Knowledge Flows from Invention to Public Value: the Impacts of Academic-industry Collaborations

by

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ABSTRACT

An important national policy motivation for the public support of academic scientific research is the economic benefits gathered from the development of new innovations and technological progress. As academic scientists are the primary recipient of federal funding and produce key new knowledge, it is important to understand how they make decisions about their research activities and involvement with industry and how these decisions impact knowledge creation and diffusion. Knowledge flows, the dispersion of ideas between individuals or groups, contribute economic benefits by generating new innovations and technological processes and connections between scientists from different fields and industries. I have three questions on this topic that are addressed in my five-chapter dissertation: 1. How do the academic-industry patenting collaborations influence knowledge flows as measured by patent citations? 2. How do patent network structure and composition impact patent citations? 3. How do institutional logics influence academic scientists' decisions to undertake research topics, collaboration partners and other activities to produce patents?

Essay one investigates characteristics of academic-industry collaborations that influence patent citation counts using a 2010 National Survey on Intellectual Property in Academic Science and Engineering matched with 2019 citation data. Essay two expands on the first essay by looking at how network collaborations span the public and private sectors, to see how the combination of the two sectors matters for knowledge flows. The study uses the same survey data merged with patent citation and new network information data. Essay three utilizes institutional logics as a theoretical lens to look at how academic scientists make decisions about their research activities. I interview early career scientists and tenured scientists across three Arizona universities to learn more about how institutional logics present and interact in academic science. Taken together, the findings expand previous research on academic-industry interactions by highlighting the fundamental collaboration and network characteristics that improve citation counts, my metric for understanding knowledge flows. Additionally, my dissertation dives deeper into academic scientists' research and collaboration decisions using an institutional logics perspective to better understand which decision parameters matter the most for maximizing knowledge flows.

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CHAPTER 1

INTRODUCTION

Overview

Universities are an important object of inquiry in Public Administration (PA) and engagement research because they play an important role in society as producers of knowledge that benefits society. Universities are important producers of new discoveries and innovations as they are conductors of research, developers of knowledge, trainers of students and contributors to other sectors including industry. Academic research greatly contributes public value through knowledge flows, the dispersion of ideas between individuals and groups, which are important for furthering scientific and technological progress. New knowledge development and diffusion helps to generate new innovations, forge connections between scientists from different fields and industries, and advance public science (Azagra-Caro and Consoli, 2016; Tseng, et al, 2020). Public science encompasses any knowledge and innovations produced by universities, government laboratories, etc., which leads to economic spillovers and other societal benefits (McMillan, et al, 2000; Partha, and David, 1994). In this case, public science refers to the outputs of research intensive and other universities that are public or use federal grants to fund their research.

An important policy motivation encouraging the public support (e.g. federal) of scientific research is the economic benefits gathered from the development of new innovations and technological progress, including opening up new industries and other opportunities such as academic-industry collaborations (Jaffe and Trajtenberg, 1999; Tijssen, 2001; Verbeek, et al., 2002). Advancing public science through increased knowledge flows and progress is a social mission, which can present tensions in values and overall goals for the scientists. University policies and research infrastructure, such as institutional and research collaboration arrangements, can impact knowledge flows within academia and between the academic and private sectors. This dissertation looks at the questions: how do academic scientists make decisions about their research activities and involvement with industry and how do these decision outcomes impact knowledge flows for the advancement of science?

The increasing prominence of intellectual property (IP) rights and the commercialization of science has reconfigured US science in ways that blur the public and private divide. Conversely, now more than ever before universities, industry and government science are more interwoven and create an interconnected field of public and commercial science (Rhoten and Powell, 2007; Saraite Sariene, et al., 2020). Industry is increasingly more involved in academic science as they contract out a lot of research from universities and collaborate with academic scientists to produce many different types of important outputs like university spin-off companies, licensing and patents. While there are many important outcomes from academic-industry relationships, this dissertation largely focuses on patents, which can be categorized as use-inspired research, indicating the merging of logics from these two sectors. Use-inspired research combines the academic goal of furthering basic knowledge with an orientation towards commercial use (Bentley, et al, 2015; Irvine and Martin, 1984). My dissertation contributes to the larger literature that looks at this change to US science and its advancement of public science by focusing on how scientists make decisions guided by institutional logics about their research activities and industry relationships, and how these decision outcomes impact knowledge flows.

Research infrastructure arrangements such as cross-sector collaborations and networks matter for knowledge flows and scientific progress. Knowledge transfer and innovation were once seen as a linear process in the literature where inventions are disclosed and evaluated, and then a patent is filed and often licensed to an interested firm (Bradley et al, 2013; Hayter, et al, 2020; Klein and Rosenberg, 1986). However, this view overlooks social influences and complexity as knowledge flows tend to be more cumulative and dynamic, having a key social context that should be considered (Meyer, 2000a; Tijssen, 2001; Verbeek, et al., 2002). Knowledge creation and diffusion often has a more network-embedded structure with an emphasis on the many actors involved and the dynamics between knowledge demand and supply leading to partnerships and academic-industry interactions (Meyer, 2002; Verbeek, et al., 2002;). Essays one and two of this dissertation focus on the social structures and relationships, including the key social characteristics of academic-industry involvement and the larger network collaborations, enabling a clearer understanding of the complexity of knowledge flows for academic science and technology.

For measuring science and technological advancements, patents are consistently used in the literature as a detailed source on inventive activities that have gone through an examination process for both the novelty and potential utility of the innovation in question. Patent citations can track relations between publicly funded research and private sector applications, highlighting knowledge flows between the two sectors and its impact on scientific progress (Ji, Barnett and Chu, 2019; Meyer, 2002). I expand on the literature on social content of knowledge flows and patenting by focusing on academic-industry collaboration efforts and network structures.

The first essay of this dissertation considers the question: How do academic-industry patenting collaboration characteristics influence knowledge flows? Building on the previous literature, the essay develops hypotheses on important relational characteristics related to the patent and individual scientist behavior that explain the relationship between industry involvement in patents and knowledge dissemination. Patents that are cited more frequently by future patents are novel and broadly applicable, sparking new scientific ideas and technology and leading to further knowledge flows (Higham, De Rassenfosse, and Jaffe, 2021; Yoon and Kim, 2011). Using data from a 2010 national survey of university scientists and engineers combined with publicly available patent citation data, I test variation in patent knowledge flow outcomes in 2019 by the strength of industry collaboration and interactions. This gap in time better captures the full knowledge exchange, as it can take a long time to fully come to fruition (Feldman, et al, 2021; Fini et al., 2018; Hayter et al., 2020). The results show that the behavior and perspective of the academic inventor involved with industry is specifically important for the knowledge flow outcomes. The type of industry activities the scientists engage in, amount of experience with industry and their views on collaboration tensions or conflicts are related to patent citations. These findings expand previous research on academic-industry interactions by highlighting the fundamental collaboration and knowledge transfer characteristics that improve citation counts.

The second essay expands on the first by focusing on the larger patent collaboration networks and their influence on knowledge flows. The essay asks: How do patent network structure and composition impact patent citations? Information and collaboration networks are important for the production and diffusion of new science and technology knowledge, as they can reduce research infrastructure costs, and increase the usefulness and flow of new ideas (Azagra-Caro and Consoli, 2016; Tahmooresnejad and Beaudry, 2018). A common way to measure direct network collaborations in the patent literature is to look at co-inventors on patents (Jaffe, Trajtenberg, and Henderson 1993; Lata, et al, 2015), which can exclude observing knowledge flows between academia and industry. Instead, this essay leverages network collaborations that include both co-inventors and industry partner specification across different disciplines to see how they affect knowledge creation and flows. By using this structural approach, I am able to look at how the collaborations span the public and private sectors, to see how the combination of the two sectors matters for knowledge flows and the advancement of science. Using data from the same 2010 national survey of university scientists and engineers matched with publicly available patent network and citation data, I apply social network data and metrics to test variation in patent citations by patent network structure and composition. This essay builds on the findings in essay one about academic-industry perceived value conflicts as measured by academic-industry network structure and composition and sets up my third essay to look at academic logics and perceptions. I also conduct an exploratory analysis of the network relationships separately by field due to important field specific findings from essay three.

While my first two essays focus on the scientists' patenting decision outcomes and how they impact knowledge flows, the third essay dives deeper into how and why scientists make decisions about patenting and working with industry utilizing institutional logics as a guide. The essay considers the research question: How do institutional logics influence academic scientists' decisions to undertake research topics, collaboration partners and other activities to produce new knowledge? To guide scientific and technological development, universities and their scientists adopt institutional logics about how to effectively share knowledge, as the boundaries between public and private research shift and get closer (Dai, et al., 2018; Powell, and Colyvas, 2008). While one logic may be dominant within an organization, there can also be multiple logics that blend, complement one another or are in conflict (Besharov and Smith, 2014; Friedland and Alford, 1991). Universities traditionally follow an academic logic that values career advancement by publishing in high-impact journals and acquiring competitive grants (Ali-Khan, et al, 2017; Hayter et al, 2020). More recently, within universities, market logic encourages generating profits and IP rights (Friesike, et al., 2015; Rhoten and Powell, 2007). While openness logic, the free sharing of ideas and other resources for future use (Levin, et al, 2016), has gained momentum through open science initiatives, but is difficult to completely commit to and implement the ideals widely in practice (Ali-Khan, et al 2017; Edwards, 2016; Nelson, 2009; Rhoten and Powell, 2007). As both can exist in the same setting, scholars are unclear about how scientists actually implement openness principles as they can overlap or conflict with traditional academic and commercialization norms.

This essay explores how academic scientists' research decisions are based on particular institutional logics, how they view any logic trade-offs or conflicts and how the logics they follow influence their many research activities including collaboration efforts and patenting. Using institutional logics theory, I interview early career and tenured scientists in biology across three universities in Arizona to learn more about how institutional logics present and interact in academic science. While the first two essays of this dissertation look at the impact of academic scientists' research decisions, findings in essay three fill in the gaps about how and why scientists make these research decisions in the first place. Essay three also presents the importance of field nuances, which inspired the exploratory analysis done in essay two. The findings from the qualitative interviews show that field context matters greatly for how and why scientists decide to engage in different collaborative research activities and that subfields can form their own customs and norms when it comes to networking. So, rather than treating scientific fields as a control variable, the respondents from distinct fields can also be looked at as subpopulations with different network rules and values.

Data and Bias Testing

The first two essays of this dissertation use data from the National Science Foundation (NSF) funded 2010 National Survey on Intellectual Property in Academic Science and Engineering (IRB approval number STUDY00013547, found in appendix D) matched with different publicly available sources. The survey asks science and engineering inventors about their patent development and interactions with industry. The survey was administered to academic scientists and engineers listed as inventors on university patents in 2006 by the United States Patent and Trademark Office (USPTO). Out of the 7,506 inventors identified, non-university inventors without valid contact information were removed. That leaves 3,032 university inventors in the sample. Given that 134 inventors were randomly sampled to participate in the pilot study, they were not given the final modified survey distributed from mid-December 2009 to mid-March 2010. The final sample size after removing all ineligible responses was 1,055 (a response rate of 36%). The response rate is larger than the norm for this type of national survey (Sauermann and Roach, 2013).

In the first essay, the survey data was matched by inventor and patent USPTO identification number to the publicly available data on the number of patent citations for 2019 from Google Patents[1]. In the second essay, the survey data was matched with both the patent citation information from Google Patents and patent network information from Patent Network Dataverse[2]. The number of patent citations was found and included for a total of 844 inventors in both essays. Due to partially completed surveys and unusable answers, the final number of inventors used in the models is 729.

To verify that there are no key differences between the population and sample or sample selection problems, I performed two bias balance tests. The first compared respondents with the population asked to respond to the survey, which includes all patentors in academic institutions that year. I ran an analysis of responding to the survey on gender and the Carnegie Mellon higher education classification[3] and both variables are not statistically significant (Appendix A). Next, I compared those included in the sample and those excluded for not having a patent or information on their citations. I ran an analysis of survey inclusion on the covariates and all variables are not statistically

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[1] https://patents.google.com/

[2] Ronald Lai; Alexander D'Amour; Amy Yu; Ye Sun; Lee Fleming, 2011, "Disambiguation and Co-authorship Networks of the U.S. Patent Inventor Database (1975 - 2010)", https://doi.org/10.7910/DVN/5F1RRI, Harvard Dataverse, V5, UNF:5:RqsI3LsQEYLHkkg5jG/jRg== [fileUNF]

[3] https://carnegieclassifications.iu.edu/

significant (Appendix B). Even with these tests of balance, there is still a possibility of selection bias as the dissertation does not have data on those who chose not to respond to the survey. To account for any potential selection bias, both essays include as many possibly related covariates as appropriate for the models.

Main Findings and Contributions

Taken together, this dissertation comprehensively advances our understanding about how scientists' choices to patent influence knowledge flows, guided by their institutional logics, academic-industry interactions, and collaboration networks. I contribute to the patenting and innovation literature by focusing on key structural and relational characteristics of patenting and academic science collaborations in the first two essays. The patenting process is highly social and nonlinear, meaning that more attention should be brought to the continual formal and informal interaction between the academic and private sectors (Bradley, et al., 2013; Klein and Rosenberg, 1986; Meyer, 2002). The type of industry involvement represents important structural, technological and relational characteristics that can influence patenting outcomes and knowledge flows. I also contribute to the theoretical foundations of institutional logics theory by exploring the choices scientists make based on the institutional logics they follow and how the logics interact and influence their research practices in the third chapter. By looking specifically at how scientists view and reconcile academic, market and openness logics, the essay shows how these active choices impact science and technological research and knowledge sharing. Taken together, my dissertation advances our overall understanding about new shifts in public science, focusing on the interactions between the academic and private sectors, and how they influence research decisions and the public value of the outcomes.

CHAPTER 2

ESSAY ONE: The impact of academic-industry collaboration on knowledge flows

Introduction:

Universities play an important role in society as producers of key knowledge and other distinguished outputs that contribute to economic growth by means of innovation, knowledge transfer, and commercialization (Bozeman and Corley, 2004; Huang, et al, 2011; Kolympiris and Klein, 2017; Thursby and Thursby, 2001). Academic knowledge flows are key for creating new scientific knowledge, connections between scientists, technological opportunities, and, generally, furthering public science (Azagra-Caro and Consoli, 2016; Tseng, et al, 2020). Public science includes any knowledge and innovations made by universities, government laboratories, government funding, etc. that have public value and provide social benefits such as economic spillovers (McMillan, et al, 2000; Partha, and David, 1994). To provide social benefits, science and technology faculty at research intensive universities are encouraged through legislation and university-based incentives to transfer technology and other deliverables, pursue patents for their research and improve knowledge dissemination.

In order to achieve this goal, academics often collaborate with industry, such as during the patenting process (Berker and Kvellheim, 2018; Mowery and Sampat, 2005). The collaboration between the two sectors, research universities and the private sector, often occurs because industry is interested in opening up information channels to learn about academic research (Thursby and Thursby, 2003) and to access new technological developments and business opportunities (Ankrah, et al, 2013). In exchange, academia receives new technical knowhow, equipment and funding from industry (D'Este and Perkmann, 2011; Tartari et al, 2012). Yet it is unclear how the specifics of the academic inventors' interactions with industry partners in the patent development process affect important knowledge flows for the two sectors.

Recent literature on technological innovation uses patent citations as an important measure of knowledge diffusion between different inventors and organizations (Azagra-Caro and Consoli, 2016; Ji, Barnett, and Chu, 2019; Kolympiris and Klein, 2017). Patent citations are a process that is shaped both by legal and social institutions (Meyer, 2000a; Meyer, 2002; Verbeek, et al, 2002). van den Belt established that much of the scientific and economic studies use a simpler and conventional view of patents[4], leaving out important relational characteristics. When in reality, patenting is a highly interactive social process that consists of collaborations and actors making decisions based on their access to resources and influence over the patents (Meyer, 2002).

To fill this gap in the literature, this research focuses on the relationship between patent knowledge flows and important relational collaboration characteristics that influence the technological impact and reach of the patent. This essay asks: How do academic-industry patenting collaborations influences knowledge flows, as measured by patent citations? This research combines a unique survey dataset collected from a national sample of academic inventors in 2010 with publicly available patent citation data from 2019. This gap in time allows knowledge exchange to be captured, as it can take a

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[4] H. van den Belt, ' Action at a distance: A. W. Hofmann and the French patent disputes about aniline red (1860-63), or How a scientist may influence legal decisions without appearing in court', in Expert Evidence: Interpreting Science in the Law (ed. R. Smith and B. Wynne), London, 1989

lot of time and resources to fully come to fruition (Feldman, et al, 2021; Fini et al., 2018; Hayter et al., 2020). By combining the bibliometric data with survey data about patenting and other research activities, this research is able to examine and exploit the gap in understanding about relational characteristics in the patenting process. The study focuses on individual inventor behavior and perceptions that explain the relationship between industry involvement and knowledge dissemination.

The essay is organized as follows. The study begins with a review of the literature on academic patents, knowledge flows and industry involvement in the patenting process. Drawing from that literature, the essay presents the hypotheses, and then describes the data and methods and presents the empirical results. The essay concludes with a discussion of the results and their implications for research and federal and university policy.

Literature Review

Academic-Industry Collaboration Impacts

As universities actively engage in more commercialization activities encouraged by university and government policies (e.g., Bayh-Dole Act), academic-industry linkages play a larger role in the innovation processes, and the dissemination of new knowledge for the advancement of public science. Academic-industry collaborations are highly social and relational, leading to the production of new, distinctive and reproducible research. The collaborations establish strategic advantages for the technology diffusion process by reinforcing knowledge transfer channels and creating more opportunities for both academia and industry, including more resources and equipment. (Berker and Kvellheim, 2018; Kim, 2013; Tseng, et al, 2020; Vick and Robertson, 2018).

The dynamics of knowledge transfer has received more attention and is a priority for science and innovation policy developments in recent years (Vick and Robertson, 2018). Collaboration furthers the development of both industries' and academics' technological capabilities (Boardman and Ponomariov, 2009), as the patenting process is highly social and nonlinear. This means that the continual formal and informal interaction between academics and industry allows both sectors to learn and make improvements (Bradley, et al., 2013; Klein and Rosenberg, 1986; Meyer, 2002; Verbeek, et al, 2002). Academic-industry collaboration encourages innovative development by giving academic inventors access to better resources that facilitate productivity and innovativeness including substantial advice from practicing experts and new tools used in scientific and technological fields (Boardman and Ponomariov, 2009; Katz and Martin, 1997; Tseng, et al, 2020). Collaborating on patents also allows academic scientists to focus more on developing fundamental, scientific understandings without the same pressure to spend time on commercialization because their industry partners have greater commercial expertise (Bikard, Vakili, and Teodoridis, 2019; Fabrizio and Di Minin, 2004; Miller, et al, 2018). Industry also gains from the collaborations by improving their theoretical understandings while helping academics learn more practical knowledge (Hurmelinna, 2004), and gaining access to novel scientific developments relevant to their product and process stream that can give them market edge (Boardman and Ponomariov, 2009; Bozeman and Crow, 1991).

Past literature uses a more simplistic and traditional view of patenting, leaving out key relational context, e.g., behavior and perceptions. The literature mainly stresses academics engaging in formal knowledge transfer channels rather than informal ones, and yet informal channels tend to have a greater impact for knowledge creation (Balven, et. al, 2018; Banal-Estañol, et al, 2015; Meyer, 2000a; Miller, et al, 2018). Balven, et al (2018) argue that to better understand academic entrepreneurship it is important to examine informal knowledge and technology transfer processes, which is not often available in annual public reports and other datasets. These informal channels include networking with firms, ad hoc advice, and pairing students with practitioners while formal channels include more contract research, and consulting (Perkmann, et al; 2013; Perkmann, and Walsh, 2008). The dataset used in this study combines publicly recorded data with survey data to better get at informal pathways and other inventor behaviors.

