). The Byrnes and McNamara (2001) study was a discipline specific study of rank, looking at faculty in developmental sciences graduate program and found that assistant professors had an average of 0.81 publications per year, associate professors, 1.19 publications per year, and full professors, 2.31 publications per year. The Blackburn and Tien (1996) study was much broader and included 2586 faculty with data from a Carnegie national survey from 1989. This study found that assistant professors published 1.83 publications per year, associate professors 1.79 publications and full professors 2.27 publications per year. The Byrnes study looked at seven years of productivity and the Blackburn and Tien at two years.

Because the question on my survey asked about productivity over the previous two years, it is highly probable that a longer time frame would have resulted in higher response counts for these variables. In many fields, the time to publication is close to a year or more, and grant awards may not be made for six months or more (Baird, 1991;

Becher, 1994). However, I chose the two year time frame based on other examples in the literature, so it was a consistent measure with other empirical research in the field.

My study examined the productivity of a collaboration, which has generally been found to increase productivity over the individual's productivity. Abbasi and colleagues (2011) examined the social network of faculty through their co-authorship and found that those who are connected to many different scholars show better performance than those with fewer connections. A follow up to this study using more measures of research performance such as grant proposals and patents had the same result (Cimenler, Reeves, and Skvoretz, 2014). In a study examining curricula vitae of faculty, Lee and Bozeman (2005) found that collaboration had a positive effect on publishing productivity in a two-year period. A similar study on collaboration among faculty in an Italian research academic community found that those with more social capital were more productive than their isolated colleagues (Rotolo and Petruzelli, 2013).

Research Question #2

> Is there a relationship between gender homophily (i.e. same gender of researchers) and interdisciplinary collaborative research productivity for tenure track faculty dyads?

Male-Male faculty dyads had the highest mean for two of the three measures of research productivity including Intellectual Contributions – Published ($M = 1.69$, $SD = 2.16$) and Grants – Awarded ($M = 0.81$, $SD = 1.50$). In the outcome variable of Presentations, female-female faculty dyads had the highest mean ($M = 2.15$, $SD = 1.79$). Female-female dyads had the lowest means on the other two measures of productivity,

Intellectual Contributions – Published (M = 0.91, SD = 1.38) and Grants-Awarded (M = 0.59, SD = 0.96).

The relationship of gender homphily and research productivity was addressed through negative binomial regression analysis of the count data of the dependent variables. This was analyzed according to gender homophily categories of male-male collaborative dyad, female-female collaborative dyad, and different gender dyad. The only research product analyzed that produced a significant result along the gender homophily characteristics was "Presentations". In the number of Presentations produced by the collaborative dyad, the female-female gender pair had an expected count of presentations that was 1.53 or 53% higher than the collaborative dyad of different genders. There was no significance in gender homophily in the other outcome variables of Intellectual Contributions-Published and Grants-Awarded. It is interesting to note that the significant relationship between gender and scholarly products was only in this one outcome research product, suggesting that collaborating on Presentations may somehow be a different type of collaboration than the others outcome variables measured. There are few studies on Presentations as a measure of research productivity, so it is difficult to compare this result to other work.

This significance in gender homophily as a predictor of the Presentations outcome variable may support earlier work on gender collaboration overall, which indicates differences in preferences and styles between men and women may translate into differences in forming collaborative relationships (Rhoten and Pfirman, 2007; Leahey, 2007). Rhoten and Pfirman (2007) found that women were more likely to be interested in

activities that have a problem-solving orientation and societal relevance than men, who were more interested in fundamental theory and computation. This preference may lead to the formation of more interdisciplinary collaborations than men (Rhoten and Pfirman, 2007; van Rijnsoever and Hessels, 2011), and less specialization than men (Leahey, 2007) although this does not necessarily translate into more productivity. The Rhoten and Pfirman study looked at participation by faculty, not publications like other studies. It is possible that "Presentations" is a precursor to publication and is more appropriately considered "participation" versus "productivity".

Research Question #3

> Is there a relationship between rank homophily (i.e. same rank of researchers) and interdisciplinary collaborative research productivity for tenure track faculty dyads?

