

GLOBAL INSTITUTIONS' INTERDISCIPLINARY RESEARCH COMMITMENTS: A
MIXED METHODS STUDY

by

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Abstract

The growing complexities of the world's grand problems calls for novel research approaches to produce solutions. World universities play a pivotal role in addressing global challenges through research generated by their faculty and students. Though traditional research approaches that utilize knowledge from single disciplines are more common, it has been found that the practice of interdisciplinary research (IDR), which encourages a synthesis of disciplines, produces more novel ways of thinking and innovative solutions. While IDR has been documented to have several benefits, such as promoting collaborations between authors from within and between institutions, it is also known to be a time-consuming approach that often requires more funds to complete. Further, although there is global recognition of the importance of IDR, little is known about how universities around the world stimulate, support and promote the practice of IDR. The theory of boundary spanning and the theory of middle status conformity help to guide this dissertation's research objectives of 1) uncovering how universities around the world facilitate IDR, 2) identifying patterns of stratification based on the differences in commitment to IDR and 3) identifying top performing universities for collaborative publications and understand their IDR specific strategies. This study applies a combination of text analysis and quantitative methodology on strategic plans and collaborative publication data of 211 universities from around the world. Findings demonstrate that level of IDR commitment varies across institutional rank. However, leaders pursue a wide range of goals to stimulate various levels of IDR and these goals do not necessarily translate to collaborative publications. Tier 1 and 2 institutions describe more *spearheading* boundary spanning goals to steer IDR. Additionally, text analysis is also utilized to confirm the theory of middle status conformity. When it comes to IDR practice, conformity was highest in tier 2 institutions and least within tier

1 and 3 institutions. Findings of this study provide ways to structure university commitments to increase IDR participation and I coin the terms *Internal Discipline Symbiosis* (IDS) and *External Discipline Symbiosis* (EDS) as strategies that university leaders can employ to better pursue IDR goals to steer innovation.

Global institutions' interdisciplinary research commitments: A mixed methods study

Chapter 1: Introduction

Interdisciplinary research involves combining knowledge from two or more disciplines (Apostel, 1972; Leahey, Beckman, & Stanko, 2017). By way of research agendas, institutions typically rely on fragmented disciplines to provide solutions to complex problems. However, owing to the increasing demands of real-world challenges, more institutions are shifting their approach to problem-solving by integrating knowledge gained through two or more disciplines as opposed to relying solely on single-discipline or narrow approaches. This collaborative approach known as interdisciplinary research (IDR) is becoming a burgeoning field as it comes with the promise of creating innovative and novel ways of thinking. The practice of IDR is “sweeping universities around the globe” (Ledford, 2015, p. 308) as it is considered to address and overcome societal challenges (Lin, 2008) and is viewed as a ‘hothouse for innovation’ (Bromham, Dinnage, & Hua, 2016, p.684). The Committee on Facilitating Interdisciplinary Research from the National Academy of Sciences, highlights the importance of IDR in the creation of new knowledge as it integrates different perspectives (National Academies of Science, National Academy of Engineering and Institute of Medicine, 2004; 2005), thus contributing to advancing our collective intelligence.

Scholars also document that they favor the practice of IDR as it has the potential to solve global challenges such as climate change, population growth, and social problems (Boix Mansilla, Lamont, & Sato, 2016; Griffiths, 2014; Leahey & Moody, 2014). Researchers engage in IDR in many ways. One example is when Doherty, Ensor, Heron and Prado (2019), all from various disciplines such as geography and environment, politics, and management came together

to identify how a common concept of resilience is understood across disciplines to study food systems. By approaching their study through an interdisciplinary lens, they provide a more nuanced definition of the term resilience and highlight the importance of the interdisciplinary ‘analytical value’ that their combined effort brings to studying food and food systems (p. 9). In another compelling example in support of IDR, Ge, Zobel, Murray-Tuite, Nateghi and Wang (2019) urge members of various disciplines to come together to build interdisciplinary research teams to find the best way of responding to natural disasters. Given the constraints of each discipline, the authors recommend that interdisciplinary research teams are better able to provide solutions during natural disaster situations that are often uncertain and comes with a short window of opportunity to respond.

However, despite IDR catching rapid momentum in all levels of education (Jones, 2010), there is little evidence of the ways in which the practice of IDR is implemented in universities around the world (Boix Mansilla, Lamont, & Sato, 2016; Lin, 2008). It is also not clear if interdisciplinary work in universities can take shape in the form of other collaborative activities beyond the scope of research. Preliminary analysis of university websites and institutional strategic plans show that some universities around the world discuss IDR and collaborative projects in their portfolios but it is unclear how they plan to initiate, promote and support IDR efforts. Less is also known about characteristics of the universities that engage in IDR. Scholars from the National University of Australia have found through their study that researchers tend to perceive IDR to be poorly funded as opposed to single discipline research projects. They suggest that if funding granters have better metrics of measuring IDR, these perceptions could be dispelled (Bromham, Dinnage, & Hua, 2016). If this is the case, then it could mean that IDR is a practice reserved for a select few who have the capacity to conduct research that integrates two

or more fields of inquiry. Considering the lack of funding for IDR as opposed to single discipline research (Porter, Roessner, & Heberger, 2008; Kwon, Solomon, Youtie, & Porter, 2017) and the need for additional resources such as large research networks to conduct IDR, it could be easily misunderstood that the practice of IDR is reserved for prestigious institutions. In other words, the greater an institution's capacity, the higher the chances of them engaging in IDR as such institutions would have more resources.