Other key relational characteristics the literature points to are prior experience and perceived orientation barriers. Continual collaboration with industry creates trust and ease in the patenting process, increasing the likelihood of engaging in other knowledge transfer activities (Aydemir, et al, 2022; Garcia, et al, 2019; Miller, et al, 2018). Orientation-related barriers include any differences in incentives and orientation between academics and industry that can lead to internal conflict for collaborations (Bruneel and Salter, 2010; Vick and Robertson, 2018). Tartari et al. (2012) finds a positive association between prior experience working with industry and low perceived orientation barriers between academics and industry, which this study applies to knowledge flow outcomes. It is important to consider negative effects of industry involvement and barriers to new knowledge creation between the two sectors.

Patents and Patent Citations

Patents are one of the many important academic innovation measures that matter for public value, as they are inputs to innovation and lead to the introduction of new products and services, production methods, and methods of organization. According to the USPTO website, a patent can be provided for any process, machine, article of manufacture, composition of matter and improvements to previous inventions in these categories that are novel, non-obvious and useful (General information concerning patents, 2021). Patents are research outputs that inspire further scientific research and commercially viable technologies (Kolympiris and Klein, 2017).

When patents are awarded, the applicant discloses any “prior art” used in their inventive process that distinguishes the invention from other innovations (Higham, De Rassenfosse, and Jaffe, 2021; Marx and Fuegi, 2019). The inventive process encompasses any effort made to create new ideas and make them work, while innovations include any ideas or inventions that are being converted for useful application (Haeussler and Assmus 2021; Roberts, 1988). The citing patent shows what existing knowledge there is related to the innovation through the cited patents, thus reflecting the origin of the technology as well as the trajectory of the knowledge flows (Érdi et al, 2013; Jaffe, Henderson and Trajtenberg, 1993; Ji, Barnett, and Chu, 2019).

Patent citations have consistently been used in the literature as an indicator of innovation and knowledge flows by reflecting the transfer of information between patents and organizations (Azagra-Caro and Consoli, 2016; Higham, et al, 2017; Ji, Barnett, and Chu, 2019; Kolympiris and Klein, 2017; Roach and Cohen, 2013). High patent citations imply greater knowledge flows beyond academic science, as they can be used to track information channels between academic science and industry technological fields (Higham, et al, 2017; Jaffe and Trajtenberg, 1999; Meyer, 2000b; Meyer, 2001). Previous work has used patent to patent citations as a way to track useful information for further scientific development, which highlights the importance of the details of the patenting process (e.g., collaboration and industry involvement) (Azagra-Caro and Consoli, 2016; Jaffe, Henderson and Trajtenberg, 1993; Jaffe, and Trajtenberg, 1999; Meyer, 2000b; Meyer, 2001; Roach and Cohen, 2013). Patents that are cited more often by later patents suggest that they are technologically important and contain key ideas that later inventors can build upon. Highly cited patents may also occupy a newly discovered scientific frontier, which attracts other inventors to utilize the innovations later on or sparks new ideas, indicating key knowledge flows (Higham, De Rassenfosse, and Jaffe, 2021; Narin. 1993; Yoon and Kim, 2011).

While there are challenges to using patent citations to measure knowledge flows, previous work (e.g., Barberá-Tomás et al., 2011; Ji, Barnett, and Chu, 2019) has corroborated the value and usefulness of the methodology. Research on citation networks finds that patent citations have lower levels of redundancy in information flow compared to academic paper citations (Collins and Wyatt, 1988; Higham, et al, 2017). The smaller amount of redundancy is due to the more controlled legal examination of patents and close ties between citation dynamics and knowledge flows, especially in patent collaborative networks (Collins and Wyatt, 1988; Higham, et al, 2017; Verbeek, et al, 2002). Patent citations for this study include any citations by future patent applications that were included as prior art by the applicant, attorneys, and examiners. These citations can be used to distinguish differences and demonstrate originality and novelty between two or more patents (Higham, De Rassenfosse, and Jaffe, 2021).

Nonetheless, there are still limitations to using solely bibliometric data such as patent citations as a measure of knowledge flows because citations tend to be multifaceted and complex (Meyer, 2000a; Verbeek, et al, 2002). For one, highly cited patents might simply reflect areas of high technological competition in the marketplace. So, this essay overcomes this limitation by matching the bibliometric data with survey data about both sectors' activities to better understand the relational characteristics involved in the patent process and knowledge flow outcomes ten years after the patent is filed.

Academic-Industry Collaboration Characteristics

Academic-industry collaborations impact the quality of the scientific research outcomes, as they entail important interactive social processes. Stronger relational ties through multiple channels and low perceived barriers influence the usefulness of available knowledge flows. While much of the literature evaluates knowledge transfer activities in isolation (Balven, et. al, 2018; Hayter, et al, 2020), the study includes multiple pathway characteristics to give better insights into the patenting collaborations and its relationship to knowledge flow outcomes.

Formal and Informal Collaboration Activities

One way to examine academic-industry collaborations is to look at the different types of collaboration activities academic scientists engage in(e.g., consulting, contract arrangements, and connecting students). Various types of interactions take place between academic and industry professionals that can act as knowledge channels, such as supervising students in business incubators or providing information to industry. The range of interactions provides a more complete picture of the knowledge transfer flows involved in academic patenting, which can be picked up by later patent citations (Thursby and Thursby, 2011; Vick and Robertson, 2018).

The many types of interactions between academics and industry can be divided into formal and informal knowledge transfer activities, which interact over time and can influence knowledge flows differently (Bercovitz and Feldman, 2006; Bradley, et al, 2013). Formal activities in this case are usually contract based (Vick and Robertson, 2018) and thus, are more industry-oriented (e.g., paid consultant, affiliated with the firm, etc). According to Nsanzumuhire and Groot (2020), formal channels of interaction are considered the least important and preferred, as they may simply reinforce more rigid established links without providing new information and opportunities. Academics engaging in mainly formal industry activities are encouraged to develop more strictly applied patents that are shaped by the firms' internal strategies and interests (Vick and Robertson, 2018), rather than more fundamental research that is novel and can spark further knowledge creation.

Informal activities that are more university-oriented are considered to be more important knowledge transfer channels as compared to more formalized ones (Banal-

Estañol, et al, 2015; Miller, et al, 2018). Informal activities tend to be based on knowledge not protected by intellectual property (IP) and can allow for greater information dissemination such as by giving informal advice on how to solve problems (Carlile, 2004; Hughes, 2011; Vick and Robertson, 2018). Academia-industry informal university-oriented activities include connecting graduate students to industry jobs, consultancy, and co-authoring papers (Miller, et al, 2018). Academics involved in patenting activities are often also engaging in other informal industry relationships. These continual informal interactions allow for new and less redundant information transfer opportunities and for greater trust, leading to future collaboration and information sharing efforts (Aydemir, et al, 2022; Vick and Robertson, 2018). These informal activities serve as boundary spanners that provide more knowledge spillovers (Swan et al, 2007; Vick and Robertson, 2018) and for academics to have the freedom to focus on scientifically significant research without as many contract obligations.

H1a: The lead academic inventor on the patent having high levels of formality during research with industry will be negatively associated with the number of patent citations over time.

H1b: The lead academic inventor on the patent having high levels of informality during research with industry will be positively associated with the number of patent citations over time.

Prior collaboration experience

Academic inventors' prior experience collaborating with industry before patenting can be a useful predictor of future involvement in knowledge transfer and entrepreneurship activities (Hayter et al, 2018; Kolympiris and Klein, 2017; Miller et al, 2018). Inventors' past experience collaborating with industry is a measure for the quality of the researcher and the strength of their ties to industry (e.g., Rybnicek and Königsgruber, 2019; Taheri and van Geenhuizen, 2016). Nsanzumuhire and Groot (2020) argue that continual interactions between academics and industry is one of the best methods for new knowledge creation and transfer. Continual collaboration builds trust and expertise in the process, which increases the likelihood of engaging in other knowledge transfer activities such as creating more shared outputs and projects to improve the innovation (Aydemir, et al, 2022; Miller et al, 2018; Rybnicek and Königsgruber, 2019). Continual collaboration also decreases the required time for success due to increased expertise (Taheri and van Geenhuizen, 2016), leading to viable and higher quality outputs that can inspire new future innovations. As well, industry may choose to continue to collaborate with researchers they deem as promising and who have had success in their previous collaborations (Chesbrough, 2003; Hurmelinna, 2004). The essay expects:

H2: The lead academic inventor having prior industry collaboration experience before the patenting process will be positively associated with the number of patent citations over time.

Perceptions of Industry Collaboration Conflicts

Academics’ perceptions of barriers or conflicts with industry involvement in their research can impact the success of the collaboration and the creation and diffusion of new knowledge. Academia and industry are two distinct systems of knowledge production that have different institutions and norms about sharing information and production expectations. Industry utilizes market logic, which emphasizes protecting intellectual property to maintain profits and focusing on more applied research. While academic inventors’ logic holds that knowledge production, reputation and education are key to further innovation and scientific progress (Aydemir, et al, 2022; Drivas, et al, 2017; Vick and Robertson, 2018). Given these different norms and values, obstacles can occur in managing industry-university collaborations if there is weak attitudinal and cultural alignment (Hughes, 2011; Garcia, et al, 2019; Vick and Robertson, 2018). Research points out the importance of orientation-related barriers, which are differences in incentives and orientation between the two parties (Balven et al, 2018; Bruneel and Salter, 2010; Tartari, et al, 2012; Siegel, et al, 2003; Vick and Robertson, 2018). Orientation-related barriers can lead to internal conflict, less information and resource sharing and lower outcome success. Scientists’ perceived value conflicts can undermine collaboration efforts, diminish their motivation in the patenting process and reduce their likelihood to work together further and share key information (Balven et al, 2018; Nsanzumuhire and Groot 2020).

H3: The lead academic inventor having high levels of perceived collaboration conflicts with industry will be negatively associated with the number of patent citations over time.

Interaction between prior experience and perceptions

While higher levels of perceived conflict weaken collaboration between academia and industry (Balven et al, 2018; Nsanzumuhire and Groot 2020), this is not a strictly linear relationship. Perceived orientation-related barriers can lessen over time as the academic inventors engage more with industry. Prior experience working with industry on commercialization projects is associated with lower perceived value conflicts (Perkmann et al, 2013; Tartari et al., 2012), which in turn can increase knowledge flows between the two sectors. By increasing trust, openness and ease with the patenting process, academics tend to change their perceptions about industry and engage in other knowledge transfer activities (Aydemir, et al, 2022; Miller et al, 2018; Perkmann et al, 2013).

H4: The lead academic inventor having prior patenting experience will perceive lower levels of collaboration conflicts with industry.

Data and Methods:

The study uses data from the 2010 National Survey on Intellectual Property in Academic Science and Engineering matched with patent citation information from Google Patents, as described in the introduction chapter. The survey asks science and engineering inventors about their patent development especially during the early stages of the process. The survey data was matched to the publicly available data on the number of patent citations for 2019, around 10 years after the survey. This gap in time was chosen to fully capture the knowledge exchange, as the creation of future patents can take a lot of time and resources (Feldman, et al, 2021; Fini et al., 2018; Hayter et al., 2020).The number of patent citations was found and included for a total of 844 inventors, however, due to unusable answers and partial responses, only 729 inventors were used in the models. These two data sources were matched in order to understand how early development collaboration characteristics influence patent knowledge flow outcomes later on in the academic's career.

Dependent and independent variables

To test my hypotheses, the study operationalizes one count dependent variable, the **Number of patent citations** for each inventor in the sample. The publicly available patent citation data comes from Google Patent. The science and engineering inventors' patent USPTO identification was used to match the citation and survey data. On average, inventors in the sample have 39 citations (SD=68.62). Figure 1 shows that the distribution of the count variable is highly skewed to the right and so using OLS regression is not appropriate in this case.

The independent variables of interest are behavioral, and perception measures that account for the many possible types of interactions between the academic inventors and their industry collaborators. The first measures are formal and informal knowledge transfer activities between academic inventors and industry. The two variables are the count of the answers to the following survey question. Thinking about the past two years, in which of the following ways have you worked with industry and industrial scientists. The detailed survey items for all independent variables can be seen in table 1. The **Formal industry-oriented activities** variable has a mean of 1.18 (SD=1.11), and the **Informal university-oriented activities** variable has a mean of 2.18 (SD=1.56).

The variable **Prior industry collaboration** measures whether the inventor has worked with industry prior to working on the patent. The survey asked if during the past 2 years, have you collaborated on research with industry scientists? (Yes “1” or No “0”). About 64% of respondents have prior industry collaboration experience (SD=0.48). Inventors’ perceptions of collaboration conflicts are the inventors’ views concerning any barriers and value misalignments that academic-industry collaboration can present. The **High conflicts** variable is measured using a binary transformation of the answers to the following survey question (details in table 1).

Figure 1. Distribution of Patent Citations

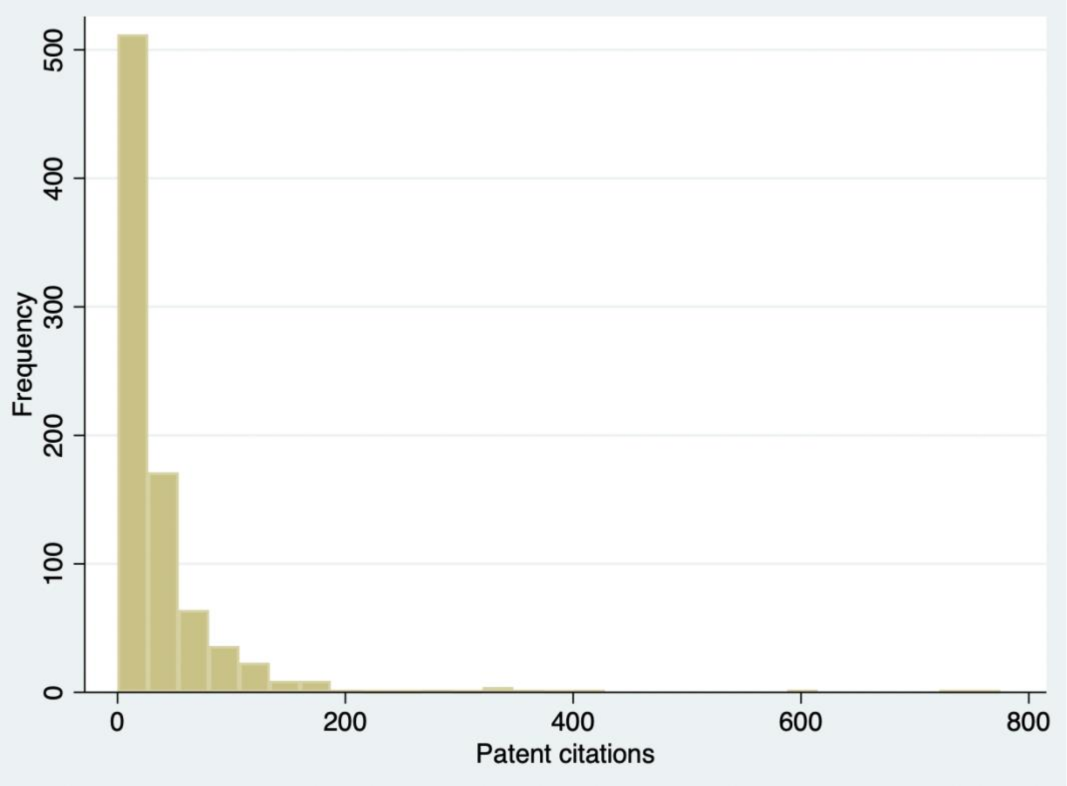


Table 1 Survey Items for Independent Variables

Survey item	N	Mean	SD	Min	Max
Formal industry-oriented activities					
I worked as a paid consultant to an industrial firm	844	.48	.50	0	1
I worked directly with industry personnel on work that resulted in a patent or disclosure.	844	.37	.48	0	1
I was affiliated with a private company either as an owner (e.g. with your own company), employee, or board member.	844	.38	.48	0	1
Informal university-oriented activities					
I have provided information to industry about my research without compensation	. 844	.80	.40	0	1
I helped place graduate students or post-docs in industry jobs	844	.68	.47	0	1
I supervised a student working in a university technology-based business incubator.	844	.45	.50	0	1
I jointly wrote a research proposal with scientists from a private company.	844	.15	.35	0	1
I co-authored a paper with industry personnel that has been published in a journal or refereed proceedings	844	.46	.50	0	1
Prior industry collaboration					
During the past 2 years, have you collaborated on research with industry scientists?	844	.54	.50	0	1
High conflict					
Industry support of research leads to greater emphasis on applied research	832	2.99	.84	1	4
Industry support of research enhances intellectual exchange and cooperative activities within departments (REVERSE).	828	2.83	.76	1	4
Industry support of research creates conflict between faculty who support and oppose such activities	832	2.89	.84	1	4

Control variables

The model controls for other factors that might influence publishing outcomes at the individual and institutional levels. Basic demographic information is important for understanding academic entrepreneurship and patent knowledge flows (Hayter, et al, 2018). Because there are documented gender differences in patenting in the literature (Azoulay, 2009; Haeussler and Colyvas, 2011), the study includes a dummy variable indicating if an inventor is **Female**. Around 18% of the inventors who completed the survey are female (SD=0.39). Respondents were asked about their primary academic discipline. To account for life-cycle effects (Levin and Stephan, 1991), the **Number of years since earning a PhD** is included in the model. On average, it has been 34 years since the academic inventors have received their PhDs (SD=12.10). Around 18% of the inventors who completed the survey are female (SD=0.39).

The inventors' discipline is important for entrepreneurship outcomes, as research focus is related to the novelty of the knowledge being transferred (Hayter et al, 2020; Hayter et al, 2018). IP outputs such as patents are associated with biological life sciences (Fini et al. 2010; Kenney and Patton 2011) and to a lesser extent associated with physical sciences and some relevant disciplines such as physics and engineering (Nelson, 2014; Hayter et al, 2018). Respondents to the survey were asked about their primary academic discipline. Twenty-two specific science disciplines are grouped together to create three dummy variables: on average, 54% are in the **Biological sciences** (SD=0.50), 30% are in **Engineering** (SD=0.46), and 12% are in **Physical sciences and math** (SD=0.33).

The model also includes controls representing the quality of the academic inventors and their research, as this could be a possible confounder and strong predictor of knowledge flows (Hayter et al, 2018; Zucker et al. 2002). Inventor quality is also important to control as it is common for industry to reach out to the more productive academic scientists and vice versa, which can confound the model (Ankrah, et al, 2013). Additionally, the perceived value of the inventor's patent matters for patent citations depending on the level and type of significance or applicability (Kolympiris and Klein, 2017). The survey asks on the following scale, please rate the level of commercial significance of this patent (1 is low and 10 is high). On average the **Commercial significance** is 6.8 (SD=2.45).

Also, publication activities are typically positively related to patenting as it is a proxy for human capital and is positively related to various entrepreneurial outcomes including co-publication with industry researchers and patenting (Hayter et al, 2018). Though this positive relationship tends to decline with an increasing number of parents by the inventor (Fabrizio and Di Minin, 2004). The essay includes measures of both total **Number of patents** and **Number of articles** in the model to account for this relationship and its impact on patenting achievements. On average, inventors in the sample are awarded seven patents (SD=15.15) and have a total of nine peer reviewed journal articles published (SD=9.37). Research finds mixed results when it comes to using the number of patents as a measure because growth in patenting is often accompanied by a decline in the quality of the patents (Hicks et al, 2001; Bradley, et al, 2013).

More inventor quality controls include receiving tenure and overall academic workload. I control for whether the academic is **Tenured** with a dummy variable that equals one if they are and zero otherwise. On average, 65% of the inventors in the sample are tenured (SD= 0.48). Another researcher quality control included is **Academic**

workload, which is the averaged scale of responses to the survey question during the past academic year, how many (0 1 2 3 4 5 or more) (details in Appendix C). Academic workload ranges from 1 to 6 with an average of 3.10 (SD=1.03). Cronbach's alpha for the scale is 0.61.