Rank homophily was determined based on the question on the survey which asked the respondent if their collaborator was the Same Rank, Junior to them, or Senior to them. Descriptive statistics of the Intellectual Contributions- Published and rank homophily show that same rank dyads had the highest mean for Contributions-Published (M = 1.74, SD = 2.24) and the lowest for the other two outcome measures of Presentations (M = 1.51, SD = 1.68) and Grants-Awarded (M = 0.59, SD = 0.63). Dyads in which the collaborator was senior to the respondent had the highest mean for Grants – Awarded (M = 0.78, SD = 1.51) and for the outcome variable of Presentations, dyads in which the collaborator was junior in rank to the respondent had the highest mean (M = 1.76, SD = 2.76). All of these descriptive statistics had high standard deviations, indicating

overdispersion of the variable. There wasn't a single rank category regularly being the most productive across all outcome measures, which is consistent with the literature which shows mixed results about academic rank and productivity (Baldwin, Lunceford, Vanderlinden, 2005; Grapin, Kranz, and Daley, 2013; Dundar and Lewis, 1998; Keim, 2008; Smeby and Try, 2005; Tien and Blackburn, 1996). All of these studies examined the relationship of the individual's rank to the number of articles they published. Dundar and Lewis (1998), Tien and Blackburn (1996), and Kiem (2008) all found that full professors published more than lower ranks across multiple disciplines in academia. In their study of faculty at higher education institutions in Norway, Smeby and Try (2005) found that lower academic ranks were more productive than their senior colleagues. In a discipline specific study, Grapin, Kranz and Daley (2013) found no significant difference in publication rates of faculty ranks in School Psychology programs.

Further analysis of this question was addressed through negative binomial regression analysis of count data of the dependent variables (Intellectual Contributions – Published, Presentations, and Grants-Awarded) on the rank homophily variable. Rank homophily was shown to have a significant relationship with the number of Intellectual Contributions - Published. Specifically, a faculty dyad in which the collaborator was junior to the respondent had an expected count of Intellectual Contributions – Published that was reduced by a factor of 0.59 or 41% lower than a dyad of the same rank. No significant relationship with rank was seen in the other dependent variables of Grants Awarded and Presentations.

The finding of rank heterophily being a significant predictor of less productivity than a rank homophilous dyad was contrary to previous findings by Jha and Welch (2010) who found that heterophilous dyads were more likely to engage in multifaceted collaboration which consists of collaboration across multiple activities such as grant proposals, conference presentations, and publications. The literature on rank of individuals and productivity is mixed, with some studies supporting the obsolescence theory that the older faculty get, the less productive they are because they do not stay up to date on cutting edge theories and their research eventually becomes obsolete (Baldwin, Lunceford and Vanderlinden, 2005; Levin and Stephan, 2001; Smeby and Try, 2005) and other studies supporting the cumulative advantage theory that more senior faculty will be more productive because early success breeds future success as publications lead to grants, which leads to more time for research, which leads to more publications (Bozeman and Corley, 2004; Keim, 2008; Merton, 1968). In my study, the rank heterophilous dyad in which the collaborator was junior to the respondent, had significantly fewer Intellectual Contributions – Published than a rank homophilous dyad. This may be because the junior collaborator may have competing responsibilities to achieve tenure, or less experience in producing publishable results, and more effort is required on the part of the respondent to make the collaboration productive.

Research Question #4

> Is there a relationship between discipline homophily and interdisciplinary collaborative research productivity for tenure track faculty dyads?

As discussed previously, disciplinary homophily was categorized based on whether or not both members of the dyad were in hard disciplines (hard-hard), both were in soft disciplines (soft-soft), or one was from each type of classification (soft-hard). In all of the outcome variables, the hard-hard dyad was the most productive, with the highest means (Intellectual Contributions - Published: $M = 1.74$, $SD = 2.12$; Presentations: $M = 1.86$, $SD = 2.46$; Grants - Awarded: $M = 0.88$, $SD = 1.26$). Dyads of opposite disciplines (soft-hard) had the lowest mean of Intellectual Contributions – Published ($M = 0.94$, $SD = 1.65$) and Presentations ($M = 1.20$, $SD = 1.50$). Soft-soft dyads had the lowest mean for Grants-Awarded ($M = 0.49$, $SD = 1.28$).

In the inferential statistical analysis, disciplinary homophily was found to have a significant relationship with all three of the outcome variables. Specifically, a collaborative pair from opposite disciplines (one soft, one hard) was less likely to have Intellectual Contributions – Published (IRR=0.54, $p = 0.03$), Presentations (IRR = 0.65, $p = 0.05$) and Grants - Awarded (IRR = 0.58, $p = 0.04$) than a collaborative pair who are both from hard disciplines. The hard disciplines are those such as engineering and physical science with a paradigm for organizing knowledge and the soft ones are disciplines such as the humanities and social sciences, which have less of a disciplinary consensus of a knowledge organizing paradigm. According to Kuhn (1962) this knowledge organizing paradigm specifies the appropriate topics for study in a discipline and appropriate methods used.