Other important measures for academic inventor and patent quality relate to academic inventors' relationship with industry. The timing of the industry involvement indicates whether the patent is more use-inspired or applied. Inventors collaborating with industry during the early research development stage implies that their research is sparking innovation (Kline and Rosenberg, 1986) and gives inventors opportunities to gain further insight during the process and increases the patent's novelty and immediate practical use (Aydemir, et al, 2022; Hulme, 2014). In comparison, industry deciding to get involved post research may indicate that the invention is more applied (e.g., directed toward a particular group) and economically focused (Bentley, et al, 2015; Stokes, 2011). The survey asked respondents to select the statements that best reflect their relationship with industry on the research underlying the patent. **During research development** is if industry was brought in during early development and equals 1 if the respondent selected that industry scientists or engineers collaborated on the research underlying this patent, 0 otherwise. Around 15% of academic inventors collaborated with industry in time one (SD=0.35). **While research is underway** is if industry showed early interest and equals 1 if the respondent selected that someone from industry showed interest in this research while it was underway, 0 otherwise. About 53% of academic inventors collaborated with industry while research is underway (SD=0.50). **After first publication** is if industry showed interest post-research and equals 1 if the respondent selected that they received my first inquiries from industry after publishing one or more articles on this research, 0 otherwise. Around 37% of academic inventors collaborated with industry after first publication (SD=0.35).

Industry funding is a key aspect of the patenting process and a common indicator of the strength of the ties between the academic and their industry collaborator in the literature (Aydemir, et al, 2022; Lowe and Gonzalez-Brambila 2007). The measure **Funding** is the percentage of research funds the inventor receives from industry-sponsored grants, contracts, and cooperative agreements as compared to other contributors. On average, 14% of the inventor' total funding comes from industry (SD=21.15). Licensing of patents is an agreement between the patent owner (the licensor) and the company that wants to use the patent (the licensee) (Friedman and Silberman, 2003). Licensing is positively related to the number of patent citations (Sampat and Ziedonis, 2004). The variable **License** measures whether the patent was licensed within two-three years of patenting (Yes "1" or No "0"), and on average, 74% of respondents said their patent was licensed (SD=0.44). As for **Royalty payments**, only 35% of the sample disclosed receiving any royalties from their patents (SD=0.48).

Research shows that institutional context and culture can affect patenting through various channels (Azoulay, 2009; Stuart and Ding, 2006; Hayter et al, 2018). inventors at more prominent universities tend to be more productive due to the availability of more resources and access to high-quality peers (Azoulay, 2009). **TTO-Firm involvement** measures whether the TTO office has worked with a company to further develop the invention for commercial use, which equals 1 if the university's technology transfer office has worked with a firm on this invention, 0 otherwise. On average, 32% of the patents have university technology transfer offices that have worked with a company on commercializing the patent (SD=0.47). The descriptive statistics for all variables in the models are in table 2.

Empirical Strategy

In order to measure the value of the research outcomes and to determine the importance of knowledge creation, the study looks at the relationship between industry involvement at early stages of development and knowledge flow outcomes around ten years later. To test the hypotheses, the study runs two regressions: model 1 for the first four hypotheses and model 2 for all hypotheses (including the interaction). The dependent variable is a count measure, the number of citations, and so the Poisson or negative binomial maximum likelihood methods are most appropriate (Cameron and Trivedi, 1998). The Poisson regression has strong assumptions that there is no over-dispersion of the dependent variable. While the negative binomial regressions adjust for inflated variance and accounts for when the dependent variable is over-dispersed (Hilbe, 2007). Additionally, a zero-inflated negative binomial estimation (ZINB) may be required if the dependent count variable includes excess zeros (Yau *et al.*, 2003; Hilbe, 2007). ZINB is typically used when there are high numbers of zeros in the count distribution.

Table 2: Descriptive Statistics for Essay One Variables

Variables	N	Mean	SD	Min	Max
Dependent variable					
Patent citations	844	39.08	68.62	0	775
Independent variables					
Formal industry-oriented activities	844	1.18	1.11	0	3
Informal university-oriented activities	844	2.18	1.56	0	5
Prior experience	844	0.64	0.48	0	1
High conflict	844	0.75	0.43	0	1
Controls					
Female	844	0.13	0.33	0	1
Number of years since earning	798	36.42	11.92	13	77
Biological Sciences	844	0.54	0.50	0	1
Engineering	844	0.30	0.46	0	1
Physical Sciences and math	844	0.12	0.33	0	1
Commercial significance	844	6.77	2.46	1	10
Number of Patents	844	10.17	17.95	1	201
Number of articles	844	23.47	25.01	0	249
During research development	841	0.15	0.35	0	1
While research is underway	837	0.53	0.50	0	1
After first publication	832	0.37	0.48	0	1
License	844	0.57	0.50	0	1
Funding	844	12.87	26.86	0	100
Royalty payments	811	0.54	0.50	0	1
Tenured	834	0.65	0.48	0	1
Academic Workload	842	3.12	1.09	1	6
TTO-Firm involvement	840	0.37	0.48	0	1

To determine the most appropriate model fit, the first step is to test whether the dependent variable is over-dispersed. The Poisson goodness-of-fit test in STATA version 15.1 determines whether the dependent variable was over-dispersed. The essay rejects the null hypothesis that the mean equals the variance (a characteristic of the Poisson, $p<.001$) and finds the negative binomial regression to be more suitable for both models. Next, the study tested if the zero-inflated negative binomial estimation was more appropriate by comparing the Akaike's information criterion (AIC) and the Bayesian information criterion (BIC). Both the AIC and BIC were lower for the negative binomial regression for both models (m1:AIC=5900, BIC=5998; m2: AIC=5931, BIC=6113) as compared to the ZINB (m1: AIC=5936, BIC=6127; m2: AIC=6765, BIC=6862).

The test results suggest that the negative binomial estimation method is the preferred method for the given data where: $E(Yi) = \lambda i = \exp(Xi\,\beta)$. λ represents the expected value of citation counts for patent i and Xi is the vector of variables predicting patent knowledge flows. β is the vector of the coefficients from the maximum likelihood estimated regression (Greene, 2003).

Results:

I present the results for each hypothesis, discussing the relationships between the predictors and the measure for knowledge flows. The results are shown in table 3. The research finds partial support for hypothesis 1. Hypothesis 1a, which states that higher levels of formality during research between academic inventors and industry will be negatively associated with patent citations, is supported (m1: $\beta=-0.12$, p-value=0.06; m2: $\beta=-0.12$, p-value=0.05). While there is no significant relationship found for hypothesis

1b, higher levels of informality during research between academic inventors and industry are positively associated with patent citations.

The research finds support for hypothesis 2. Academic inventors with more prior industry collaboration experience are positively associated with patent citations (m1: $\beta=0.28$ p-value=0.05; m2: $\beta=0.67$, p-value<0.00). Hypothesis 3 is also supported in model 2. Higher levels of perceived conflict during research between academic inventors and industry are negatively associated with patent citations (m1: $\beta=-0.23$, p-value=0.09). The research finds support for hypothesis 4 in model 2. The interaction term shows that academic inventors that have prior patenting experience perceive lower levels of collaboration conflicts with industry, which is negatively associated with patent citations (m2: $\beta=-0.56$, p-value=0.02).

Seven of the controls are statistically significantly related to patent citations in both models: commercial significance, number of patents, if the patent is licensed, industry funding, royalty payments, tenure status, and TTO firm involvement. The patent's commercial significance, the inventor's number of previous patents and are negatively related to the patent citations. If the patent is licensed, industry funding, receiving royalty payments, being tenured, and the university TTO office working with the firm are positively associated with patent citations. Interestingly, the four scientific fields included are not statistically significant, even though both the literature and essay three interviews point to their importance. Due to this, I decided to take a different approach to field differences in the next chapter, essay two.

Discussion:

These results have important implications for theory, practice, and policy including the design of university policies aimed at fostering university–industry relationships and increased knowledge sharing. While the findings confirm that academic-industry collaboration is important for greater knowledge flows and reach of the innovations (Higham, et al, 2017), the relationship depends on important relational and nonlinear collaboration characteristics, which are often overlooked. The key relational characteristics shown in this study to impact patent citations are formal versus informal knowledge transfer channels, prior patenting experience and perceived orientation barriers between industry and academia. While the literature more commonly stresses academics engaging in formal knowledge transfer channels (Balven, et. al, 2018; Miller, et al, 2018), this research shows that it is important to look

Table 3: Negative Binomial Regressions Predicting Patent Citations Essay One

	(1) Model 1	(2) Model 2
Formal industry-oriented activities	-.12*	-.12*
	(.06)	(.06)
Informal university-oriented activities	.06	.07
	(.05)	(.05)
Prior industry collaboration	.28*	.68***
	(.15)	(.23)
High conflicts	-.23*	.20
	(.13)	(.16)
Interaction		-.66***
		(.24)
Years since earning a PhD	0	0
	(.01)	(0)
Female	.02	.01
	(.14)	(.14)
Biological Sciences	-.01	-.01
	(.12)	(.12)
Physical Sciences and math	.18	.19
	(.16)	(.16)
Commercial significance	-.04**	-.04**
	(.02)	(.02)
Number of Patents	-.01**	-.01**
	(0)	(0)
During research development	-.13	-.16
	(.13)	(.14)
While research is underway	.13	.16
	(.11)	(.11)
After first publication	-.20*	-.24**
	(.11)	(.1)
License	.30***	.32***
	(.11)	(.11)
Funding	.01**	.01**
	(0)	(0)
Royalty payments	.24**	.21*
	(.12)	(.12)
Tenured	.42***	.38***
	(.14)	(.13)
Academic Workload	.07	.08
	(.05)	(.05)
TTO-Firm involvement	.18**	.18**
	(.07)	(.07)
_cons	2.79***	2.54***
	(.36)	(.35)
/lnalpha	.19***	.18***
	(.05)	(.05)
Observations	729	729
Pseudo R^2	.01	.02

Robust standard errors are in parenthesis. Reference category: Engineering

**** p<.01, ** p<.05, * p<.1*

at the differences between formal and informal channels. The level of formality has implications for the type of relationship between the academic and industry collaborators and how familiar they are with one another. Higher informality implies better information exchange and knowledge sharing, which over time leads to inventions with a greater scientific reach and impact. However, the results are only significant for formal information channels. This suggests that if formal contracts and transactions lead to less information flow, the real issue is that universities may be spending more time contracting for research and less time producing outputs that are disseminated broadly to society. Deliberate privatization may produce lower quality patents, while trusted collaboration with industry may not suffer in the same way.

Prior collaboration experience at the early development stage is positively associated with more later patent citations, which is consistent with expectations. Non-academic experiences are typically predictive of academic scientists' entrepreneurial activity (Hayter, et al, 2018). Continual interactions between academics and industry increases knowledge transfer, builds trust and expertise in the process (Nsanzumuhire and Groot 2020; Rybnicek and Königsgruber, 2019). Similarly, the relationship between inventors' perceptions of collaboration conflicts and knowledge flows is consistent with expectations. Academic science and engineering inventors with high perceptions of collaboration conflicts are negatively associated with patent citations. The orientation-related barriers are the differences in incentives and orientation between the involved actors. The finding lends support to the growing evidence that orientation-related barriers impact knowledge flows (Bruneel and Salter, 2010; Tartari, et al, 2012; Vick and Robertson, 2018) and that there are negative impacts to these interactions. However, prior experience and negative collaboration perceptions do not exist in a vacuum, rather they are related to one another. The findings show that perceptions of value conflicts can lessen due to prior collaboration experience, leading to higher patent citations down the line.

Practical implications include creating more university policies to encourage academic-industry engagement practices, and increased training and resources to reduce perceptions of conflicts to collaboration. Possible future research areas include (i) looking at other barriers to academic-industry collaboration besides value conflicts and how they impact citation counts, (ii) using other measures for knowledge transfer to confirm the results. Less attention is given to the consequences of academic engagement when the participants are not on the same page and have less experience working together. Thus, research would benefit from looking at other barriers and how these barriers interact with prior parent experience. Additionally, there are multiple ways to measure knowledge sharing between academia and industry besides citation counts including other innovation outcomes (i.e., startups). In general, the study shows that the social context of academic-industry collaborations is important and often leads to a nonlinear relationship with knowledge flows between the two sectors.

CHAPTER 3

ESSAY TWO: STEM collaboration practices: how academic patent networks influence knowledge flows

Introduction:

Science and technology (S&T) faculty at US research intensive universities are encouraged through legislation and university-based incentives (e.g., Bayh-Dole Act) to create new knowledge, patent their inventions and pursue commercialization opportunities for resulting innovations (Colyvas, 2007; Rhoten and Powell, 2007). The creation of innovations and new knowledge is critical for advancing public science (knowledge produced by universities, government funding, etc.), which is a social mission that leads to societal benefits such as economic spillovers and global competition (Ács and Audretsch, 1990; McMillan, et al, 2000; Partha, and David, 1994; Romer, 1990). To pursue their innovations successfully along with their other academic commitments, faculty must consolidate their resources and use their time effectively. Networks are one way to save time and gain the necessary resources to transfer knowledge and advance scientific development. Information and collaboration networks are important for the production and diffusion of new knowledge; these networks reduce research infrastructure costs, help to integrate existing knowledge, and increase the usefulness and influence of new ideas (Breschi and Lissoni, 2004; Tahmooresnejad and Beaudry, 2018).

Focusing on one innovation output (patents), academic collaboration networks during the patenting process provide new scientific knowledge, connections between scientists, and technological opportunities (Azagra-Caro and Consoli, 2016; Higham, et al, 2017; Roach and Cohen, 2013). Thus, the structure and composition of the academic patent networks can influence knowledge flows, which contribute to overall S&T advancement (Lata, et al, 2015). Network structure outlines the pattern of network member relationships, and network composition encompasses the types of actors within a network including their features and resources (Phelps, 2010; Wasserman and Faust, 1994). Both types of network characteristics can influence knowledge flows, the dispersion of ideas between individuals or groups (Azagra-Caro and Consoli, 2016; Tseng, et al, 2020). A common way to measure direct network collaborations in the patent literature is to look at co-patents (i.e., multiple inventors on a patent), which represents an important part of the overall knowledge networks (Lata, et al, 2015; Leydesdorff and Meyer 2002). Focusing solely on co-inventors and not specifying industry involvement can exclude observing knowledge flows between academia and industry through other means such as licensing and informal activities. Excluding industry links leaves out important information as the private sector often encourages academic researchers to adjust their research agendas and can provide new resources (Cheah, et al, 2019; David, Mowery and Steinmueller, 1994).

To emphasize industry involvement in academic networks, this essay leverages data on network collaborations that include co-inventors and specifying industry partners across different disciplines to answer: How do patent network structure and composition impact patent citations? By examining how network collaborations span the public and private sectors through collaborative ties, I gain insight into how the mixing of the two sectors matters for knowledge flows and the advancement of academic science. This study uses data from a 2010 national survey of university scientists and engineers matched with publicly available network and patent citation data from 2019 to answer the following research question: how does the structure and composition of the co-patent inventor networks affect patent citations? This study tests 2019 patent citation outcomes on network characteristics from ten years prior to fully capture the knowledge exchange, as it can take time to come to full fruition (Fini et al., 2018; Hayter et al., 2020).

The rest of the essay is organized as follows. I begin with a review of the literature on collaboration networks in the patenting process and industry involvement. Next, I present my hypotheses based on the literature. Then I describe the data and methods and present the empirical results. I conclude with a discussion of the results and their implications for network practices, knowledge flows and university policies to encourage academic and collaborative patenting.

Literature Review:

Patent citations and the patenting process

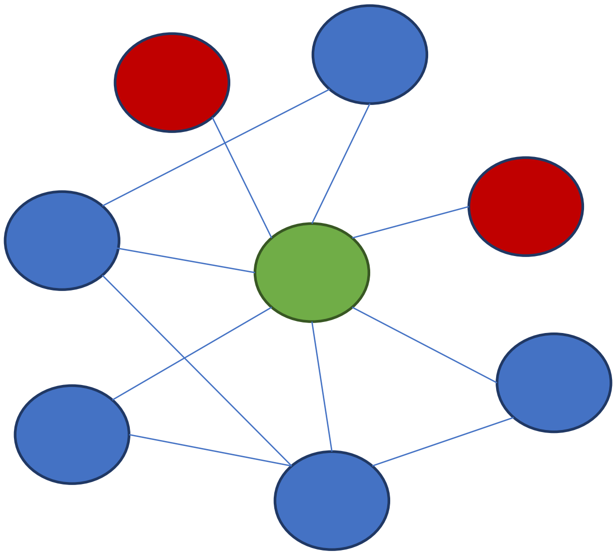
As academic collaboration networks used in the patenting process improve innovation outcomes by providing new information and resources, patent citations serve as a reliable measure of knowledge flows (Azagra-Caro and Consoli, 2016; Higham, et al, 2017; Roach and Cohen, 2013). Academic patents are research outputs such as any process, machine, or composition of matter and improvements to previous inventions that are novel and useful (General information concerning patents, 2021). As such, patents contain S&T information about new inventions that later patents build upon depending on the novelty, field influence and usefulness (Azagra-Caro and Consoli, 2016; Narin, 1993). Patent citations convey the trajectory of the knowledge flows related to the patents across networks and organizations (Érdi et al. 2013; Ji et al, 2019) and are consistently used in research as an indicator of innovation and knowledge flows (Azagra-Caro and Consoli, 2016; Higham, et al, 2017; Ji, Barnett, and Chu, 2019; Kolympiris and Klein, 2017; Roach and Cohen, 2013).

Additionally, the literature shows how patent citation data can be used to understand key details of the patenting process, including collaboration and industry involvement (Azagra-Caro and Consoli, 2016; Jaffe, Henderson and Trajtenberg, 1993; Jaffe, and Trajtenberg, 1999; Meyer, 2000b; Meyer, 2001). Other research on networks shows that patent citations have less redundancy when it comes to measuring information flow as compared to other measures like academic paper citations due to the controlled legal examination of patents (Collins and Wyatt, 1988; Higham, et al, 2017).

Collaboration networks influence on knowledge flows

To better understand how patent network collaborations influence knowledge flows, social network data and metrics provides a useful perspective. Social network metrics are commonly used to view the relationship between network members and have gained relevance in scientific context (Meng, et al, 2016; Tahmooresnejad and Beaudry, 2018). Networked social ties can span organizational boundaries to transfer knowledge and diversify skills, and can enhance the learning and adaptive practices involved in the patenting process (Bozeman et al., 2001, Dietz and Bozeman, 2005, Heinze and Bauer, 2007; Meng, et al, 2016). Information and collaboration networks for patents are made up of nodes (inventors on a patent) and ties (the cooperation between co-inventors while working on a patent). This essay focuses on personal or ego-centric networks where an ego is the primary inventor node that is of current focus and the alters are the other connected inventor nodes (Perry, et al, 2018). These ego invention networks capture structural features that influence knowledge flows (Marin and Wellman, 2010; Meng, et al, 2016). Figure 2 is an example of the ego-centric invention networks, which include all connections (co-authors and industry partners) at time zero (i.e., before and when the patent was granted) for the 2007 academic patents and their impact on 2019 patent citations. This gap in time allows knowledge exchange to be captured, as timing matters for networks and it can take time to see the effects of the information flows (Feldman, et al, 2021; Fini et al., 2018; Hayter et al., 2020).

Figure 2: Ego-centric Network



Ego centric network of co-inventors (all authors on the patent)

- Ego is in green,
- Alters are in blue,
- Red is industry.

The structural dimensions of networks include the strength of the different network ties and patterns between the nodes, emphasizing density or connectivity (Jha and Welch, 2010; Nahapiet and Ghoshal, 1998). Density, also called the clustering coefficient in personal network analysis, is a fundamental network structural characteristic that measures the strength of the ties or connectedness of alters in a network (Chang, 2021; Parker and Welch, 2013; Perry, et al, 2018; Rizzuto, et al, 2009). For ego-centric networks, density is [n ties/n-1 possible ties] and is also a measure of structural holes, by default. So, density measures the availability and diversity of support and resources from network members and their other ties, and if there are any gaps (i.e., structural holes) in the network (Kazak and Marvin 1984; Perry, et al, 2018).

Research finds and supports two alternative views on the influence of network density or connectivity depending on the type of networks involved (Gulati et al., 2000; Human and Provan, 1997; Phelps, 2010; Rizzuto, et al, 2009; Song, 2019). Highly connected networks typically improve communication and knowledge diffusion due to higher trust and reciprocity norms that allow for more cooperation (Coleman, 1988; Phelps, 2010; Portes, 1998). Alternatively, higher density can also lead to homophily with greater information redundancy within a given network, reducing the range of resources the members have access to and thus their innovativeness (Parker and Welch, 2013; Rizzuto, et al, 2009; Ruef et al., 2003; Song, 2019). These competing views on network density indicate the importance of also looking at network composition along with structure, as the type of actors involved in a network can lead to different results.

Looking specifically at co-patent networks, it is likely that the co-inventors are regular collaborators and so familiar with the same information and sources, as opposed to more open networks (Balkundi and Kilduff, 2005; Parker and Welch, 2013; Song, 2019). While dense networks may increase trust and use of a functional language, empirical studies find it can be detrimental to innovation and emergence of new groundbreaking ideas (Gulati et al., 2000; Ruef et al., 2003). Academic scientists tend to have higher levels of homophily due to a shared professional identity and norms (Bozeman, et al., 2001; Ruef et al., 2003). Thus, having connections outside the inventor's typical research group, university, and geographic region allows for greater knowledge creation and can positively impact innovation outcomes like patenting (Bozeman and Corley, 2004). Meaning, less dense networks that have weak ties and alters that serve as bridges between networks can provide more diverse sources of non-redundant information. Weaker ties tend to provide more useful and novel information and connections to other relevant researchers and resources (Friedkin, 1982). This wider knowledge base can inspire new uses and combinations of the available information for future research, leading to higher patent citations and further scientific and technological advancement (Ahuja, 2000; Balkundi and Kilduff, 2005; Friedkin, 1982).

H1: Networks with a lead inventor with high density will be negatively associated with patent citations.

Findings from the qualitative interviews done in the third essay of this dissertation and a review of the literature stress key network differences by scientific fields, which extend to co-patent networks as well. Field differences depend on the nature of the science along with disciplinary culture in norms. Research finds that life science networks have a tendency of homophily, meaning network members are more similar and may have redundant information channels (Whittington, 2018), and often are more secretive about their work as compared to other scientific fields (Walsh and Maloney, 2007). In comparison, physical sciences and math are more open and typically organized around large instruments and dispersed collection sites, which requires larger efforts of collaborations across geographic distances, fields, etc. (Vermeulen, et al, 2013; Walsh and Maloney, 2007). Another study finds that academic biologists tend to have fewer multifaceted relationships as compared to engineering and physical sciences, where scientists collaborate on multiple different projects increasing trust and improving efforts (Jha and Welch, 2010). Due to these findings on science field network differences, the study includes an exploratory analysis of density by fields (biology, chemistry, engineering, physical sciences and math).

H1a: The relationship between networks' lead inventor density and patent citations will differ by scientific fields.

Another important complementary network structure characteristic that describes the overall compactness of a network is centrality. While density looks at the overall connectedness of the network, centrality refers to how much the network is organized around a focal point or central inventor (Scott, 1988; Tuire and Erno, 2001). Central actors in a network are members who hold prominent positions due to their experience, knowledge, power, communicative abilities and access to informational resources. Central actors can serve as information gatekeepers for internal and external network informational sources, and so they are mediators between inventors that impact knowledge flows (Goetze, 2010; Hauschildt and Schewe, 1997). Central actors in a patent network are characterized by high network centrality.

The three most common established measures for centrality are degree centrality, betweenness centrality and closeness centrality, although there are others (Freeman, 1978, Goetze, 2010). This essay uses degree centrality, the number of direct links between individuals through joint patents, to measure the inventors' prominence in their networks at time zero (i.e., before and when the patent was granted). Inventors with high degree centrality are considered the most active in their networks and have the most ties between networks (Schalk, et al, 2010). Specifically for S&T, central inventors tend to have high scientific visibility and recognition leading to more professional excellence and opportunities to mediate between others and transfer knowledge (Goetze, 2010). High degree centrality can increase the opportunities for unique information combinations and more novel innovations, spurring further research and cooperation (Dougherty and Hardy, 1996; Song, et al, 2019), meaning higher citations and future work in public science.

H2: Networks with a central lead inventor will have higher patent citations.

Scientific and technological (S&T) human capital encompasses all of the S&T knowledge, training, and resources embedded in an individual from formal education, and both academic and industrial experiences. Inventors’ individual knowledge and capabilities are significant resources for scientific productivity and their collaborative relationships (Bozeman, et al, 2001; Kim, 2013). Networks within the science domain integrate these individual resources in novel ways to produce new scientific knowledge (Beckmann, 1994; Constant et al., 1996). Past research looking at S&T human capital has found experience with the private sector to be a significant source for academic network collaborations (e.g., Bozeman, 2005; Lin and Bozeman, 2006). Diversity (ties across social divides) benefits individuals and enhances the exploration of new ideas and methods and the use of scarce resources (Burt, 1992; Granovetter, 1973; Meng, 2016; Powell et al, 2996; Smart, et al, 2007). In the S&T context, diversity in terms of social ties spanning sector divides is important for knowledge flows, creativity and more innovative outcomes (Bozeman et al., 2001, Dietz and Bozeman, 2005, Heinze and Bauer, 2007). Co-patent networks with industry ties gives academic science and engineering inventors access to new and diverse information flows and other resources from the private sector such as practical applications and funding (Azagra-Caro and Consoli, 2016; Hurmelinna, 2004; Ji, Barnett, and Chu, 2019). Academic network ties to industry can come in many forms including consulting, licensing and co-publishing, which can all serve as channels of knowledge flows. The diverse resource base produces novel and useful innovations that can spark more work, amounting to higher patent citations (Breschi and Catalini, 2010; Smart, et al, 2007).

H3: Networks with industry ties will be positively associated with patent citations.

Network ties can also negatively impact knowledge flows and performance, as there are insecurities and risks to knowledge sharing between the public and private sectors (Smart, et al., 2007; Tahmooresnejad and Beaudry, 2018). Academia and the private sector are two distinct systems in terms of incentives, orientation, and knowledge creation and sharing. The two sectors value different norms about information diffusion and production expectations. Industry uses market logic that stresses applied research, commercial exploitation and intellectual property (IP) protection to gain profits. In other words, progress is best leveraged by financial incentives and protection from free riders (Rhoten and Powell, 2007; Teece, 1986). In comparison, academic logic is more oriented towards knowledge production, professional reputation and education to further innovation (Aydemir, et al, 2022; Drivas, et al, 2017; Vick and Robertson, 2018). The misalignment in orientation and incentive structure can lead to internal conflict for networks made up of both academic and industry members, lessening information and resource sharing (Hughes, 2011; Nsanzumuhire and Groot 2020; Vick and Robertson, 2018). Academic inventors' perceived value conflicts or lack of trust can weaken their network relationship and collaboration efforts with industry. Perceived industry conflicts can diminish network members' motivation and likelihood to share information in the patenting process and to work together again (Meng, et al 2016; Nsanzumuhire and Groot 2020). This reduction in cooperation and information flows between academia and industry can strengthen the sectoral divide and limit the availability of diverse resources and novel research opportunities, meaning fewer citations and broader impact.

H4: Networks with a lead inventor who perceives industry collaboration conflicts will be negatively associated with patent citations.

Data and Methods:

The study matches survey data with bibliometric data in order to detect social connections among academic inventors. The 2010 National Survey on Intellectual Property in Academic Science and Engineering provides information about the network composition (ties to industry and perceptions), and academic inventor and university quality measures used as controls. The quality of inventors is an important control as it could be a possible confounder and strong predictor of knowledge flows, as it is common for industry to reach out to more productive academic scientists and vice versa (Ankrah, et al, 2013; Hayter et al, 2018; Zucker et al. 2002). The co-patent network structure measures (density and degree of centralization) and citation information comes from the Patent Network Dataverse and Google Patents.

The 2010 survey data was matched by lead inventor (i.e., the principal investigator (PI)) and patent USPTO identification number to the publicly available data on co-patent networks and number of patent citations in 2019. The number of patent citations was found and included for a total of 837 lead inventor-patent pairs. Due to unusable survey answers and missing network data, 729 inventors were included in the models. The three data sources were matched in order to understand how early development network and industry involvement characteristics influence patent outcomes later on in the academic inventor’s career.

Variables of interest

To test my hypotheses about how networks influence knowledge flows, I use the same count dependent variable from essay one, the **Number of patent citations** for each lead academic inventor in the sample. In both studies, patent citations are all citations by future patent applications that were included as prior art and the inventors in the sample have on average 39 citations (SD=69.02). As stated before, the distribution of the count variable is right skewed, so OLS regression is not appropriate for this data.

The key independent variables are two measures of network structure common in the literature, density and degree centrality, and two measures of network composition, industry ties and perceived conflicts. **Density** for personal network analysis (i.e., ego's clustering coefficient) is the percentage of actual social ties of alters within each network out of all potential ties (potential ties $=\frac{n(n-1)}{2}$) (Burt, 1992; Chang, 2021). Density ranges from 0 (no connections) to 1 (100% connected). Lead inventors in the sample on average have a density of 0.99 (SD=0.05). The second measure is **Degree centrality**, the number of direct social links between the lead inventor and other network members through any joint patents (i.e., the size of the lead inventor's network). Respondents in the sample are linked to about 3 other individuals through joint patents (SD=0.85). Figure 3 shows a diagram of inventor relationships, with the center containing the most central lead inventors. Figure 4 shows a histogram of the frequency of patent ties, with the red line showing the mean and the green line the overall distribution. Both figures together imply that while there are a few highly connected patents and a few poorly connected ones, more are moderately tied. It is a snapshot of the diffusion of knowledge across a patent network.

Figure 3. Ties Between Co-authors

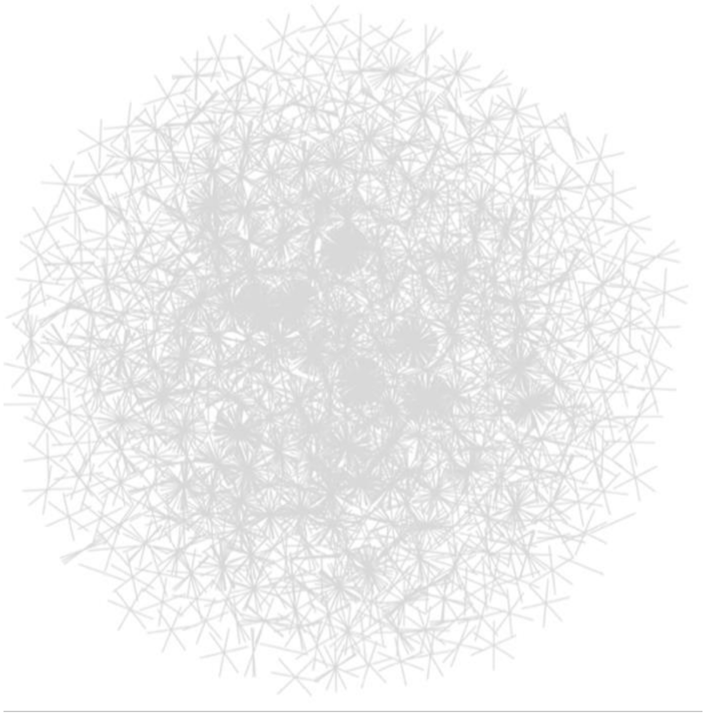
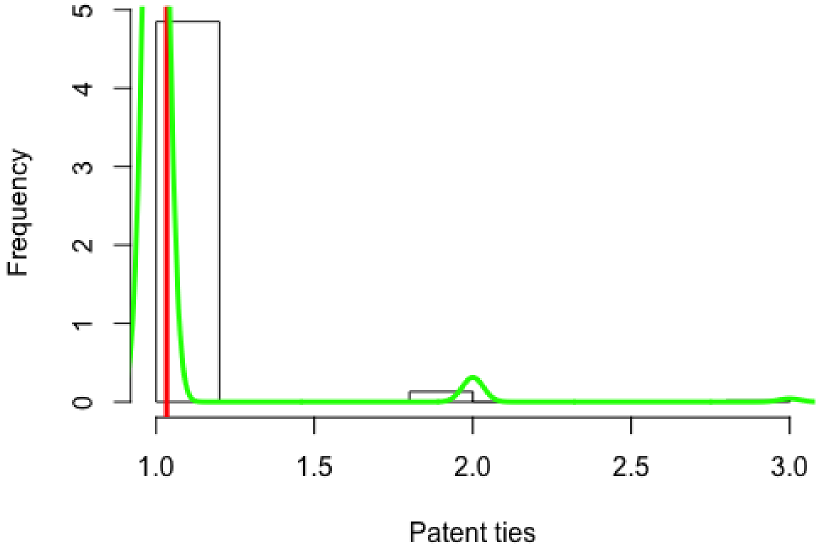


Figure 4. Frequency of Patent Ties



As for bridging the public-private sector divide, the variable **Industry ties** is an E-I index for industry network membership, where -1 means that all members of a network are academic, +1 means that all members of a network are from industry, and 0 is balanced membership. On average, networks have an EI index score of -0.82 (SD=0.54). The **Perceived industry conflicts** variable is an averaged index of the answers to the survey question found in table 1, with a Cronbach's alpha of 0.65.

Control variables

The model controls for other factors that can influence patent citation outcomes at the network, institutional and individual levels. The network level measure come from the Network Dataverse and Google Patents datasets. **Foreign coauthors** are the total number of co-patentors whose main university is outside of the US. On average, networks in the sample have less than 1 foreign co-patentors (SD=0.55).

The institutional and individual level measures come from the survey data and are ego level responses. At the institutional level, I include controls for university quality. **TTO-Firm involvement** measures whether the university technology transfer office (TTO) has worked with industry to develop the invention for commercial use (Yes "1" or No "0"). On average, 31% of the patent universities have TTOs that have worked with the private sector to commercialize the patent (SD=0.46). I also include the Carnegie Mellon higher education **Classification scores**[5] to control for university type differences. On average, most patents come from R1 universities (score=15, SD=1.79).

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[5] https://carnegieclassifications.iu.edu/

I also control for ego (surveyed inventor) characteristics to control for quality, discipline and experience differences. The literature finds that patents are more common in the biological life sciences (Fini et al. 2010; Kenney and Patton 2011) and to a lesser extent in physical sciences and other relevant fields (Knockaert et al. 2011; Nelson, 2014; Hayter et al, 2018). Inventors in the sample were asked about their primary academic discipline, which were grouped together to create four dummy variables: on average, 39% of respondents are in the **Biological sciences** (SD=0.49), 15% are in **Chemistry** (SD=0.35), 33% are in **Engineering** (SD=0.47), and 13% are in **Physical sciences and math** (SD=0.34).

To further account for experience, I control for whether the inventor is **Tenured** with a dummy variable (Yes “1” or No “0”), and 69% of the sample are tenured (SD= 0.46). **Academic workload** is the averaged scale of responses to the survey question found in Appendix C, which ranges from 1 to 6 and has a Cronbach's alpha of 0.61. Another measure for academic inventor experience in the patenting processes is **Royalty payments**, which 53% of the respondents disclosed receiving royalties from any of their patents (SD=0.50).

Patent activities are a measure for human capital and are typically positively related to various innovation outcomes including patenting (Hayter et al, 2018). Although, research finds mixed results for patents as growth in patenting is often followed by a decline in the patent quality (Hicks et al, 2001; Bradley, et al, 2013). The total **Number of patents** is included as controls to account for this relationship. On average, respondents are awarded around ten patents (SD=17.8). The descriptive statistics for all study variables are in table 4.

Table 4: Descriptive Statistics for Essay Two Variables

Variable	Obs.	Mean	Std. Dev.	Min	Max
Variables of interest					
Patent citations	830	38.94	69.02	0	775
Density	958	.99	.05	.46	1
Degree centrality	1050	2.77	2.42	0	15
Industry ties	1050	-.82	.54	-1	1
Perceived industry conflicts	946	2.98	.85	1	4
Controls					
Foreign coauthors	830	.14	.55	0	12
TTO-Firm involvement	963	.31	.46	0	1
Classification scores	1050	15.49	1.79	11	27
Biological Sciences	1046	.39	.49	0	1
Chemistry	1046	.15	.35	0	1
Engineering	1046	.33	.47	0	1
Physical Sciences and math	1050	.13	.34	0	1
Tenured	1040	.69	.46	0	1
Academic Workload	1033	.69	.46	0	1
Royalty payments	938	3.13	1.10	1	6
Number of Patents	961	.53	.5	0	1

Empirical Strategy

In order to better understand knowledge creation in academic science, I look at how network structure and composition characteristics during the patent development phase influence knowledge flow outcomes around ten years later. The same as in essay one, because the dependent variable (number of citations) is a count measure, the Poisson or negative binomial maximum likelihood methods are best fit for the data (Cameron and Trivedi, 1998). Similar to before, the dependent variable is over-dispersed according to the Poisson goodness-of-fit test in STATA version 15.1, and so the negative binomial regression is more fitting for the data. Next, to see whether a zero-inflated negative binomial estimation is needed in this case, I compare the Akaike's information criterion (AIC) and the Bayesian information criterion (BIC) of the two models. Both the AIC and BIC were lower for the negative binomial regression (AIC=6432, BIC=6509) as compared to the ZINB (AIC=6472, BIC=6663), meaning that the negative binomial estimation method is the preferred model for the data. I use this model on the full sample and individual for each scientific population subsample in the exploratory analysis.

Results and discussion:

I present the results for each hypothesis (found in table 5), discussing the relationships between the network structure and composition predictors and the measure for knowledge flows. Looking at the network structure measures, I find support for hypothesis 1, networks with high density are negatively associated with patent citations ($\beta = -2.84$, $p\text{-value} < 0.01$). Following the network literature, the results support the view that high network density in co-patent networks indicates redundant information channels (Parker and Welch, 2013; Rizzuto, et al, 2009; Song, 2019). Specifically in the case of patent networks, density implies more closed off networks where academic science and engineering inventors typically interact with familiar collaborators, reducing the availability of new and novel resources and information flows.

The exploratory analysis shows key differences in the relationship between density and citations by scientific fields, supporting hypothesis 1a. While for most of the fields the negative association between high density and patent citations hold, networks with a lead inventor with high density in the physical sciences and math field are positively associated with patent citations (β= 11.86, p-value<0.01). This finding implies that there are key differences in the nature of collaborations for the physical sciences subfield as compared to biology. The subfield typically is a smaller discipline that depends on more labor-intensive activities such as computation and other coding work, thus requiring more dense interdisciplinary networks to produce quality patents.

Hypothesis 2 is also supported, networks with central inventors (have high degree centrality) are positively associated with patent citations (β=0.12, p-value<0.01). Following social capital theory, the positive association between networks with high degree centrality and knowledge flows indicates the importance of central inventors and the social capital they have and use to increase information sharing. Central inventors, as mediators between internal and external network members, are important for the patenting process and providing access to more informational resources (Goetze, 2010; Hauschildt and Schewe, 1997). While common in the literature, both structural dimensions of networks are relevant in the context of S&T, as they help to predict knowledge flow outcomes and how network decisions contribute to academic science.

Focusing on private sector network ties, I find no support for hypothesis 3 that networks with more industry ties are positively associated with patent citations. The exploratory analysis does find a negative relationship between more industry ties and citations for the engineering subfield. This finding implies that for engineer inventors, more industry involvement can lower the novelty and reach of the patents, possibly due to the pressure to create more strictly applied patents. However, hypothesis 4 is supported, networks with inventors who perceive industry collaboration conflicts will be negatively associated with patent citations (β= -0.17, p-value=0.01). Academia and industry have different logics and incentives structures when it comes to information diffusion and production expectations, which can create value misalignments (Hughes, 2011; Nsanzumuhire and Groot 2020; Vick and Robertson, 2018). The finding supports that the perceived value conflicts can weaken network relationships and efforts, harming information channels between the two sectors. Exploratory analysis shows that while perceived industry conflicts matter for the full model, the predictor is also heavily influenced by the biology subfield.