The result may indicate the difficulty that disciplines from such different viewpoints have in producing intellectual contributions as a collaborative dyad. This has

been suggested in a number of theoretical studies on the differences of disciplines (Baird, 1991; Becher 1994; Bentley and Blackburn, 1990; Porter and Umbach, 2000) and more recently in empirical research. In a comprehensive study of research products using the NSOPF:04 data set, Webber (2011) found that faculty in physical and life sciences produced more research outcomes than faculty in other fields. In a similar study of data from the Survey of Doctorate Recipient, Sabharwal (2013) found that physical sciences and biology produced the highest number of journal articles over a five-year span. In a study of an applied discipline (nanoscience) and a pure one (astrophysics), Jansen and colleagues (2010) found that the applied discipline tended to benefit more from interdisciplinary collaboration than the pure field because of access to different knowledge from other disciplines needed to advance the field. This kind of knowledge and access in hard disciplines is often concrete and instrumental, while in soft disciplines, the collaboration is more fluid and expressive, although that exists across all disciplines (Lewis, Ross and Holden, 2012). Lewis and colleagues' study of different types of collaboration across different disciplines found that there were statistically significant patterns of research across disciplines, with humanities disciplines generally conducting research alone, science with others, and social sciences mixed.

Research Question #5

What is the relationship among gender, rank, discipline and interdisciplinary collaborative research productivity for tenure track faculty dyads?

The final research question was one that combined all of the independent variables into one model to examine the effect on the dependent variable. This was

Model 4 in my model building scheme and also added the control variable of institution to the outcome variable. Rank homophily was not significant in the full model for the Intellectual Contributions - Published outcome variable, as it was in the bivariate model. This finding indicates that other variables in the model predict the Intellectual Contributions – Published, accounting for the effect of rank homophily in the reduced model. The significant relationship of disciplinary homophily with Intellectual Contributions - Published that existed in the bivariate model, persisted in the multivariate model (IRR = 0.66, $p < 0.10$), although the significance decreased. As discussed previously in this chapter, norms for publications differ by discipline. This difference in disciplinary norms may explain the significance of disciplinary homophily on the outcome of Intellectual Products – Published.

For the outcome variable of Presentations, there was a significant relationship between gender homophily and disciplinary homophily in the multivariate model. These variables were both significant in the reduced models (Model 1 and Model 3), and the significance persisted in the full Model, although it was reduced for gender homophily. That is, female-female dyads had expected counts of presentations that were increased by a factor of 1.55 or 55% more than different gendered pairs, and dyads from opposite disciplines (one soft, one hard) had expected counts of presentations that were reduced by a factor of 0.59 or 41% lower than a dyad from hard-hard disciplines ($p = 0.047$). The significance of these two predictor variables in the more conservative model indicates their influence on the outcome variable of Presentations.

The third outcome variable studied was Grants-Awarded. In the multivariate model for this variable, two categories of disciplinary homophily were significant, as was the institution. Collaborative dyads from soft-soft disciplines and from soft-hard disciplines were significantly less productive than hard-hard disciplinary dyads. Soft-Soft dyads had expected counts of Grants-Awarded that were reduced by a factor of 0.62 or 38% lower than dyads from hard-hard disciplines and soft-hard disciplinary dyads had expected counts of Grants-Awarded that were 0.54 or 46% lower than dyads from hard-hard disciplines. This was also the only outcome variable in which the control variable of institution was significant.

Across all outcome variables in the full model (Model 4), disciplinary homophily was the only predictor variable that was significant indicating that it may have a greater role in predicting outcomes than the other variables under study.

Other Results

Data was also collected in the study about respondents' definition of their collaboration along the interdisciplinary continuum. Cross disciplinary collaboration is no longer simply defined as two individuals from different disciplines working together, but terms in the literature range from disciplinary to transdisciplinary. These terms describe the construct of collaboration between individuals from more than one discipline and to what extent they are crossing disciplinary boundaries in their collaboration. These disciplinary boundaries are not necessarily firm, but academia has sought to categorize not only the disciplines, but the labels for the collaboration. While there is no one accepted definition of these terms, I used ones that have been used in other studies

(Meeth, 1978). The purpose of this question was to see the extent to which the individual views their scholarship, since it is generally expected that the spectrum of collaboration goes from disciplinary to multidisciplinary to interdisciplinary to transdisciplinary. While no category is suggested to be better than another, how people define their collaborative scholarship may be an indicator of the extent to which they collaborate, and therefore produce. The results of the descriptive data to this question indicated that most individuals view their collaboration as "interdisciplinary" (32.5%). When broken down by disciplinary homophily categories, this was the highest for hard-hard dyads (36%) suggesting that although this classification is within the same Biglan classification, there is significant difference within the disciplines defined as "hard" such that individuals from two hard disciplines see their collaboration as interdisciplinary. Dyads that were in opposite categories also chose interdisciplinary as the most frequent definition (38.8%).

The other question posed to respondents was about their reasons for collaboration. Rhoten and Pfirman (2007) proposed four mechanisms for collaboration, based on gender research in interdisciplinary collaboration. These four were: (a) Cross-Fertilization; (b) Team Collaboration; (c) Field Creation; and (d) Problem Orientation. Responses to this question can provide information about initiatives or strategies that might facilitate the preferences for collaboration by diverse individuals. In my study, "Problem Orientation" had the largest number of responses. The definition provided for this category was "to engage in topics that not only draw on multiple fields or disciplines, but also serve multiple stakeholders and broader missions outside academics". The high mean for this

response suggests the interest of the faculty in having an impact of their work beyond academia.

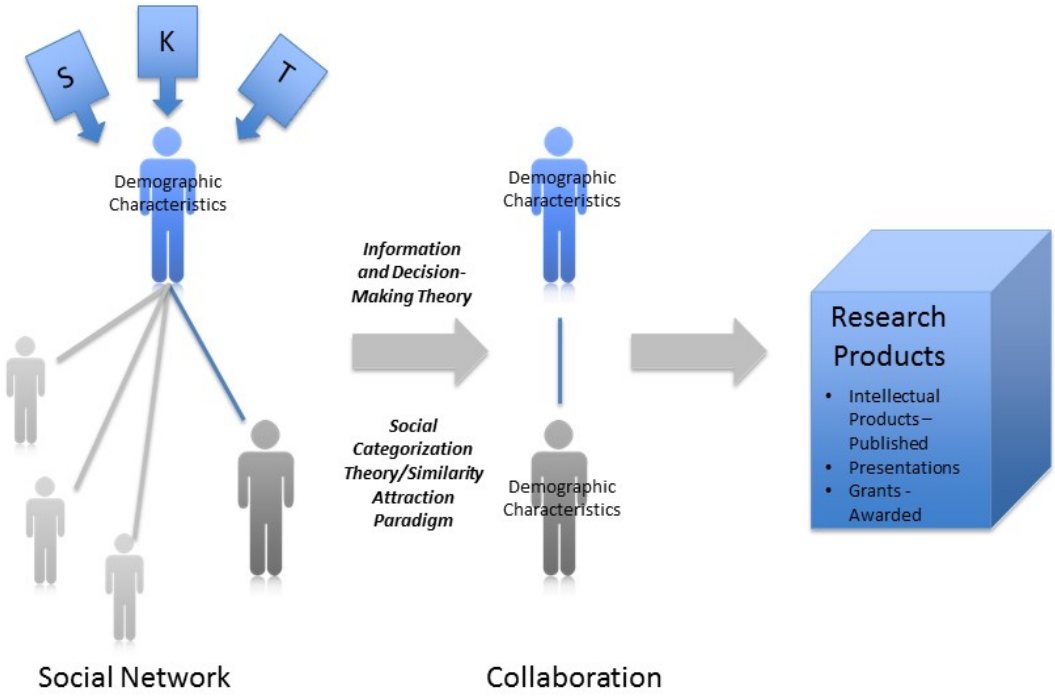
The third question related to how the collaboration was formed. The results of this descriptive analysis suggested that intentional efforts at facilitating interdisciplinary collaborations are not as successful as other mechanisms that are driven more by the individual involved in seeking out a collaborator for a particular reason. These reasons might include a particular skill of the other person, or some knowledge or expertise of the potential collaborator.

Recommendations from Study

In Chapter 2, I presented a conceptual model of research productivity by collaborative dyads based on the demographic characteristics of the individuals involved. In analyzing my data and revisiting the framework it became apparent that underscoring the data was a theory as to why certain types of individuals would collaborate. The conceptual framework is shown below in Figure 5.1 with the addition of a theoretical model describing why heterophily or homophily might lead to a more productive collaborative dyad.

The Information and Decision-Making Theory says that individuals different from each other will collaborate because of the benefits of the disparate knowledge and information they bring to the problem, thus increasing the resources and complementarities of a group (Hambrick and Mason, 1984; Gruenfeld, Mannix, Williams, and Neale, 1996). This would underscore the finding of heterophilous dyads being more productive.