The exploratory analysis shows interesting results for one of the controls, TTO-Firm involvement. Whether the university technology transfer office (TTO) has worked with industry to develop the invention for commercial use is significantly negatively related to patent citations for the full model, and faculty in chemistry, engineering, and physical sciences and math. The innovation literature largely finds that biology is most suited for patenting and so favored by the TTO as compared to other fields like computer science and some engineering (Fini et al., 2018). So the university TTO working with industry might not be favorable for the novelty and reach of the patents in certain fields as compared to others. Overall, academic researchers express frustration working with their university TTOs and so the process could negatively impact the quality and potential of the patents (Markman et al. 2008; Thursby et al. 2009).

Table 5: Negative Binomial Regressions Predicting Patent Citations Essay Two

	(1) Citations – Full model	(2) Citations – Biology	(3) Citations – Chemistry	(4) Citations – Engineering	(5) Citations – Physical and math
Variables of interest					
Density	-2.85***	-4.68**	-2.60	-2.20**	11.86***
	(1.00)	(1.89)	(1.78)	(1.08)	(.84)
Degree centrality	.12***	.20***	.10*	.09**	.08
	(.03)	(.05)	(.05)	(.04)	(.07)
Industry ties	-.18	.04	-.43	-.73***	.25
	(.11)	(.16)	(.28)	(.14)	(.19)
Perceived industry conflicts	-.17**	-.25**	-.07	-.13	-.11
	(.07)	(.1)	(.14)	(.14)	(.16)
Controls					
Foreign coauthors	-.17*	-.12	-.48*	-.22	-1.08***
	(.09)	(.26)	(.28)	(.26)	(.27)
TTO-Firm involvement	-.28***	-.12	-.44*	-.40**	-.65**
	(.1)	(.16)	(.24)	(.17)	(.29)
Classification scores	-.03	-.03	-.06	-.09	-.03
	(.03)	(.03)	(.05)	(.07)	(.11)
Chemistry	0				
	(.15)				
Engineering	.17				
	(.14)				
Physical Sciences and math	.14				
	(.17)				
Tenured	.22*	.31*	.66**	-.16	.49
	(.13)	(.16)	(.33)	(.26)	(.3)
Academic Workload	.18***	.14	.29**	.13*	.34***
	(.06)	(.10)	(.13)	(.08)	(.13)
Royalty payments	.18*	.22	.03	.31	.13
	(.11)	(.17)	(.25)	(.19)	(.31)
Number of Patents	0**	0	0	-.01***	-.02***
	(0)	(0)	(.01)	(0)	(.01)
_cons	6.14***	8***	5.22***	6.41***	-8.49***
	(1.1)	(2.08)	(1.87)	(1.90)	(1.74)
/lnalpha	.17***	.12	-.17	.21**	.07
	(.05)	(.09)	(.12)	(.08)	(.13)
Observations	693	260	109	237	89
Pseudo R^2	.02	.02	.05	.02	.04

*Robust standard errors are in parentheses. *** p<.01, ** p<.05, * p<.1*
Reference category: Biological Sciences, R2 and other public universities

Conclusion

The results of this study have important implications for theory and practice. Consistent with the literature, the specifics of the networks’ structure and composition matter for knowledge flows, which increase the usefulness and influence of the new ideas and contribute to the advancement of public science. Focusing on science and technology (S&T) co-patent networks, the lead inventor having high density can undermine networks and their knowledge flows by reinforcing the usual information channel available to the academic inventors rather than providing new resources and novel ideas (Parker and Welch, 2013; Song, 2019). This density finding is particular to networks made up of academic inventors working on the same patents, as they interact and form connections differently than other groups. The field differences highlight that network density has different effects depending on the type of network involved, where certain fields include more interdisciplinary work and less redundant information channels. Additionally, the high centrality finding suggests that central lead inventors in co-patent networks have the necessary prestige and information channels within S&T communities to do well in the patenting process and spark future innovations.

As for bridging the academic private sector boundaries, the results imply that industry involvement in academic science and patenting is complex and should be looked at in multiple dimensions. While generally having networks with industry ties may improve knowledge flows, it depends on the specifics of the relationship between the two sectors. If network members perceive misalignment in incentives between academia and industry members, this can negatively influence knowledge diffusion due to value conflicts (Nsanzumuhire and Groot 2020). This finding also has practical implications for university and other policies when it comes to academic-industry relationships. While some universities and government policies push for academics to engage in commercial practices with industry partners (Kolympiris and Klein, 2017; Tahmooresnejad and Beaudry, 2018), involvement alone is not enough to help networks improve knowledge flows and other outcomes. Rather, academic inventors would benefit from training about how to interact with industry scientists with different incentives and information sharing norms and why they should care about this. By alleviating some of the negative perceptions about industry involvement in public science, academics may be more willing and able to expand their networks to bridge the public-private divide more effectively. Having greater network trust helps members accumulate knowledge more widely, thereby advancing science and amounting to more progress. Both essay one and two suggest that a perceived conflict in logic between academics and industry is important for knowledge flows and research outputs. This finding partially inspired the next essay, which focuses on the academics' various logics and delves deeper into how these perceptions influence research decisions and interactions with industry.

Overall, this study shows that important network structure and composition characteristics for knowledge flows and sheds light on the importance of industry ties and perceptions. Future research would benefit from expanding on the complexity of industry involvement in academic science by looking at other knowledge sharing mechanisms besides patents such as co-publications in journals. These findings can also be strengthened by studying industry ties with other public institutions such as government laboratories.

CHAPTER 4

ESSAY THREE: Linking institutional logics and academic collaboration decisions to research outputs

Introduction:

The advancement of scientific research is a cumulative process that can depend on how new findings are disclosed so that the information can be rapidly discarded or confirmed and used along with other reliable knowledge (David, 2003; Friesike, et al., 2015). An important part of the process of how science is being conducted includes the relationship between public and private research, as boundaries are continuing to shift between academia and the private sector (Dai, et al., 2018; Powell, and Colyvas, 2008). As findings in the first two chapters of this dissertation show, the mixing of the two sectors matters for knowledge flows and the advancement of science.

The shifting relationship between public and private research can be expressed as a mixture of or conflict between different deeply held values and beliefs that help guide researchers and influence patenting activity. These deeply held values and beliefs are also known as institutional logics in the organization literature. Institutional logics are socially constructed assumptions and values that guide appropriate behavior and form actor identity (Barth, 2018; Colyvas, 2007; Friedland and Alford, 1991; Thornton et al., 2012). Logics offer a ‘link between the individual agency and cognition and socially constructed institutional practices and rule structure’ (Thornton and Ocasio, 2008). While each institutional logic provides organizing principles for academic science, there can be multiple logics within a social domain that may overlap or conflict (Besharov and Smith, 2014; Friedland and Alford, 1991).

The traditional tenure system in academia manifests an institutional logic that values career advancement through publishing in high-impact journals and acquiring competitive grants and other funding (Ali-Khan, et al, 2017; Hayter et al, 2020). However, changes to universities and their incentive systems have welcomed another institutional logic to gain prominence in academia that values developing and commercializing research outputs. Market logic (i.e., more industrial or applied science and technology) promotes commercial exploitation and intellectual property (IP) rights to generate profits outside of private sector boundaries (Friesike, et al., 2015; Murray, 2010; Perkmann and West, 2014; Rhoten and Powell, 2007).

At the same time, a third logic gaining recognition in academia is open science, which is broadly described as publicly and freely sharing resources and ideas for future use and scientific and technological progress (Levin, et al, 2016). Open science is gaining momentum more recently with open access initiatives (e.g., creation of open access journals) and amongst publishers, institutions, and particularly practicing scientists (Hillyer, et al, 2017; Levin, et al, 2016; McKiernan, et al, 2016). While the literature commonly sees market logic as one institutional logic somewhat compatible with the more traditional views in academia (see Colyvas, 2007; Leišytė and Sigl, 2018; Jain and George, 2007; Powell, and Colyvas, 2008), there is less consensus about openness as an institutional logic and how its values and beliefs are actually activated in practice.

This chapter of my dissertation seeks to explore the nature of academic scientists' decisions about their research collaboration and other activities including open access publishing, patenting and other commercial practices. Building on the first two chapters' findings that academic-industry relationships matter for knowledge flow outcomes, this essay focuses on the interplay of the three academic logics, with a focus on what that means for knowledge creation and diffusion. I utilize an exploratory approach focused on the academic researcher perspective and guided by institutional logics theory, as they are influential and embedded, and individuals are generally aware of them and so are better able to exercise agency and manipulate them (Friedland and Alford, 1991; Ocasio, et al, 2017). Using semi structured interviews with 19 early career and tenured academic biologists across three universities in Arizona, the research explores the question: How do institutional logics influence academic scientists' decisions to undertake research topics, collaboration partners and other activities to produce new knowledge?

The chapter is organized as follows. I begin with a comprehensive literature review that sets up institutional theory and how the academic logics shape research behavior and how market and openness logics can fit together or not in one space. The literature review provides a comprehensive grounding that helped me guide the interview protocol used in the study. Next, I describe my sample, data and methods, and present the interview results. The chapter concludes with a discussion of the findings and their implications for public research and university policies.

Literature Review

Institutional logics theory

Institutional logic theory has gained recognition in the organizational literature for looking at how cultural patterns and social behavior fit within organizations (Glynn, 2017). Institutional logic is defined as the values, norms, assumptions and rules used by individuals as a framework to organize their behavior and add meaning to their social realities (Thornton et al., 2012). The various institutional logics originate within different societal sectors such as professions, communities, the state, etc. (Friedland and Alford, 1991; Thornton et al., 2012), including higher education. As such, the logics do not exist in a vacuum, but rather can interact with one another causing conflicts and/or cooperation, leading to institutional complexity (e.g., Besharov and Smith, 2014; Thornton et al., 2012). As new actors join academia, they bring with them different experiences and exposure to various practices that existing members have to contend with, which can lead to collective action (Clemens & Cook, 1999; Hardy and Maguire, 2017). The multiple logics within the same social space can cause tension if they are less complementary and depend on how the actors individually and collectively cope with the associated conflicting demands and goals (Ocasio, et al, 2017). This holds true in the higher education sector where there are multiple institutional logics that present different benefits and can be more or less complementary.

What institutional logics are dominant within the social space can depend on many cultural, logistical and organizational pressures such as the role of the actors involved. There is some debate in the organizational literature as to the role of dominant versus more peripheral actors. Some scholars argue that new logics gain recognition when there are organized dominant actors with sufficient resources that take advantage of opportunities to realize their highly valued interests, leading to changes within a field (Hardy and Maguire, 2017; Lawrence and Suddaby, 2006). Central and powerful actors have the means to create institutional change and advance new logics if they are in dominant positions in their fields or are a part of new field creations (Bourdieu, 1986;

Hardy and Maguire, 2017). This implies that in the academic setting, more tenured academic scientists that have more resources and networks can encourage the use of a different or newer institutional logic depending on their positions.

In comparison, some scholars argue that while the dominant actors have the resources they do not have the motivation to follow a newer logic as they are already embedded in the current dominant norms and framework (Greenwood and Suddaby, 2006; Hardy and Maguire, 2017). Meanwhile, the peripheral or less dominant actors can lead to institutional change because while they may lack the resources and needed networks, they have more to gain and are less embedded in the dominant logic (Hardy and Maguire, 2017; Smets, Morris, & Greenwood, 2012). Additionally, less dominant actors may be more disadvantaged by the current institutional norms and prescriptions, so they may have more motivation to follow a different framework outside of their field (Hardy and Maguire, 2017; Leblebici et al., 1991). There are also internal sub-groups to consider, which may have divergent demands (Besharov and Smith, 2014).

Looking at early career academic researchers that are newer to university culture, they are less constrained by the dominant norms and practices and often have new ideas about what research, collaborations and other practices should look like. However, they also are constrained by tenure rules and need to focus on publications and growing their networks to be successful in academia. This research considers this paradox of central versus more peripheral actors’ role in institutional logics and change, as it reviews the three current more dominant logics in higher education: academic logic, market logic and open science.

Institutional logics operating in institutions of higher education

Academic logic

Traditionally in academia there is the institutional logic incentivized by the current collegiate reputational reward system (David, 2003). The academic logic values reputation and career advancement through publishing in high-impact journals and acquiring competitive grants and other funding (Ali-Khan, et al, 2017; Hayter et al, 2020). Research consistently shows that academic scientists are motivated by career advancement on top of ethics and other incentives due to the structure of higher education (e.g., publication records, tenure evaluations, etc.) (Ali-Khan, et al, 2017; McKiernan, et al, 2016). Research decisions and collaborations are often centered around bolstering reputation or professional standing through increased publication productivity in high-impact journals and other credits towards promotions (Link, et al, 2015). Academics prioritize research topics and activities that lead to higher publication success to accumulate reputation and acknowledgement within their professional communities (Link, et al, 2015).

The university reputational reward system is also associated with norms of competitive and non-cooperative behavior as the academics and their research units compete to publish first and establish priority within their respective fields. There are many career benefits for being the first out of the gate when it comes to novel discoveries in academic science (Ali-Khan, et al, 2017; David, 2003). So, researchers may engage in non-cooperative behaviors until publication in order to ensure they receive the most benefits from their work (Fecher. et al, 2015; Levin, et al, 2016). Such activities include limiting access to raw data, documentation, annotation and other information needed to create reliable public database resources (David, 2003).

Market logic

At the same time, changes to university policies and goals lead to the prominence of another institutional logic that values proprietary technology and intellectual property (IP) protection. Market logic promotes more applied science and technology, and other commercial exploitations to generate profits outside of sector boundaries (Friesike, et al., 2015; Murray, 2010; Perkmann and West, 2014; Rhoten and Powell, 2007). Following legislative initiatives starting in the 1980s and changes to university incentive structures, the distinct divide between public and private science began to blur as academia focused more on commercialization practices (Colyvas, 2007; Rhoten and Powell, 2007). A clear example of the altered university-industry relations is the Bayh–Dole Act in 1980, which streamlined technology transfer and how universities retain the IP rights from federally funded research and innovations (Colyvas, 2007; Rhoten and Powell, 2007; Sampat, 2006). The legislation led to a more ingrained commercial logic in academia over the following 30-40 years. Additionally, starting in 2006, many universities such as Texas A&M started to explicitly reward commercialization in their tenure decisions (Link, et al, 2015).

The trend towards further private sector involvement in academia and more commercialization practices such as patenting was also driven by increasing financial pressures. As universities faced a decrease in public funds, they sought alternative financial resources through different research and commercial activities including licensing and patenting (Chataway, et al, 2017; Friesike, et al, 2015; Jones et al., 2014). The market logic values the view that scientific and technological progress is best leveraged by financial incentives and free rider protection (Rhoten and Powell, 2007; Teece, 1986).

Openness logic

Another practice becoming more common and well-known in academia is openness, a framework of values and beliefs about the purpose and ethics of academic research that guide information sharing practices (Dai, et al, 2018). Open science practices include the publicly sharing of data, findings and other resources for future scientific and technological progress and societal benefits (Levin, et al, 2016; Saraite Sariene, et al., 2020). Openness values the spread of resources to those who are often excluded, and increased transparency and reliability of scientific data and platforms to enable collaborations to further information flows (David, 2003; Hillyer, et al., 2017; Saraite Sariene, et al., 2020). Multiple qualitative studies found that interviewees expressed ethical motivations as to why they want more frequent sharing of data and other information. Their ethical considerations include ensuring that their data and research is widely usable to maximize discoveries and reduce bottlenecking of information before publication (Ali-Khan, et al, 2017; Fecher. et al, 2015).

Openness in academia can vary depending on the context of the field and research. So, scholars often use the term open science to encompass when academic scientists move towards more openness in their research practices and share any new scientific knowledge openly as early as is practical (Levin, et al, 2016; Nielsen, 2011).

Open science in academia includes various open access initiatives such as publicly available data and software platforms and open access journals (Hillyer, et al, 2017; Levin, et al, 2016; McKiernan, et al, 2016).

Conflicts/reconciliation of logics

As the traditional academic logic remains dominant in many fields in universities, some scientists chose to prioritize other logics (openness and market) or find ways to balance multiple logics at once. The academic scientists' decisions about which logic to follow and when can depend on many factors including how the values of the three logics fit together. While open science follows the long-standing goal of academia to further knowledge creation and scientific progress, the guiding ideals can conflict with the more traditional system of research and career advancement through reputation and publishing in high impact journals (Ali-Khan, et al, 2017; Chataway, et al., 2017). Fewer universities and colleges (e.g., Harvard's School of Engineering and Applied Sciences in 2014) have more recently altered their promotion and tenure systems to recognize open practices and to encourage faculty to archive articles and utilize open repositories (McKiernan, et al, 2016). This trend suggests that open science can fit within the more traditional university logic if the universities are on board.

Looking at market logic, while the literature typically finds that commercialization limits investigation, collaboration and knowledge production (Link, et al, 2015), some argue that scientists can still reconciled market logic with the more traditional academic logic to enable compatibility through the tenure and advancement system (see Colyvas, 2007; Leišytė and Sigl, 2018; Jain and George, 2007; Powell, and

Colyvas, 2008). Changes to some university incentive systems now allow for patenting academic research findings, participating in startups and other commercialization activities to become core features of science for career advancement and knowledge diffusion (Colyvas, 2007; Leišytė and Sigl, 2018; Powell, and Colyvas, 2008). This trend of reshaping salient practices has led to more early career scholars devoting time to inventorship through collaborations and gaining recognition and opportunities from commercial work (Colyvas, 2007).

There is less consensus about general openness in academia and how the ideals of open science and free access are used in practice. It can be difficult for scientists to be fully open and transparent, and these goals can overlap or conflict with both commercialization and reputation norms (Ali-Khan et al, 2017; Edwards, 2016; Levin, et al, 2016; Nelson, 2009). The logics often in practice have points of friction due to differing goals and transaction costs that can harm academic-industry collaborations and the spread of knowledge between the two sectors (Friesike, et al., 2015; Murray, 2010; Perkmann and West, 2014; Rhoten and Powell, 2007). For one, academics often choose research topics that fall under the category of basic science, where the focus is on knowledge creation rather than applied use (Friesike, et al., 2015; Link, et al, 2015). While firms tend to be more interested in inventions that are more applied (e.g., directed toward a particular group) and economically focused (Stokes, 2011; Bentley, et al, 2015). Additionally, firms' use of IP protections create transaction costs and can limit access to the research materials, going against the principles of openness (Link, et al, 2015; Murray 2010).

However, possible reconciliation of the logics can be seen through the idea of use-inspired basic scientific work. This concept suggests the discovery provides an important new understanding of a phenomena (e.g., radical innovations) and still has a specific market that is interested in using and building off of the invention (Azagra-Caro et al., 2017; Stokes, 2011), increasing its distinctiveness and immediately practical usefulness (Hulme, 2014; Bentley, et al, 2015). Therefore, the innovation still furthers the development of basic science, but also has market applications.

Ali-Khan, et al (2018) find that both researchers and university central administrations are reluctant to encourage openness and specific open science practices due to more simplistic or linear beliefs about academic patenting and the risks to their IP rights over joint-research. In this linear model of discovery and commercial dissemination of information, knowledge takes a straight path from creation to disclosure and patenting to licensing to a private company to be commercially developed (Nicol, 2008). The model ignores other possibilities for academic-industry collaborations and the possible value of adding knowledge into the public domain. Thus, in this view, open science is seen as an alternative to proprietary technology, an active way to resist the control of information sharing through IP rights and other commercialization tools (David, 2003; Rhoten and Powell, 2007).