Figure 5.1: Theoretical framework for study showing the relationship between the social network of a faculty member, the resulting collaboration and consequent research products. S=Skills, K=Knowledge, and T= Tools.



In examining the homophily characteristics of gender, rank, and discipline, the results of my study show that homophilous dyads tend to be more productive than their heterophilous counterparts, thus supporting the social categorization theory and similarity attraction paradigm (Byrne, 1971; Tajfel, 1974, 1981; Turner, 1975, 1987). According to these theories, individuals that are more similar to each other are likely to collaborate because the individuals are comfortable with someone who is "like them" and they are better able to communicate, and have better group cohesion. According to Granovetter's social network theory (1973), because these individuals are more alike than dissimilar, these dyads may be the result of "strong ties" in their social network. "Weaker ties" or

more indirect ties are what expands an individual's knowledge of the world beyond their own limited scope of knowledge and expertise. These strong ties may limit the individual's exposure to others who are not like them. In the context of my study, collaborative dyads of heterophilous individuals, particularly in relation to discipline would indicate a broad network of potential collaborators, with different knowledge and skills to bring to the collaboration. Since homophilous dyads were the most productive in this study, this would indicate that at these institutions, there are fewer "weaker ties" and faculty tend to collaborate with those close to them on the disciplinary continuum. Encouraging more broad ranging collaborations might need to be more deliberate through incentives and opportunities that facilitate interaction between faculty from dissimilar disciplines. Recommendations for practice based on the findings of this study include:

1. Mentoring of junior faculty to participate in collaborations and training senior faculty to engage junior faculty in collaborations.

2. Provide support for faculty to attend conferences outside of their discipline.

3. Provide guidance and training for female faculty to publish work based on conference presentations.

4. Form problem-based working groups to encourage interdiscisplinary interactions from a range of disciplines.

This study on the homophily of collaborative dyads on research productivity indicated that there are differences in the Intellectual Contributions - Published based on the rank of the dyad. Same rank faculty dyads were statistically significantly more productive on this outcome variable than dyads in which the collaborator was junior to

the respondent. This finding was also evident in the multivariate model in which all of the variables were added to the equation. Since publication is one of the major metrics for promotion and tenure, this is an important area in which faculty need to be productive. The finding that dyads in which one member is junior to the other are less productive suggests an opportunity for mentoring between the faculty dyad. Mentoring of less senior faculty in publishing findings and navigating the publication process could lead to more fruitful collaborative dyads in which one member is less senior than the other.

Another finding supporting the theory that homophilous dyads are more productive was for gender homophily. This study found that female-female collaborative dyads produced significantly more Presentations than different gender dyads. This finding was only for the outcome variable of Presentations, suggesting there is something about this collaborative product that is different than the other outcome variables of Grants-Awarded and Intellectual Contributions - Published. Since conference presentations in many fields lead to publication, it seems that mentoring or support for that next step from presentation to publication may increase the yield on publications published, helping both of the collaborative dyad members in their academic pursuits.

Another recommendation from the study is based on the significant finding of disciplinary homophily on research productivity. Collaborative dyads from opposite disciplines (soft-hard) were significantly less productive than dyads from hard-hard disciplines in all three of the outcome variables studied. The level of significance dropped slightly for Presentations in the multivariate model, and disappeared for

Intellectual Contributions - Published and Grants - Awarded. This finding suggests that while interdisciplinary collaboration may be occurring, it may not be across a wide spectrum of disciplines, which is often called for in national initiatives. This kind of collaboration between, for instance, the physical sciences and the social sciences, may require extra incentives and deliberate effort in order to occur. A difficulty with this strategy may be that in the collaborative dyads I studied, most of them occurred not through institutional efforts, but on a more informal and networking basis. Institutional policies and practices should take this into account when designing reward structures and methods to facilitate collaboration.

The message for institutions is to encourage such collaboration in order to access not only the interdisciplinary funding opportunities, but to participate at the interface of disciplines in "wicked problems" that may lead to solutions of global, important issues as well as to access and acquire funding in areas that are specifically targeted for interdisciplinary collaboration. It is becoming increasingly difficult for a faculty member to isolate themselves within their discipline and own research. The opportunity for productive faculty members to collaborate and share their knowledge and skills can increase the products and benefits to the academy and the intellectual community. Given the results in the descriptive questions about how the collaboration was formed, institutions might find more ways for faculty to participate in "professional networking" to facilitate these sorts of collaboration. This method of finding the collaborator was the most frequently cited. "Professional Networking" was defined as meeting the person at conferences, workshops, panels or through colleagues. Given that the collaborations in

this study were not across significantly different disciplines, it might take institutional resources to encourage faculty to attend conferences outside of their professional network, thus expanding the pool of potential collaborators.

Limitations

There are several limitations of this study that will be addressed in the following section. The first is that the sample came from only two institutions. Both are research active, doctoral granting institutions, but due to geographic location and demographic profile, they may not be representative of all research universities. While similar to each other (see Chapter 3), they are located in the same part of the country and have a mostly white student and faculty population. There is, however, no reason to believe that they are significantly different than other research universities, so results could be generalizable.

A second limitation is the response rate to the survey. While it was higher than the 19.8% that is typical for electronic survey research (Sax, Gilmartin, and Bryant, 2003), it was still only 26% after multiple emails were sent to the population to encourage them to participate. However, chi-square analysis of the independent and dependent variables indicated that there wasn't skewness or kurtosis in the final sample that would affect the analysis. The low response rate may, however, limit the internal validity of the sample in that it may be a certain profile of faculty who responded, so it may not capture the breadth of collaborative activity conducted by faculty at the two institutions.

Another limitation was the small number in some disciplinary categories which made me unable to examine the full range of disciplinary homophily and heterophily in which I was interested. Biglans' original categorization included the dichotomies of soft-hard, pure-applied, and life-nonlife. I had originally planned to examine the soft-hard and pure-applied classifications (four different quadrants), but since there was less than 10 responses in two of the categories, I aggregated the results and ran my analysis only on the soft-hard dichotomy. This was less informative about the types of disciplines that engage in productive collaborations, but it did result in some significant results, and can inform research and practice even without the finer-grained categorization of disciplines that a four quadrant classification would have shown. According to Biglan, the hard-soft dichotomy is generally the difference in disciplines with a paradigm and those that do not have a paradigm. The "paradigm" of the discipline is a body or theory which serves as an important organizing principle of the field (Biglan, 1973a). My study showed that collaborations across paradigmatic and non-paradigmatic fields were less productive, providing information for researchers and practitioners about areas for further study on the need to encourage collaboration.

The survey design was such that the respondent chose one collaborator about which to report their productivity. This was done in order to study the research unit of the collaborative dyad. In reality, faculty may have multiple collaborators, so asking them to pick just one and limit their responses to that collaboration may have been difficult for some of the respondents. This may have led to some respondents combining

results across multiple collaborators instead of isolating the contributions of one collaborator.

Another limitation had to do with the open response to the "What is your primary discipline?" question. The question was posed in this way so that respondents were not limited by a list of pre-determined disciplines that may or may not accurately represent their identified discipline. This response type did, however, necessitate some coding on my part of the responses. While most could neatly fit into one of Biglan's named disciplines, or in the follow up analysis of more disciplines by Drees, in seven instances I had to make a judgment call based on the similarity of the discipline to others. These determinations were made based on the similarity to known disciplinary classifications. If my interpretation of their disciplinary classification was not accurate, this may lead to different results than what the respondent would have designated as their discipline, given the choices in Biglan's classification.

A final limitation is that a number of factors contribute to one's research productivity including internal motivation, intelligence, and drive. These factors were not considered in this study. Controls for factors that have been found to influence productivity in previous studies such as the teaching load of the faculty member and the number of children the faculty member has were also not considered in this study.

Recommendations for Future Research

The research presented here, while providing more empirical data about interdisciplinary collaborative research, also provides some opportunities and questions for further research. Regarding gender homophily, further study into why female-female

dyads are so much more likely to produce collaborative presentations but not other products than a male-female dyad is an interesting topic. Some research on the collaborative behaviors and preferences of different genders may partially explain this (Leahey, 2007; Rhoten and Pfirman, 2007), but more research is needed, and this is another data point to indicate that need. This was also one of the few studies in the literature that used Presentations as a measure of research productivity, rather than just publications. Further study using Presentations as the outcome variable may lead to more information about the types of individuals and collaborations who produce this research product.

Results on the disciplinary homophily of dyads and research products is another area in which the results point to the need for more research. The results shown here indicate that collaborative dyads across categories (i.e. soft-hard) are significantly less likely to produce research products than the dyads from hard-hard disciplines. This may indicate that despite the best efforts of attention to global problems across disciplines and calls for funding that bring together physical sciences and social sciences, higher education is not becoming as interdisciplinary as thought, at least across paradigmatic and non-paradigmatic disciplines. However, Biglan's research was conducted almost 50 years ago, and given the changes in academia and knowledge production, it is possible that new classification and ways of thinking about paradigms in fields are needed (Steocker, 1993). This finding indicates higher education institutions are still fairly siloed, but further study could delve into this disciplinary difference at a finer level. For example, a study in which disciplinary heterophily across multiple dichotomies such as

pure-applied and soft-hard could provide information about just how productive disparate disciplines are in their collaborations. The hard-soft dichotomy is still a rough discriminator of differences between disciplines, as there are still differences between disciplines found in this quadrant.