Conversely, some researchers are moving away from the more linear commercial dissemination of knowledge tools towards pathways that reconcile and blend multiple norms or logics such as co-publishing and open licensing (Hayter, et al, 2020). While the patenting process was designed to defend intellectual property, scientists seek avenues for logic reconciliation and so the patenting system has become a way to make information about inventions and their ownership easily accessible, a prerequisite for knowledge sharing (Dai, et al, 2018), which coincides with openness principles. Salter and Martin (2001) argue that openness and open publications provide important technological opportunities for firms that have enough resources to acquire and use the information. Taking this idea further, academic scientists can both publish and patent their research findings in pairs as an alternative to simply focusing on maximizing IP rights. Other alternatives to the linear commercialization model include open or non-exclusive licensing so the academics retain control reuse and can disseminate the new knowledge more broadly (Nicol, 2008; McKiernan, et al, 2016).

In order to better understand how these three logics appear in practice, the essay employs an exploratory qualitative approach focusing on the academic researcher perspective. I conduct semi structured interviews with academic biologists to get at how scientists view and reconcile the various academic logics and the impact these choices have on research. This exploratory and descriptive study uses institutional logics theory as a lens and is largely inductive in order to yield new ideas and questions.

Case Selection and Methods

Research strategy

This exploratory research aims to better understand how institutional logics are presented by academic collaboration decisions. The study is guided by theory but largely inductive, as it builds off of prior bodies of work and inferences are made from observable phenomena (Reiter, 2013; Worster, 2013). Largely inductive exploratory studies have the goal to discover potential generalizable ideas that can later be hypotheses and theories confirmed with data, and to yield new questions (Stebbins, 2001) (see examples Liu, 2016; Ospina and Saz-Carranza, 2010; Romzek, et al, 2012; Schillemans, 2013).

This research is both exploratory and descriptive and focuses on the academic researcher perspective, so I utilized a qualitative analysis of interviews. To guide the analysis, I considered the university context in which the researchers operate, and individual behavioral rationales. Academic scientists operate within university regulations, pressures and resources, which set the norms and incentives for particular research collaborations and other actions. Although organizational factors do influence the scientists' actions, I am interested in individual behavior as academics often act as free agents within the university system. Qualitative interviews are an ideal method to investigate questions of personal behavior and better understand how individuals perceive and interpret their experiences (Rubin and Rubin, 2011).While this research draws from previous academic collaboration research and institutional theory, the goal is to discover previously unknown institutional logic patterns and reconciliations academic scientists use to explain their collaboration behavior.

The interview instrument (shown in figure 5) is meant to help link institutional logics and academic collaboration decisions to research outputs. The instrument is relatively open to encourage participants to provide broad context about their views on open science and market logic within academia and what factors impact their research projects and other decisions. The semi-structured interviews allow for me as the interviewer to use probes and follow-up questions to better examine important ideas and explore a full understanding of the complexity of personal experiences. The interview instrument, sampling procedure, recruitment materials, etc. were reviewed and approved by the ASU Institutional Review Board (IRB #STUDY00016626, found in appendix E) before being implemented. Interviewees were sent an email invitation (Figure 6) and consent form asking for permission to be audio recorded (Figure 7). Then again before the interviews began I confirmed verbally with each participant that they consent to being audio recorded.

Sampling strategy

For sample selection, I randomly selected scientists to interview from the biology departments at three universities in Arizona (Northern Arizona University (NAU), Arizona State University (ASU) and University of Arizona (UOA)). I first identified a list of researchers in biology at each university from the publicly available faculty websites, for a total of 148 tenure track biologists (NAU=45; ASU=53; UOA=50). Then I randomly selected scientists to invite to be interviewed based on subfield, rank and gender across the three universities to ensure a diverse sample of academic biologists (shown in table 6). I started by emailing the interview requests to two biologists from each category at all three universities before randomly selecting more respondents due to nonresponses that most closely matched the specific categories. The goal was to get heterogeneity within each biology subfield in terms of rank and gender. I invited a total of 120 scientists for interviews to reach 19 interviews. I set up the interviews with the academic biologists from October 2022 to December 2022. Interviews ranged from 30-45 minutes. Interviews were recorded using the Zoom audio recording tool, which also transcribed the interviews. I verified all transcriptions with my corresponding notes and recordings.

Table 7 shows the breakdown of interview participants by university and other key characteristics (rank, gender, subfield). Due to the large size of the biology department at ASU and overall diversity, participants from the ASU are more evenly distributed across characteristics compared to NAU and UOA.

Figure 5 Interview Protocol

1. Introductory questions [Conversation tone to gain familiarity and build relationship]
    a. To help orient us a bit, could you briefly describe your main research?
    b. How is collaboration typically structured for your research? In terms of membership, sector, size, geographical distributions, disciplines…
    c. I am interested in how you usually manage data in these projects. I am thinking about storage access, record keeping, and agreements to share. Are there rules or protocols for data management? Can you talk a little about that?
2. Institutional logics: I am interested in better understanding what influences your decisions to undertake research topics, collaboration partners and other activities to produce patents or other research. To get at this question, I am going to ask you about different research practices in academia.
    a. One practice gaining recognition in academia is the opening up of science, which is broadly described as publicly and freely sharing resources and ideas for future use and scientific and technological progress. Open science values the spread of resources to increase transparency and reliability of scientific data and platforms to enable collaborations through open access initiatives such as posting data in publicly available websites and publishing in open access journals.
        i. Open science is everywhere now. Are you familiar with it? Would you say your lab practices it all the time? Why or why not?
        ii. How often do you share your data? How about publishing in open access journals? When you do not use open access publication, do you still share the data? Does your university support open access journals or data repositories?
        iii. Does your approach to data sharing and open access publishing affect who you collaborate with?
        iv. What are the benefits to these open access practices and what are the detriments?
    b. Thank you for that information about open access and data sharing. Now I would like to talk about developing inventions and commercialization.
        i. Have you ever disclosed an invention? Do you work with people on other proprietary things? Have you ever patented any of your research?
        ii. When you decide to patent/engage in proprietary practices how does this affect what you do with publishing and sharing data?
        iii. Do you ever find it difficult to make a decision about whether to commercialize or not? What makes it difficult?
        iv. What are the benefits to these proprietary practices and what are the detriments?
    c. Now I would like to go over some examples.
        i. How do you instruct your students or talk to people in your lab about these dual pressures – to be open and provide open access and engage in commercial activities and capture the rents from research?
        ii. Has there ever been a time you decided not to be open in favor of keeping your research proprietary? Can you talk about it? How about the opposite? Have you decided not to commercialize in favor of openly sharing your data or publishing? Can you talk about it?

Figure 6 Email Invitation

Dear Dr. ,

As part of my PhD dissertation, I am conducting a study to understand how scientists make research collaboration decisions and how their sharing preferences and behaviors change based on the type of research they are conducting.

I am contacting you to see if you would be willing to talk with me about your perspectives and practices related to research outputs and information sharing for future research.

The interviews are designed to inform about how academic scientists make research collaboration decisions and how these decisions influence research practices and knowledge creation for public science. Project findings will contribute practical insights for universities, and research communities by showing how researchers respond to university movements and pressures such as for commercialization and/or open science.

I know you are very busy and promise to keep the interview short. It should last 40-45 minutes and will cover several topics including your perspectives and practices about collaboration practices, information sharing, and research outcomes. There is no need for you to prepare as the topics concern your normal research activities. The interviews are confidential, and all data will only be reported as aggregated findings or as de-identified inputs in my dissertation.

I would like to set up a time to talk with you over zoom. I know you are busy and will do everything to accommodate your schedule. Please let us know if you are willing to participate and I will follow up to schedule a convenient time.

Thank you for your time. I hope to hear about your work. Feel free to contact me via email or phone if you have any questions.

Sincerely,

Ashlee Frandell
PhD candidate in Public Administration and Policy,
School of Public Affairs,
Arizona State University

Figure 7 Consent Form

Dissertation Research: Linking institutional logics and academic collaboration decisions to research outputs – Consent Form

As part of my PhD dissertation I am conducting a study to understand how scientists make research collaboration decisions and how their sharing preferences and behaviors change based on the type of research they are conducting. The purpose of this interview is to inform about how academic scientists make research collaboration decisions and how these decisions influence research practices and knowledge creation for public science.

I would like to talk to you because of your research collaboration experience, as well the insights you have about using data and other research outcomes for further scientific research. The interview will last 40-45- minutes and will cover several topics including your perspectives and practices about collaboration practices, data access, and sharing for research.

Your participation in this study is voluntary, if you choose not to participate or to withdraw from the study at any time with no penalty. There are no foreseeable risks or discomforts to your participation. Your responses are confidential, you and any other persons mentioned during the interviews will not be identified in the results. All data will only be reported in the aggregate. The results of this study may be used in my dissertation, presentations, or publications but your name and other potential identifiers will not be used. The de-identified data collected as a part of current study will not be shared with others for future research purposes or other uses.

I would like to audio record this interview. The interview will not be recorded without your permission. Please let me know if you do not want the interview to be recorded; you also can change your mind after the interview starts, just let me know. Additionally, any information that you might wish to be removed from the interview will be erased from the recording and will not be included in any research outputs. All interview notes, registration and transcripts will be stored on a secured shared driver located in SPA, ASU. All data from this research project will stored for a duration of 10 years after which they will be destroyed.

For your convenience, we will ask you to verbally consent to participating in the study prior to starting the interview.

If you have any questions concerning the research study, please contact me at afrandel@asu.edu. The PI is Dr. Eric Welch and he can be reached at ericWelch@asu.edu. If you have any questions about your rights as a subject/participant in this research, or if you feel you have been placed at risk, you can contact the Chair of the Human Subjects Institutional Review Board, through the ASU Office of Research Integrity and Assurance, at (480) 965-6788.

Table 6 Interview Subject Sample Distribution Subfield, Rank and Gender

Subfield	Rank	Gender
Genetics	Early career (Assis; Assoc)	Male
		Female
	Tenured (prof, semi-retired)	Male
		Female
Biomedicine	Early career (Assis; Assoc)	Male
		Female
	Tenured (prof, semi-retired)	Male
		Female
Ecology	Early career (Assis; Assoc)	Male
		Female
	Tenured (prof, semi-retired)	Male
		Female
Biotechnology	Early career (Assis; Assoc)	Male
		Female
	Tenured (prof, semi-retired)	Male
		Female

Table 7 Sample Breakdown by University and Rank, Gender and Subfield

	NAU	ASU	UOA
Total	5	10	4
Rank			
Early career	3	4	1
Assistant	1	2	0
Associate	2	2	1
Tenured	2	6	3
Professor	2	4	2
Semi-retired	0	2	1
Gender			
Male	4	5	2
Female	1	5	2
Subfield			
Genetics	0	5	2
Biomedicine	3	2	0
Ecology	1	2	2
Biotechnology	1	1	0

Data analysis

After I finished all of the interviews, I started my analysis by comparing characteristics gathered during the interview process across respondents. First I compared open access (OA) data sharing and publishing frequency across rankings to see how early career academic scientists compare to more senior faculty. The four rankings included are assistant professors, associate professors, full professors, and faculty who are semi-retired and still actively engaging in research. Table 8 shows that how often scientists publicly share their data do somewhat differ by rank.

Table 8 Sample Breakdown by Rank and OA Frequency

	Assistant	Associate	Professor	Semi-retired
Data sharing frequency				
Sometimes	3	2	2	1
Always	0	2	0	0
When required for publication	0	0	5	0
Other (e.g., unsure, plan to, etc.)	0	2	1	2
OA journal publishing frequency				
When there is good journal fit	2	1	3	0
A little	0	2	3	0
Always	1	1	2	0
Not yet	0	1	0	1

Table 9 compares participants across subfields and important open access (OA) and commercialization characteristics. The comparisons show significant subfield differences when it comes to OA and commercialization views and practices. Interesting differences can be seen for their engagement in proprietary practices and whether those practices influence their OA decisions across the four fields. There also seems to be differences when it comes to having difficulty commercializing and if their decisions to publish in OA journals influenced the collaborations.

Table 9 Sample Breakdown by Subfield and Key Characteristics

	Genetics	Biomedicine	Ecology	Biotechnology
Total	7	5	5	2
Engage in publicly available data sharing	6	4	5	1
Publish in OA journals	6	4	5	2
View that OA influence their collaborations	2	0	0	1
Have proprietary work (patent)	5	2	1	2
Have difficulty commercializing	4	4	0	1
View that patent decisions impact OA	2	2	0	2

Due to this initial finding of key research activity differences by field along with my later qualitative analysis of subfield nuances, I decided to revisit essay two and my use of fields as a control. While field differences did not seem to be significant as a control, my consistent findings in this chapter sparked the idea to instead treat the scientific field as separate samples. Thus, I decided to perform an exploratory analysis treating each scientific field as a subgroup along with the overall analysis in essay two.

Coding strategy

For the open coding strategy, the initial stage was based on my first reading of the cleaned transcripts and initial ideas about categories and themes (including following institutional logics theory). After assessing and revising the coding scheme, another reading was done in the open coding process to reflect and analyze the text (Kuckartz, 2014). The final coding categories/themes were used to code the interviews and are divided into two types. The first group of codes outline the type of institutional logic or if multiple logics are present: (1) academic logic, (2) market logic, (3) openness logic, (4) conflicts/reconciliation of logics. The second group of focused codes and sub-categories describe how the various logics are presented and implemented: (5) cultural foundations and differentiation (5a) founder effect (5b) generational changes, (5c) fearing of being scoop, (6) university incentives, norms and structure.

Table 10 outlines the type of logic codes and table 11 defines the focused categories and gives representative empirical material examples for each code. Finally, the text from the codes was analyzed separately to better understand how the answers informed the key questions of this research project. Direct quotes included in the analysis from the interviews have the following notation: sex, scientific subfield, rank, and interview ID code.

Findings

In order to better understand what institutional logics (e.g., academic, open science and market) are being implemented and when by the academic scientists, I coded the participants' answers under three categories: cultural foundations and differentiation, logistics, and university pressure. Cultural foundations in academic science include the founding of new subfields and the rules and structures that go along with them. While cultural differentiation is present in the vocabularies and content of professional knowledge adopted by different scientists within their subfields (Ocasio, et al, 2017). Subcategories under cultural foundations and differentiation include founder effect, generational changes, and fear of being scooped. University incentives, norms and structures include how the university system is set up and the incentives it provides for faculty including the burden of using fair principles in terms of time, funding and opportunity costs.

1. Academic logic

Cultural foundations and differentiation

While institutional logics may be changing within academic science, academia still values bolstering reputation and professional standing through increased publishing and acquiring competitive grants (Ali-Khan, et al, 2017; Hayter et al, 2020). This logic is associated with a competitive culture as seen through how scientists are selective with sharing research until publication and highly focused on getting grants and top-tier publications. Multiple participants explained during their interviews that the same cultural expectations and structures put on scientists to be the first to publish new knowledge remains active and a key constraint during their careers. Some of the scientists claimed that a lack of cultural and structural changes in their subfields makes it harder to prioritize other logics.

Table 10 Codes, Definitions and Representative Examples for the Types of Logics

Codes	Definition of the category	Examples
Academic logic	Description of the current collegiate reputational reward system including emphasis on career advancement through publishing in high-impact journals and acquiring competitive grants and other funding.	Traditional society journal system, which allows for cheaper pricing for faculty members and may offer some OA options, but typically are not fully open (Female, Ecology, Semi-retired, 17).
		University and prestigious federal grants as a way to for their research and collaboration practices, which often have their own requirements when it comes to openness (Female, Genetics, Prof, 1).
Market logic	Priority given to applied science and technology, and other commercial exploitations to generate profits outside of sector boundaries.	An IP is only valuable if somebody else wants it, so if a company calls me then it does have value and I'm fine with commercializing (Male, Biomed, Prof, 5).
		Several of my Chinese postdocs and graduate students have gone to industry after first working in my lab…try to be more entrepreneurial and I strongly support my students in that goal (Female, Biomed, Prof, 3).
Openness logic	Value given to the spread of resources, increased transparency and reliability of scientific data and platforms.	My collaboration groups always elect to publish the data in freely accessible repositories because it is valuable to the field, and to show how easy it can be. (Female, Biomed, Assis, 8).
		The Journal of Insect Science was based in the UOA library and pushed to use an open access approach, which happened because the science librarians were strongly in support of it (Male, Genetics, Semi-retired, 18).
Conflicts/reconciliation of logics	Description of scientists prioritizing one logic over others or find ways to balance multiple values, norms, etc. at once.	Open access sounds nice, scientists need funding and should not take risks that could endanger monetary gains. Instead, waiting until after publications to share data is fine (Male, Genetics, Semi-retired, 13).
		I am currently up for tenure and realize that once you are more established, those concerns about being scooped and needing to have IP protection dissipate. (Male, Biotechnology, Assis, 9).

Table 11 Codes, Definitions and Examples for How the Logics are Implemented

Codes	Sub categories	Definition of the category	Examples
(5) Cultural foundations and differentiation		Overview of the founding of subfields, vocabularies specific to certain groups, subfield differences, etc.	The culture is changing in the academy so fast, there is no longer just one guy is in charge, instead it is much more collaborative and inclusive, like more for women. Women tend to do things differently (Female, Ecology, Semi-retired, 6).
	(5a) Founder effect	Description of the founders' experiences and social capital and how they shape what resources are available and what terminology is used (e.g. open science, ethics, etc.)	Five guys started the field in the late 60s/70s valued and they felt that openness was important. Then anyone in their labs got the same idea to share (Male, Genetics, Prof, 16).
			It is important to lead by example especially if because later we want the data themselves (Female, Biomed, Assis, 8).
			It is not one of my priorities, so when I let others take the lead, if they want to do so then it is fine (Male, Biotech, Assis, 9).
	(5b) Generational or reputational changes	Discussion of any cultural differentiation due to generational or reputational changes or rank differences	My students are actually the ones that tend to know more about repositories than I do and believe in open science as an equity issue (Female, Ecology, Semi-retired, 6).
			Open science sounds nice but is naïve. Younger scientists still need funding and eventually will realize they won't share with their competitors (Male, Genetics, Semi-retired, 13).
			Science can have good societal impacts by students applying what they learned through pure basic research to companies (Male, Genetics, Semi-retired, 18).
	(5c) Fear of being scooped	Discussion of scientists' research being taken and used or published by someone else before they get the chance or not.	It is rare to get scooped as it is not as competitive as other fields focused on cutting-edge science where research happens very quickly and often has a monetary benefit (Female, Ecology, Prof, 15).
			Conferences are a good time to show interesting findings and to network, but this time I could not share much for fear of the ideas being taken" (Female, Biotechnology, Assoc, 2).
			Companies can cut their funding a lot easier than academic or government partners, leading to uncertainties I worry more about (Male, Biomed, Prof, 5).
(6) University incentives, norms and structures		Description of how the university system is set up and the incentives it provides for faculty and the burden of using fair principles in terms of time, funding and opportunity costs	The benefits are real for using data repositories. It looks good on a C.V. Some place like GitHub. Also sometimes preprint with enough citations and use (Male, Genetics, Assoc, 10).
			It takes five minutes, so sure why not. I always give the go ahead because there are no grenades to hit in this process or field (Male, Genetics, Prof, 16).

> “*There have been no big changes in my field. The same pressures remain. Essentially, I have a 20-year career focused on publishing.*” (Male, Genetics, Assoc, 10).
>
> “*Where I am in my career, my focus needs to be on getting grants and publishing. I would hate to miss out on other opportunities and to miss out on cash, but commercializing does not help me, or my post doc, achieve our career goals. Publishing is what he needs to do to build a career in evolutionary cell biology*” (Male, Genetics, Assis, 19).