The question of one's social network and how it affects their potential collaborators also merits continued study. While Granovetter's (1973) theory indicates that weak ties expand and diversify one's social network by exposing them to people dissimilar than themselves, my research indicated that individuals who are more similar tend to collaborate and be productive - the "strong ties" in Granovetter's work. Further study into the processes by which individuals expand their network in the higher education context and access these weak ties is an area for future research.

Finally, this study was conducted at two institutions in the Rocky Mountain West. Further study on faculty at more institutions could provide more information about the profile of research collaborators and their productivity.

Conclusions

Results from this study show that different profiles of faculty dyads have differing productivity. The research indicates that there is a statistically significant relationship between rank homophily and Intellectual Contributions - Published, between gender homophily and Presentations, and between disciplinary homophily and all three of the dependent variables of Intellectual Contributions - Published, Presentations, and Grants - Awarded. In the full, multivariate model, gender and disciplinary homophily is significantly related to the number of Presentations, and rank homophily is statistically

significant in the full model to Intellectual Contributions – Published. This significance in different predictor variables and outcome variables suggests that the process for producing the types of products is different, requiring different collaborative skills that are more prominent in certain profiles of collaborative dyads. Overall though, the research supports the Similarity Attraction Paradigm theory in that homophilous dyads tend to be more productive than their heterophilous counterparts.

This study adds to the growing body of knowledge about interdisciplinary collaboration, and specifically the micro-level characteristics of what productive collaborations look like. Recommendations for promoting such collaborations include mentoring of different ranks, and facilitating collaborations across disciplines that are more different from each other than would typically be found in a research collaboration. This is particularly necessary if there is some incentive such as a grant that requires collaboration across categories of disciplines. Areas for further study include the differences in the outcome products that might lead a certain profile of collaborative dyad to be more productive and to understand why the disciplinary collaborations across soft-hard disciplines is not as fruitful as other collaborations.

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APPENDIX A

SURVEY OF TENURED AND TENURE TRACK FACULTY

A Study of Characteristics of Interdisciplinary Research Productivity

The purpose of this survey is to determine if there is a relationship between the demographic and academic characteristics of interdisciplinary collaborations among tenured and tenure track faculty (a faculty dyad) and the research productivity of the dyad. The survey of 34 questions, asks about research activity in the past two years, so it may be useful to have your CV on hand as you answer the questions.

1. What is your primary academic discipline? *"Academic discipline" is defined as the department in which you have an appointment or the subject area which most closely matches the courses you teach.*

   _____(Text answer – will need to be coded in one of Biglan's quadrants).

2. What is your current rank?
   a. Assistant professor
   b. Associate professor
   c. Full professor
   d. Other (specify) _____

3. How long have you been at this rank?
   a. Less than 1 year
   b. 1-2 years
   c. greater than 2 years

4. What is your gender?
   a. Man
   b. Woman
   c. Transgender

5. In which institution are you located?
   a. Montana State University
   b. University of Montana

In the past two years, indicate the number of each of the following activities in which you have participated. This should be the cumulative total for your work during these two years including individual, sole author, works as well and collaborative, co-authored, works:

	ITEM	Number
6.	Intellectual Contributions **Submitted** – Book, book chapter, conference proceedings, journal articles, technical report	

7.	Intellectual Contributions **Published** - Book, book chapter, conference proceedings, journal articles, technical report	
8.	Presentations – paper, poster, reading of creative work, exhibit, keynote, plenary address	
9.	Artistic and Professional Performances and Exhibits	
10.	Contracts, Fellowships, Grants and Sponsored Research – **Submitted.**	
11.	Contracts, Fellowships, Grants and Sponsored Research – **Awarded.**	
12.	What is the total number of Tier I faculty collaborators you have? *(Tier I collaborators are those where the interaction results in co-authored tangible outcomes such as publications, presentations, grants, or patents)*	
13.	What is the total number of Tier II faculty collaborators you have? *(Tier II collaborators are those where the interaction is based on sharing resources or exchanging ideas but does not result in any co-authored tangible outcomes as described above)*	

14a. Which of the following definitions most closely matches your approach to your primary scholarly activity?

a. Disciplinary – I approach research questions using the paradigms, tools, and methods specific to my discipline and if I collaborate it is with others from my discipline.
b. Multidisciplinary – Multidisciplinary research draws on the knowledge from different disciplines, but stays within the boundaries of those disciplines
c. Interdisciplinary – Interdisciplinary research analyzes, synthesizes, and harmonizes links between disciplines into a coordinated and coherent whole.
d. Transdisciplinary – Transdisciplinary research integrates the natural and social and health sciences in a humanities context and in so doing transcends each of their traditional boundaries .