Some of the interview participants argued that the OA journals’ reputations are a big reason why they do not always follow openness, and rather stick to the traditional journal societies that have high-impact standings. “*OA journals are a nuisance similar to predatory journals, especially when doing open science cannot even be used on my C.V. as a benefit to my career and reputation as a scholar as compared to a top-tier journal”* (Female, Ecology, Semi-retired, 6). Another participant described how he receives multiple emails from OA journals he has never heard of before, which “*does not instill confidence that they are respectable. There are a lot of opportunists out there, and often follow a business model. Sure there is rapid publication, but it comes at a cost and it is not seen well in my field*” (Male, Genetics, Assoc, 11). Many participants in all four fields claimed that publishing in OA journals and their associated data repositories can be time consuming, messy, a pain to utilize, and often showcases incomplete and unusable data. They mentioned fear of reputational consequences for using these sources and so they have a preference for the traditional system with trusted society journals. This finding from the interviews imply that the culture of reputational cache remains a priority for many academic scientists.

University incentives, norms and structures

Beyond that many of the culture and reputational aspects of academia have not changed much over time, the traditional tenure system also remains as a main pressure. The traditional tenure system and societies in academia are structured to put pressure on academics to focus their efforts on getting prestigious grants and on publishing in high impact, top-tier society journals. This logic pushes the norm for faculty to spend their time applying to competitive grants and other similar funding opportunities as a way to gain prominence and to do their work appropriately.

> "*Most scientists pursue university and prestigious federal grants as a way to for their research and collaboration practices, which often have their own requirements when it comes to openness*" (Female, Genetics, Prof, 1).

As for publishing, most high impact journals belong to the "*traditional society journal system, which allows for cheaper pricing for faculty members and may offer some OA options, but typically are not fully open*" (Female, Ecology, Semi-retired, 17). These journals also have an extensive review process that sets these scientists up for success and greater career impact.

> "*The high-impact journals' review process is important. In one case, the reviewers caught something that changed the paper. Reviews by experts and those with the know-how make it better*" (Male, Genetics, Assoc, 10).

Following this, some of the scientists feared that because of how OA journals and other open science initiatives (e.g., preprints) are presented and structured, there can be ethical issues. Some of the open science initiatives do not have the same peer review norms and pressures as traditional journals and without these checks, information can be lost and misused.

> "*There is greater scope for the public to misinterpret things without any push back, especially in human genetics. I also get push back from senior collaborators about these OA journals and even putting initial findings as preprints, especially in the medical field*" (Male, Genetics, Assoc, 10).

These findings from the interviews imply that both the reputational aspects and university norms of encouraging the traditional society journal system leads many academic scientists to continue to prioritize academic logic over other logics. In other words academic logic remains somewhat dominant in academia as every scientist spoke about career advancement through top-tier publications, even as other logics are presented.

2. Market logic

Cultural foundations and differentiation

When it comes to market logic, scientists explained their views through describing their reputational changes over time. Multiple tenured career scientists had industry reach out to them about their works' market potential, lowering their work load and allowing them to lead and gain significance within their subfields.

> "*Companies approach me based on my reputation, like when people read my work and see that what I have done is valuable to them or heard me speak at a conference and reach out about patents or licensing*" (Male, Genetics, Semi-retired, 18).

> "*An IP is only valuable if somebody else wants it, so if a company calls me then it does have value and I'm fine with commercializing*" (Male, Biomed, Prof, 5).

Another scientist remarked about his experience when his field was starting out.

> "*I patented some strains that I slated in the beginning of my field, which I try to still give them out if they will not be used for any financial reasons, like with a pharmaceutical company. For them it has to be officially licensed. I have this reputation that everyone knows about*" (Male, Genetics, Prof, 16).

Comparatively, both early career scientists and students working with late stage scientists may not be as dominant in their fields or have the same reputational cache. Still, they may prioritize market logic because they want to be seen as more entrepreneurial and that their work has a greater societal impact. In this way both the dominant and preferable actors both find ways to prioritize a nontraditional logic.

> "*Several of my Chinese postdocs and graduate students have gone to industry after first working in my lab, even though they do mostly basic research. Even so, some of them try to be more entrepreneurial and I strongly support my students in that goal*" (Female, Biomed, Prof, 3).

This pattern in responses implies that early career scientists and students may place more value and priority on being entrepreneurial and focusing on commercialization (i.e.

market logic) as compared to their tenured counterparts when they are starting off their careers. These interviews suggest slow cultural changes for early career scientists and students as entrepreneurship gains more prominence and is seen as a positive goal.

Another scientist spoke about the need for clinical impact and recognizes how industry and market logic can make that happen better than other logics (e.g. academic logic).

> "*With my breath biomarker research, we wanted to improve clinical practice and to do so, we needed an industry partner to be interested. For that, the invention needs to be money making or if insurers see that there is a lot of benefit to the biomarker and they push for it. I have no interest in trying to take advantage of the money making through like spin offs, but happy to license to companies. It is important to do the work to improve clinical practice, but somebody has to economically benefit for it to happen. That is simply the way it works*" (Female, Biomed, Assis, 8).

Another scientist agreed that "*science can have good societal impacts by students applying what they learned through pure basic research to their work in companies*" (Male, Genetics, Semi-retired, 18). In other words, students are prioritizing and pushing for a culture that understands the importance of clinical practices and how market logic and being entrepreneurial can be of benefit. These interview responses indicate some cultural differentiation between early career and tenured scientists.

University incentives, norms and structures

Many of the scientists that have disclosed an invention previously described the commercial practices as fast and simple. "*It takes five minutes, so sure why not. I always give the go ahead because there are no grenades to hit in this process or field*" (Male, Genetics, Prof, 16). A few stated that if their IP is valuable enough, companies reach out to them about licensing and collaborations, reducing a lot of their work and allowing them to reap monetary benefits. Their motivations behind applying for their patents partly are related to "*not wanting to miss out on cash or any monetary gains"* (Male, Genetics, Assis, 19),

> *"In biomed everything happens very fast and it's competitive with potential monetary benefit from patents. Same in agricultural fields and anything related to technology. Anything with potential money to gain has to be protected with an IP*" (Female, Ecology, Semi-retired, 6).

Other views from scientists who patented previously include that commercializing is a straightforward and less time-consuming system because "*with a company I don't have to write two to three grants just to get funding*" (Male, Biomed, Prof, 5). Grant writing and applications take time and a lot of effort, while industry can make funding available a lot quicker and easier.

In comparison, a few scientists who considered disclosing an invention but ended up deciding not to, saw the process as "*too much of a hassle and industry can cut their funding easily and without notice*" (Male, Biomed, Prof, 5) and "*not corresponding to their career goals as compared to publishing*" (Male, Genetics, Assis, 19). This disconnect in views about commercialization and the patenting system structure at their universities may account for some of the tensions between market and the other academic logics. These interview findings suggest that firsthand experience with the commercialization process can make a difference in views and prioritization of one of institutional logics over another.

Almost every respondent that had disclosed an invention mentioned needing more funding and industry sponsors and how universities advertise that possibility through commercialization practices as an influence on their decision making "*Money drives most of it from spin-off companies to the potential of using money as funding for research and independent wealth*" (Male, Biotechnology, Assis, 9).   However, one participant did point out that while there are many opportunities for industry funding, "*companies can cut their funding a lot easier than academic or government partners, leading to uncertainties I worry more about*" (Male, Biomed, Prof, 5).

Beyond simply funding, commercialization practices help to industrialize knowledge as universities are less able on their own.

> *"When you develop a technology, you need an infrastructure for it, which companies usually have. That way, eventually prices go down and students can easily get the technology like what we did with the kits. Now they are fast to get and advanced, which is helpful for student development*" (Male, Genetics, Semi-retired, 13).

In general, many of the scientists who have disclosed an invention previously stated during their interviews that it is pretty much a product of how universities are set up now. University pressure and support in the patenting process makes it more likely for them to patent their research. The scientists explained how universities are set up to now encourage market behavior.

> "*Universities like mine want to make money and hope patents will bring in profits. Even though I would prefer to have my research freely available, it is part of the deal I made here to patent whenever I invent something. I usually am okay with working with a company further as long as ASU thinks the company can do what they say they will.*" (Male, Genetics, Semi-retired, 13).
>
> "I am *required to disclose to ASU any new inventions discovered and then the school decides if it is valuable enough to file an IP. I only wait till all the steps are done, and I always have first rights to refusal*" (Male, Biomedicine, Prof, 5).

These responses indicate that the scientists chose to follow market logic often out of necessity and the options presented and available through their universities.

3. Openness logic

Cultural foundations and differentiation

The use of different academic institutional logics (e.g., academic, open science and market) can be rooted in the specific scientific subfield's founding team, also known as the founder effect. The founders' experiences and social capital shape what resources are available and what terminology is used to define the given space and to increase legitimacy of the values and rules (Almandoz, 2012). This founder effect adds to the field differences when it comes to adopting and utilizing different institutional logics. Founding members of scientific subfields, especially niche ones, are dominant actors and often have a lasting influence on their community's culture, norms and framework about how to conduct scientific research and form collaborations. Many respondents presented their priority of the openness logic through the founder effect. For example, one scientist in the genetics field described how the founders of yeast genetics pushed for open science and now the logic is highly valued in the smaller subfield.

> "*Five guys started the field in the late 60s/70s and they felt that openness was important. Then anyone in their labs got the same idea to share as much as you can whenever you can. This principle was passed down to their students as well*" (Male, Genetics, Prof, 16).

Due to the founders' lasting influence and the small size of the subfield, the scientist argued that reputation and social pressures ensure that colleagues freely share their scientific work without concerns. In other words, this subfield acts as a "*small village with social enforcement of proper behavior*" (Male, Genetics, Prof, 16).

Another participant from biomedicine also described key field differences due to the pioneers in the metabolomics subfield. "*It is important to lead by example especially if later we want similar data ourselves. We need to show others in the field how it is done*" (Female, Biomed, Assis, 8). Compared to the genomics subfield where funding institutions and journals often require researchers to put their data in public repositories, metabolomics researchers have not faced the same requirements in the past for structural reasons.

> "*Even though it is harder in metabolomics to correctly share the data due to structural issues, my collaboration groups always elect to publish the data in freely accessible repositories because it is valuable to the field, and to show how easy it can be. We want to incentivize others to follow and be leaders in the field as it changes*" (Female, Biomed, Assis, 8).

Overall, six participants from genetics, biomedicine, biotechnology and ecology argued that founder and reputational influence is a big factor as to why their narrower subfields tend to primarily follow the ideal of openness and engage in open science initiatives like public sharing of data, OA publishing, preprints, etc.

While cultural foundations often start with the field founders' values and reputational influence, differentiation can occur also due to generational changes or rank differences. Eight of the participants specifically mentioned differences in views on following openness principles between early career and tenured scientists. All eight scientists mentioned that their students are often the ones suggesting the use of OA publishing and other open science initiatives. "*My students are actually the ones that tend to know more about repositories than I do and believe in open science as an equity issue*" (Female, Ecology, Semi-retired, 6). Additionally, many of the full professors mentioned taking further considerations when collaborating with early career scientists.

> "*I often only commit to open science publications only when the newer scientists on my team push for it*" (Male, Genetics, Assoc, 10).

> “*My mentor told me that being open such as with reviews and publications is dangerous and could have reputational influence, which is silly and a more traditionalist way of thinking. Where I am not a traditional scientist*” (Male, Genetics, Assis, 19).

This result indicates that the openness logic is finding traction with more early career scientists overall. However, in niche subfields where the founders started out with open science principles, almost all scientists (early and tenured) in these subfields tend to consider openness as important and a priority.

University incentives, norms and structures

Following newer institutional logics in academia may lead to more costs than benefits where there are burdens to using seemingly fair principles. Most of the scientists remarked specifically about one of the openness initiations, open access (OA) publishing, when I asked about any costs to open science generally. All participants except for two mentioned that the associated OA journal costs are a main reason behind not focusing on OA and publishing in other journals first. Many of the scientists explained that their universities do not really support full OA publication options in terms of funding (e.g., NAU does not due to its small size) and OA journals tend to be a lot more expensive compared to traditional journals.

> “*While I agree with the principle that research should be available to everyone, I am at a small school and I don’t have access to many journals, and even if I do, I*

> *often have to wait a long time. Meaning it is not equal access for everyone*" (Female, Biomed, Prof, 13).

> "*Publication costs are usually written into grants and other funding, but they are never quite enough to cover the large OA journal prices, and I would rather pay to hire a student or other research costs than pay more to publish. This system seems to have more of a corporate purpose than a scientific purpose*" (Male, Biomed, Assoc, 3).

On top of that, one scientist in the genetics field argued for problems with using data repositories and other methods to share genetic data.

> "*We have a moral obligation to talk about the caveats of the data, which is not easily done through the repositories or proprietary work either for that matter*" (Female, Ecology, Prof, 6).

Overall, the participants described OA publications as "*a poorly incentivized system that is challenging and in need of better options*" (Female, Ecology, Semi-retired, 6) and "*more tricky, time consuming and super expensive, like practically five-thousand to publish one article, which could be spent on students instead*" (Female, Ecology, Prof, 4). The scientists talked about both their universities' and the general academic science communities' support and views on openness.

> "*The academic scientific community skipped a couple steps in the open science implementation when it comes to open access journals, like how do we afford it in our budget, especially as NAU doesn't have the same budget as a university like*

> *UOA and the department cannot make up the difference*” (Female, Biomed, Assoc, 12).
>
> “*I have worked with collaborators from countries like Brazil, and they can’t afford open access publications, which sort of invalidates the whole concept*” (Female, Ecology, Prof, 7).

These interview findings imply that OA journals are often seen as going hand in hand with open science in general and that many scientists find fault with how open access journals are set up.

In comparison, some respondents had a different view about open science if they were aware of universities with a library and/or associated journal that advocates for openness. Seven participants from all three schools, all four rankings and all fields except for biomedicine praised the open science efforts made by university libraries. “*Libraries are an important part of the puzzle for how to make open science principles work better in practice and should use their market power*” (Female, Ecology, Semi-retired, 17). One tenured researcher at ASU explained how the UOA library was a pioneer in his field of insect genetics for OA journals.

> “*The Journal of Insect Science was based in the UOA library and pushed to use an open access approach, which happened because the science librarians were strongly in support of it. Now, the journal is a vehicle for leading the Entomology Society of America and following open science*” (Male, Genetics, Semi-retired, 18).

Beside publishing in OA journals, libraries and other journals also can influence other open practices such as publicly and freely posting data. This trend in the entomology field illustrates how scientists' needs by field and subfield are different and so universities and journals may need to take a more scientist specific approach when designing policies and advocating for the various logics.

While many of the scientists spoke generally about how libraries influence open access practices, only a few mentioned specific actions taken such as the example of the entomology journal. In that case, the scientist did sit on the board of the journal, therefore having more insider knowledge. This finding implies that knowledge about openness may not be that widely known and having insider knowledge about specific actions may have greater influence over how scientists feel about certain logics.

The scientists also mentioned that more and more journals are requiring "*all data to be published on publicly available repositories in order to accept their articles*" (Male, Genetics, Assis, 19). Along with grant requirements, these pressures have led to the creation of more systematic repositories to help with the ease of freely publishing data in some fields. "*Grant mechanisms have implicit in them how data have to be shared in the application process, along with federal requirements*" (Female, Biomed, Assis, 8). For example, in the ecology field and biomedicine, "*a lot of the community uses Dryad as their data repository*" (Female, Biomed, Prof, 14). Other respondents argued that the lack of unified systems for depositing and using data makes open sharing more difficult and takes up a lot of time.

> "*Compared to genomics, in the metabolomics subfield the data samples tend to be more complex and there are quite a few platforms to view the data, making it*

> *harder to know where all the data is and to be able to analyze what the data is showing*" (Female, Biomed, Assis, 8).

This finding shows that there is a difference between openness and access, where complexity comes in. More complex data also serve to protect intellectual rights as simply publicly posting the information is not useful if it is not structured correctly.

The scientists' responses indicate that universities and their libraries have a lot of pull when it comes to which institutional logics these scientists prioritize or find available. Following the various institutional logics in academia may lead to more costs than benefits where there are burdens to using seemingly fair principles. All participants except for two mentioned open access (OA) journal costs and/or money for patents as a main reason for their research decisions. Many of the scientists explained that their universities do not really support full OA publication options in terms of funding (e.g., NAU does not due to its small size) and OA journals tend to be a lot more expensive compared to traditional journals.

> "*While I agree with the principle that research should be available to everyone, I am at a small school and I don't have access to many journals, and even if I do, I often have to wait a long time. Meaning it is not equal access for everyone*" (Female, Biomed, Prof, 13).

> "*Publication costs are usually written into grants and other funding, but they are never quite enough to cover the large OA journal prices, and I would rather pay to hire a student or other research costs than pay more to publish. This system*

> *seems to have more of a corporate purpose than a scientific purpose*" (Male, Biomed, Assoc, 3).

On top of that, one scientist in the genetics field argued for problems with using data repositories and other methods to share genetic data.

> "*We have a moral obligation to talk about the caveats of the data, which is not easily done through the repositories or proprietary work either for that matter*" (Female, Ecology, Prof, 6).

4. Conflicts/reconciliation of logics

Cultural foundations and differentiation

While many of the responses show the scientists following one institutional logic over another, there are also indications of the scientists trying to reconcile multiple logics or taking time to purposefully choose one over the other due to conflicts in values. The reconciliation of the different academic logics can be seen in the scientists' responses during the interviews about fear of their research being 'scooped' in certain subfields and between ranks. The seven scientists who spoke about their research being taken and published by someone else (i.e. being scooped) have all also disclosed an invention previously. Out of the seven scientists, there was almost an even split between viewing their work being scooped as a real threat and as unnecessary paranoia, which did differ by subfield.

> “*It is rare to get scooped in the ecology field, as it is not as competitive as other fields focused on cutting-edge science where research happens very quickly and often has a monetary benefit*” (Female, Ecology, Prof, 15).
>
> *“The ecology field is a lot slower than others and there is less urgency when it comes to planetary health and so it is also less competitive. Data just needs to get out there and we care about proof of concepts, not ownership*” (Female, Ecology, Prof, 6).

The responses indicate that the ecology subfield may not experience the same restraints that come along with fear of being scooped as other fields that are more competitive in nature. So, these scientists are more likely to share their data openly along with disclosing an invention or some other proprietary actions. One scientist in the biotechnology field doing more software and less competitive work had a similar view.

> “*I am currently up for tenure and realize that once you are more established, those concerns about being scooped and needing to have IP protection dissipate. Even with commercialization, and I am concerned a little, it is still more important to have transparency, to show you can do it well and get more collaboration interests. Once you are seen as an expert, the net benefits outweigh potential downsides*” (Male, Biotechnology, Assis, 9).

In this way, the scientists were able to reconcile openness and market principles due to the nature of their subfields to be less competitive and more about gaining reputation and other opportunities to collaborate.

In comparison, the participants across ranks who engaged in more fast paced, technologically focused and/or commercial work (i.e. biomedicine and genetics) explained how their fear of being scooped shaped their research decisions.

> "*It is naïve not to consider being scooped as a threat and have to be careful when sharing data and findings*" (Male, Genetics, Semi-retired, 13).
>
> "*It takes a long time to publish, and meanwhile others will publish on your data before you do. They act like data miners, not creators. Although they provide a broader synthesis and combine many datasets that individual projects can't get to, science needs data and someone needs to generate it*" (Male, Biomed, Assis, 3).
>
> "*Open science sounds nice, but scientists need funding and should not take risks that could endanger monetary gains. Instead, waiting until after publications to share data and their work is fine*" (Male, Genetics, Semi-retired, 13).

Three of the interview respondents said that using IP protection (patents, etc.) to safeguard their research did influence their open science practices including not answering all data requests, slowing down publications, networking less at conferences, etc.

> "*We had to be quiet about our findings until the embargo was over, which influences data sharing and limits conferences. Conferences are a good time to show interesting findings and to network, but this time I could not share much for fear of the ideas being taken*" (Female, Biotechnology, Assoc, 2).

Another scientist remarked how her teams can still publish in traditional journals without disclosing all of their work and harming the commercial potential.

> "*For biomarkers research, when publishing on intermediate outcomes, we withhold the chemical name until we have filed the appropriate paperwork for protections. The names of compounds are what is useful for commercialization and the diagnostic model, so we don't have to slow down our publication because we can still mask the identities*" (Female, Biomed, Assis, 8).

In this case, the scientists made a choice between following market logic versus open science principles, often putting the patenting benefits above those for open science. In comparison, patenting did not seem to have the same priority over the traditional academic logic as publications was still a priority even if not all the information was included in the journal article. In this case, complexity again plays a factor into openness versus access. While others have access to this biomarkers research through publication, the results are still not completely open and not completely useful without the chemical names.

University incentives, norms and structures

The potential for a career advancement and other university pressures can impact and lead to conflicts in logics depending on the field. Many of the scientists mentioned how being able to put their work on their C.V. as a big draw towards the more traditional academic logic that emphasizes the use of high impact journals. "*Publishing in OA journals is not great for your C.V. It is not a well incentivized system*" (Female, Ecology, Prof, 6). In comparison, for certain subfields understanding how to clean and post data to public repositories can be added to an academic C.V. and is seen as useful for career advancement.

> "*The benefits are real for using data repositories. It looks good on a C.V. Some places like GitHub. Also sometimes preprint with enough citations and use*" (Male, Genetics, Assoc, 10).

This change in some subfields to now allow publicly sharing data in repositories to be a career impacting activity indicates a reconciliation of openness and academic logics, which also occurs when it comes to market logic. For instance, some of the scientists spoke about the university system changes to incorporate commercial practices in the tenure and career advancement system.

> "*Once the patent is published, you can use it like a citation, and put it in your C.V. in its own category. This looks strong on your C.V. as compared to another paper, as it is harder to do*" (Female, Biotechnology, Assoc, 2).

This shows attempts at reconciliation between market and academic logic, as the university system is attempting to broaden what is considered important for career advancement and to incentivize certain research. This coincides with how more than half of the participants in the interviews mentioned how both university and/or grant support and structures matters for whether they follow open science and/or commercialization activities. Four scientists argued that their smaller universities are at a disadvantage as compared to ASU when it comes to institutional support for OA publishing, while commercialization can be a lot easier. "*NAU doesn't have the same budget that larger* *ones like ASU have, and my department can't make up the difference*" (Female, Biomed, Assoc, 12).

Another example of reconciliation between the logics given by the interviewed scientists is the use of traditional journals that also offer OA publications.
Some of the traditional society journals offer OA publications as an option after a certain amount of time for a smaller fee as compared to pure OA journals. "*The traditional journal system has societies running journals with member fees, and they also have some open access options if desired*" (Male, Genetics, Assoc, 11). Also, some scientists spoke about other methods besides publishing in an exclusive OA journal that follow the openness logic such as by using preprints of their initial results and conference proceedings.

> "*I try to use preprints as much as possible, especially if the first author pushes for it. Really it is up to whoever has the time and effort. Preprints do take up time, but can help with networking and to get to publications later used on your C.V.* (Male, Genetics, Assis, 19).

Discussion

This study explored 19 interviews of early career and tenured academic biologists from three universities in Arizona in order to better understand how institutional logics influence their research decisions. The research identifies three institutional logics (academic, market and openness) from respondents' answers along with cases of conflict and reconciliation between the logics. The analysis produced two categories to organize how the institutional logics are presented and identified by the scientist, which are cultural foundations and differentiation, and university incentives, norms and structures.

All three institutional logics have cultural foundations and differentiation, starting with academic logic, which is traditional and mostly dominant in academia. The interviews show how market oriented cultural changes come from new views on the importance of entrepreneurial behaviors and clinical practice as well as money motivations. In comparison, some of the founders of subfields valued openness, which led to its continued use down the line.

University incentives, norms and structures impact what opportunities are available to the scientist as well as the importance of doing certain research activities such as publications, patents, etc. While many of the scientists in the interviews spoke generally about journals and libraries' impact on open access practices, only a few mentioned specific actions they have taken (e.g., the entomology journal). This disconnect implies that university/library openness support may not be widely known among all academic scientists. Rather, the respondent who spoke about the UOA library's openness strides sat on the board of the journal, therefore having more insider knowledge. This trend brings up a question for future research about how widely known these academic openness initiatives are and whether scientists have incentives to communicate about their actions. It seems the current academic system is not set up so that scientists benefit from communicating more about their research decisions and views on initiatives like OA to push the logic forward. An implication from this finding suggests that the universities or associated organizations like libraries that do value openness should be more transparent and vocal about efforts taken and opportunities for researchers.

The findings from the interviews also highlighted important field and rank differences. The apparent conflict between the three logics presented by the interviews holds true in certain fields while not in others. As ecology is not considered a highly competitive field compared to others, many of the researchers are able to prioritize openness principles without jeopardizing their academic publishing. In comparison, the competitive atmosphere found in more technological and fast paced fields such as biomedicine and genetics heightens conflicts between openness and market practices due to fear of being scooped.

Besides logic conflicts, there are also field differences when it comes to reconciliation between the various logics. For instance the respondents in biotechnology and other competitive fields highlight reconciliation between market and academic logic through changes to C.V.. specifications. New pressures within universities have allowed some scientists to now include patents on their C.V.s as a key research product besides journal publications. In comparison, attempts to reconcile openness with traditional academic logic seems to be more difficult due to complexity. For example, one of the interviewed scientists was able to publish findings right away by concealing the names of the chemicals used, which expands access to the research, but not usability. This finding suggests an important difference between access and true openness which can be more difficult with increased complexity.

This finding of key subfield differences in how scientists make research decisions and follow different institutional logics implies the importance of subfield nuances when looking into academic science. Due to this, I decided to go back to essay two to take the time to rethink my use of fields as merely a control in the regressions. While in my first edition of the essay field differences did not seem to be significant as a control, the findings from these interviews suggested otherwise and sparked the idea to instead treat the scientific field as separate samples. So, I decided to add an exploratory analysis to essay two in order to treat each scientific field as a subgroup to supplement the overall analysis already done.

The results from the interviews also presented rank differences in how institutional logics influence scientists' research decisions. The interviews present a distinction between early career and tenured scientists when it comes to cultural foundations and differentiation, and university pressure. As for openness logic, the interview findings imply that it is more appealing to early career scientists overall in all subfields and that they are the ones to emphasize open access practices when collaborating with tenured faculty. Although, when looking at smaller niche subfields where the founding team believed in open science principles, both early career and tenured scientists tend to consider openness as a priority. This differentiation by rank also can be seen in how some early career scientists see the importance of clinical and entrepreneurial practices, and that market logic is beneficial. These key subfield and rank differences matter for research and practice and call for a more nuanced approach to policies aimed at promoting certain research activities associated with one logic over another.

CHAPTER 5

DISCUSSION

Overview

Overall, this dissertation advances understanding about how scientists' decisions and research activities (i.e., patenting) impact knowledge flows and the public support of scientific research, an important policy topic about academia's role in society. Universities serve a key function in society as producers of important and novel knowledge that can lead to problem solving, economic spillovers, innovation and other benefits for the public. The successful production of innovations and other new knowledge by universities depends on many factors including ease of knowledge flows and the involvement of industry (McMillan, et al, 2000; Partha, and David, 1994). As a result, it is important to understand how academic scientists' make research and collaboration decisions and how these choices impact knowledge creation and diffusion, which are important for scientific and technological progress.

This social mission to advance public science through increased knowledge flows can present tensions in values and overall goals for the academic scientists. The private sector plays a role in higher education through their involvement in academic-industry collaborations and the commercialization of academic research. Due to some academic goal changes, there are shifts to industry involvement in higher education and tensions around increased demands for commercialization of publicly funded research So, this dissertation set out to answer the questions: How do academic scientists make decisions about their research activities and involvement with industry and how do these decision outcomes impact knowledge flows for the advancement of science? My dissertation contributes to the academic science and engagement literature by looking at changes to US science and its advancement through scientists' decision-making guided by institutional logics about their research activities and industry relationships, and how these decision outcomes impact knowledge flows.

The first essay builds on the previous literature to develop hypotheses on important relational characteristics during the patenting process and individual scientist behavior that explain the relationship between industry involvement in patents and knowledge sharing. Patents that are highly cited by future patents are novel and broadly applicable, and lead to further knowledge flows (Higham, De Rassenfosse, and Jaffe, 2021; Yoon and Kim, 2011). Using data from the 2010 national survey of university scientists and engineers combined with publicly available patent citation data, I answer the question: how academic-industry patenting collaboration characteristics influence knowledge flows? The findings from this essay show that the behavior and perspective of the academic inventor when it comes to industry collaborations is important for patent citations. The type of industry activities the scientists participate in, whether they have previous experience collaborating with industry and their views on collaboration conflicts are related to the knowledge flow outcome. However, the relationships are not strictly linear as academic scientists' views about industry collaboration conflicts can depend on their previous experience working with industry.

The second essay both expands on the first and is guided by the third essay, as it focuses on how patent collaboration networks influence new science and technology knowledge flows and exploring field differences. Networks are important for the creation and dispersion of new knowledge in academic science because the ties reduce research infrastructure costs, and also increase the flow of the new ideas (Azagra-Caro and Consoli, 2016; Tahmooresnejad and Beaudry, 2018). This essay leverages co-inventor network collaborations specifying industry partners across different disciplines to see how they influence knowledge flows. This structural approach enables a closer look at how the collaborations span the university and industry sectors, to see how the combination of the two sectors matters for knowledge flows and the advancement of science. Using the same data from the 2010 national survey matched with publicly available patent network and citation data, I apply social network data and metrics to test variation in patent citations by patent network structure and composition. The essay finds that academic-industry perceived value conflicts, a factor used in essay one, is also a significant network composition characteristic. As the first two essays both point to the significance of perceived value or logic conflicts, the third essay delves deeper into how these perceptions of industry and academic logics influence research decisions. I also conduct an exploratory analysis of the relationship between networks and knowledge flows separately by field due to important field specific findings from essay three.

The third essay builds on the first two by diving deeper into how and why scientists make decisions about patenting and working with industry utilizing institutional logics as a guide. To guide scientific and technological development, universities and their scientists adopt institutional logics (academic, market and openness) about how to effectively share knowledge, as the boundaries between public and private research shift and get closer (Dai, et al., 2018; Powell, and Colyvas, 2008). This essay explores how academic scientists' research decisions are based on particular institutional logics, how they view any logic trade-offs or conflicts and how the logics they follow influence their everyday research activities. Using institutional logics theory, I interview early career and tenured scientists in biology across three universities in Arizona to learn more about how institutional logics present and interact in academic science. Findings in essay three about how academic scientists integrate the logics help to fill in the gaps from the first two chapters about how scientists make their patenting and other research decisions. Essay three also presents the importance of field specifics, which inspired the exploratory analysis done in essay two. The findings from the qualitative interviews show that subfield context matters greatly for how and why scientists decide to engage in different collaborative research activities and that subfields can form their own customs and norms when it comes to networking. Additionally, the qualitative analysis produced two categories to organize the scientists' institutional logics, cultural foundations and differentiation, and university incentives, norms and structures, which differ by both rank and subfields.

Main contributions

My main contributions are threefold. First, I advance the science and innovation literature by focusing on key structural and relational content of patenting and academic science collaborations and networks in the first two essays. Collaborations across public institutions and with other sectors are important for the improvement of knowledge flows. As the patenting process is highly social and nonlinear, my findings highlight key social structures and relationships involved in knowledge transfer that improve knowledge flows, measured by citation counts.

The first essay highlights the importance of key social influences that are often overlooked and contribute to the complexity of knowledge flows for academic science and technology, which tend to be more cumulative and dynamic (Meyer, 2000a; Tijssen, 2001; Verbeek, et al., 2002). The results suggest that more attention in the literature should be on the type of industry involvement, such as continual formal and informal interaction between the academic and private sectors. As for nonlinear relationships, academic scientists' views about industry collaboration conflicts interact with their previous experience collaborating with industry. While less attention is generally given to negative effects of academic-industry engagement, this study implies the importance of focusing on barriers to these interactions and how they interact with prior experience in future research as well as university policies. Overall, both the behavior and perspective of the academic inventor involved with industry impact citation counts and so are important for the knowledge flow outcomes.

The second essay illustrates how knowledge creation and diffusion often has a more network-embedded structure, leading to partnerships and academic-industry interactions (Meyer, 2002; Verbeek, et al., 2002;). The chapter builds on the findings in essay one about how academic-industry perceived value conflicts can influence knowledge production depending on their prior collaboration experience and adopts a network structure. The findings point out key network structure and composition characteristics for knowledge flows and supplement the results of essay one, the importance of industry ties and perceptions. The results imply the need for further policies aiming at bridging the academic private sector boundaries by encouraging networks with industry ties and more alignment between the perceived incentives between academia and industry members.

I also include an exploratory subpopulation analysis of the network relationships separately by scientific subfield, an important finding highlighted in essay three during the interview process. The interview responses show that in-depth field context impacts why and how scientists decide to engage in different collaborative research activities depending on their subfield’s customs and norms when it comes to networking and industry involvement. The field subpopulation analysis shows that network density differently impacts knowledge flows depending on the type of network involved, such as more interdisciplinary members.

Second, after showing how the decision outcomes impact knowledge flows, I explore why and how scientists make these research decisions using an institutional logics lens. I contribute to theoretical foundations by integrating institutional work with the science and innovation literature. By looking specifically at how scientists view and reconcile market and openness logics, I show how their research choices impact science and technological progress and knowledge sharing. This essay shows how academic scientists’ research decisions are based on particular institutional logics, including any logic trade-offs or conflicts and how the logics influence their many research activities. The results in essay three help to fill in the gaps from the first two essays about how scientists integrate their logics and make collaboration and other research decisions.

Taken together, my dissertation advances knowledge about new shifts in university science, looking at the interactions between the academic and private sectors and how they influence research decisions and the public value of the outcomes. The first essays of this dissertation show that the mixing of the two sectors, in terms of patenting, networking and collaborations, matter for knowledge flows and the advancement of science. The findings from the qualitative interviews show how academic scientists' view the relationship between public and private values through their use of institutional logics, deeply held values and beliefs that help guide researchers and influence patenting activity (Barth, 2018; Friedland and Alford, 1991). The mixing of multiple institutional logics, openness and market, can impact what research activities the academic scientists choose to engage in and when.

Limitations and next steps

Beyond reviewing the implications of the findings for research and practice, it is important to comment on the limitations of this dissertation. The cross-sectional nature of the data in the first two essays limits causal inference and is vulnerable to endogeneity. One form of endogeneity possibly in my model is omitted variable bias such as university and local policies and incentive programs. However, to limit this bias, the studies include controls accounting for inventor and university quality differences, which encompass differences in incentive opportunities and other various predictors of network membership and citations.

Another endogeneity concern is that while many scientists self-select into collaborating with industry involvement, the most productive scientists engage more with industry and vice versa. In order to limitless possibility I do include multiple proxies for researcher quality in my models. Finally, the Cronbach's alpha for the perceived industry conflicts variable is somewhat low, which may be caused by a low number of questions or heterogeneous constructs. However, a strength of the studies is that they limit the risks of common source bias by including a dependent variable that is not reported by survey respondents and instead comes from the bibliometric dataset. Additionally, the third essay is an exploratory look into how academic scientists use institutional logics to form their research decisions. This study is exploratory in nature and is meant to highlight key themes and areas for future investigation.

Future research should look into other academic-industry collaboration activities beyond patenting, as there are many that influence the involvement of industry in academic science and contribute to scientific and technological knowledge creation and progress. Industry involvement in academic science in general is complex as there are multiple knowledge sharing mechanisms such as co-publications in journals and spin-off companies. As for spin-off companies based on the academic work, there can be tensions between the institutional logics used and ethics around hiring students, etc. Additionally, the third essay of this dissertation leaves open many avenues for future research looking into how institutional logics are presented and mixing within academia. Future work can build off of the exploratory analysis' finding about the use of logics to guide academic-industry collaborations and other work.

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APPENDIX A

SAMPLE SELECTION BIAS TEST

	B	SE
Female	0.18	0.13
Classification	-0.02	0.02
Constant	-0.01	0.33

*** *p<.01*, ** *p<.05*, * *p<.1*

APPENDIX B

INCLUSION IN THE SAMPLE BALANCE TEST

	B	SE
License	0.10	0.43
Funding	0.003	0.01
Prior industry collaboration	0.20	0.49
Formal industry-oriented activities	0.18	0.25
Informal university-oriented activities	-0.19	0.19
Conflicts	0.58	0.37
Female	-0.45	0.50
Number of years since earning	-0.01	0.02
Biological Sciences	-0.01	0.47
Physical Sciences and math	1.98	1.46
Commercial significance	-0.07	0.10
Number of Patents	-0.01	0.01
Royalty payments	0.10	0.43
Tenured	-0.13	0.54
Academic Workload	0.15	0.22
TTO-Firm involvement	0.04	0.53
_cons	1.51	1.70
Observations	776	

**** p<.01, ** p<.05, * p<.1*

APPENDIX C

DETAILED SURVEY ITEMS

Survey item	N	Mean	SD	Min	Max
Academic Workload					
How many courses did you teach or co-teach?	840	2.79	1.41	1	6
How many doctoral dissertations did you supervise?	840	2.99	1.80	1	6
How many university committees did you serve on?	836	3.17	1.66	1	6
How many department committees did you serve on?	830	2.51	1.58	1	6
How many research assistants did you supervise?	840	4.14	1.88	1	6

APPENDIX D

IRB APPROVAL 1

ASU Knowledge Enterprise Development

EXEMPTION GRANTED

Eric Welch
WATTS: Public Affairs, School of
-
EricWelch@asu.edu

Dear Eric Welch:

On 3/12/2021 the ASU IRB reviewed the following protocol:

Type of Review:	Initial Study
Title:	Patenting Behavior of Academic Scientists and Engineers Secondary Data Analysis
Investigator:	Eric Welch
IRB ID:	STUDY00013547
Funding:	None
Grant Title:	None
Grant ID:	None
Documents Reviewed:	• IRB_Social_Behavior.docx, Category: IRB Protocol; • Patent_questionarie.pdf, Category: Recruitment Materials; • UIC_Aproval_letter.pdf, Category: Other;

The IRB determined that the protocol is considered exempt pursuant to Federal Regulations 45CFR46 (2) Tests, surveys, interviews, or observation, (4) Data, documents, or specimens on 3/12/2021.

In conducting this protocol you are required to follow the requirements listed in the INVESTIGATOR MANUAL (HRP-103).

If any changes are made to the study, the IRB must be notified at research.integrity@asu.edu to determine if additional reviews/approvals are required. Changes may include but not limited to revisions to data collection, survey and/or interview questions, and vulnerable populations, etc.

Sincerely,

APPENDIX E

IRB APPROVAL 2

ASU Knowledge Enterprise Development

EXEMPTION GRANTED

Eric Welch
WATTS-PA: Science, Technology and Environmental Policy Studies, Center for (C-STEPS)
-
EricWelch@asu.edu

Dear Eric Welch:

On 9/22/2022 the ASU IRB reviewed the following protocol:

Type of Review:	Initial Study
Title:	Dissertation Research: Linking institutional logics and academic collaboration decisions to research outputs
Investigator:	Eric Welch
IRB ID:	STUDY00016626
Funding:	None
Grant Title:	None
Grant ID:	None
Documents Reviewed:	• CITI training, Category: Other; • consent_form.pdf, Category: Consent Form; • Frandell_email_invitation.pdf, Category: Recruitment Materials; • Interview instrument, Category: Measures (Survey questions/Interview questions /interview guides/focus group questions); • Social Science protocol, Category: IRB Protocol; • Summary, Category: Other;

The IRB determined that the protocol is considered exempt pursuant to Federal Regulations 45CFR46 (2)(i) Tests, surveys, interviews, or observation (non-identifiable), (2)(ii) Tests, surveys, interviews, or observation (low risk) on 9/22/2022.

In conducting this protocol you are required to follow the requirements listed in the INVESTIGATOR MANUAL (HRP-103).