15. Do you collaborate with a faculty member from a discipline other than your own on research activities?

a. Yes (continue with Q16, then skip to Q18)
b. No (skip to Q17 then continue)

16. What is your primary reason for collaborating with someone from another discipline?

a. Cross-fertilization of ideas – to use the tools, concepts, data, or methods of another field or discipline

b. Team Collaboration – to collaborate as a team or network that exchanges or creates new tools, concepts, data, or methods across different disciplines
c. Field Creation – to engage in research in domains that are at the intersection of multiple fields or disciplines
d. Problem Orientation – to engage in topics that not only draw on multiple fields or disciplines, but serve multiple stakeholders and broader missions outside academics.

17. Do you collaborate with a faculty member from your discipline on research activities?
    c. Yes (continue)
    d. No (thank you – end of survey).

18. Do you hold a formal joint appointment in more than one department?
    a. Yes
    b. No (skip Question 20)
19. If so, what discipline is the second department?

    _____(Text answer – will need to be coded in one of Biglan's quadrants). Open-ended

Collaborations:
For the following questions, please think about your most significant **faculty** collaborator **from a discipline other than your own** with whom you have collaborated in research activities in the past two years.

For the following questions, please think about your most significant **faculty** collaborator with whom you have collaborated in research activities in the past two years. (*this would be question logic for the faculty who say they only collaborate within discipline.)*

20. What is the primary academic discipline of this faculty collaborator? *"Academic discipline" is defined as the department in which they have an appointment or the subject area which most closely matches the courses they teach.*

    _____(Text answer – will need to be coded in one of Biglan's quadrants). Open-ende

21. What is the relative rank of this person?
    a. Junior to you?
    b. Same rank as you?
    c. Senior to you?

22. What is this person's gender?
    a. Man
    b. Woman
    c. Transgender

23. How long have you been collaborating with this person?

24. Is this person at the same institution as you?

a. Yes (if yes then "For purposes of ensuring research integrity and removing duplicates from the data, can you indicate the collaborators name and your name? This data will only be used to match if there is another survey response about this same dyad").
Then skip to Question 26)

b. No

24. Is this person at UM or MSU?

a. Yes (if yes then "For purposes of ensuring research integrity and removing duplicates from the data, can you indicate the collaborators name and your name? This data will only be used to match if there is another survey response about this same dyad"). Then skip to Question 26.

b. No

25. How would you classify the institution in which this person works?

a. Doctorate Granting University
b. Master's College/University
c. Baccalaureate College
d. Associates College
e. Special Focus Institution (i.e. medical schools, school of law, theological seminaries)
f. Tribal Colleges

In the past two years, indicate the number of each of the following activities you have participated in with this individual (most significant faculty collaborator. Activities that include other authors or contributors in addition to yourself and this collaborator should be included)

	ITEM	Number
26.	Intellectual Contributions **Submitted** – Book, book chapter, conference proceedings, journal articles, technical report	
27.	Intellectual Contributions **Published** - Book, book chapter, conference proceedings, journal articles, technical report	
28.	Presentations – paper, poster, reading of creative work, exhibit, keynote, plenary address	
29.	Artistic and Professional Performances and Exhibits	
30.	Contracts, Fellowships, Grants and Sponsored Research – **Submitted.**	
31.	Contracts, Fellowships, Grants and Sponsored Research – **Awarded.**	

32. What is the primary reason for collaborating with this person?

a. They have specialized expertise or knowledge that contributes to a problem I am studying or want to study
b. They have access to specialized equipment or tools that are useful in my research/scholarly activity
c. They have a different way of approaching a larger problem I am studying
d. They have connections to other researchers or collaborators that are important to my research
e. They have grant funding to support our collaborative efforts
f. Other _____

33. Which of the following most accurately describes how this person became your collaborator?
a. This person is a colleague from graduate school or a post-doctoral position
b. Through professional networking at conferences, workshops, panels or through other colleagues
c. I intentionally sought out this collaboration because of the other person's skill set, knowledge, or expertise
d. Through Institutional efforts to facilitate this collaboration
This person sought me out

e. Other _____

34. Is there anything else you would like to share regarding collaboration?

Thank you!