The practice of IDR has been documented to have several benefits for the students, researchers and the institution (Lin, 2008; Leahey & Moody, 2014). Besides being better equipped to overcome societal hurdles, interdisciplinary degree programs also nurture life-long learning habits in students as they can solve problems by synthesizing knowledge from various fields. Such training also makes way for brighter career prospects as more employers seek them out to meet the demands of the current economy (Jones, 2010). Considering these highly emphasized benefits, a comprehensive understanding of the ways in which globally-ranked institutions state their commitments to IDR in their strategic plans allows us to gain insight into the ways institutions weave IDR into their portfolio and the ways in which they seek to secure funds to align with such goals.

While current literature on IDR shows the growing interest in its proliferation (National Research Council, 2014; Ledford, 2015), what is still inconclusive is if there are global trends in IDR practice and whether it is exclusive to specific institutions, countries or regions. For every university that practices IDR now, there are several others that still have strongly emphasized boundaries around fragmented disciplines (Ledford, 2015). It could be that the leaders of such institutions believe that engaging in IDR distracts researchers from conducting in depth studies within a single discipline. Global studies of IDR are somewhat scattered and do not show if

engaging in IDR is just in vogue or if it indeed makes a difference. One way to understand the doubtful permanence of IDR is by understanding it through Birnbaum's (2000), organizational fad concept. Birnbaum argues that organizations at times engage in fads or practices that will lead them to innovation. Often such 'fads' are widely accepted and adopted across institutions but 'enjoy brief popularity' (p.2). In adopting this view, it begs the question of how university leaders decide that engaging in IDR is not just a short-term practice but one that is supported over time. Also, should they choose to continue commitment to IDR, what indicators do leaders rely on as they continue to provide support for IDR? Current studies on IDR do not provide a robust narrative of its impact on institutions around the world and if participation in IDR differs across institutions. Furthermore, there is no prior evidence of how institutions can be assessed if they engage in IDR. Understanding this is important particularly because it has been found that 'excellence-based journal rankings exhibit a systematic bias in favor of mono-disciplinary research' (Rafols, Leydesdorff, O'Hare, Nightingale, & Stirling, 2012; 2011, p.1).

This dissertation utilizes two conceptual frameworks to further our understanding of how institutions may work with other organizations/actors or attempt to conform to accepted research norms. Given the growth of IDR in recent times (Van Noorden, 2015), it is essential to understand the ways in which universities around the world are utilizing IDR to their benefit as well as identify challenges institutions face in IDR participation. Moreover, considering the power of global rankings on institutional behaviors (Pusser & Marginson, 2013), this study demonstrates the extent to which world university rankings have influence over current global institutional strategies that promote IDR practices and vice versa. Utilizing the theoretical framework of boundary spanning in this study also furthers our understanding of academic institutions' network building capacity as well as members of such organizations' role in creating

innovation through IDR. The application of the second theoretical framework, the theory of middle status conformity allows for a closer analysis of characteristics of institutions across the various university stratification in this study's sample.

In a nutshell, this study is driven by three specific motivations: 1) to understand if institutions around the world engage in IDR and if they do, what are the ways in which institutions stimulate IDR participation and contribute to the production of new knowledge; 2) to identify patterns of stratification across ranks with respect to level of IDR commitment of institutions from around the world; 3) to propose strategies for institutions that want to increase their IDR efforts. This study's significance lies in the methodological approach of using a global lens to understand the ways in which institutions express their commitment to IDR as majority of studies done currently only examine IDR's impact on institutions in the United States (US) (See: Leahey & Moody, 2014; Leahey, Beckman & Stanko, 2017). The contribution made to the field via this study is that it examines the patterns of IDR practice from a more comprehensive and diverse institutions' perspective as opposed to only examining its country specific impact. It will also highlight if institutions emphasize IDR in limited fields of study as opposed to building a broad culture around the practice of IDR. This study will further document the ways that IDR goals are pursued via the strategic planning documents of an institution to propel its research agendas further.

In the following chapter (two), I provide an overview of the literature discussing IDR. The chapter covers IDR's definition, its numerous documented benefits as well as the criticisms and challenges the practice of IDR faces. Further, this chapter also provides literature review sections that discusses IDR from a global perspective, the implications university rankings lists may have on IDR and the use of strategic plans as a data source. The chapter ends by describing

the two theoretical frameworks that this study utilizes to guide the analysis conducted. In chapter three I describe the study design and mixed methodology used to conduct analyses. Here I also provide findings from a preliminary study that helped to draw direction for the present study. I then discuss the procedure I followed to collect and analyze strategic plan data and to provide context for the quantitative section of this, I also describe the institutional level data I gathered to design a dataset unique to this study. Chapter four begins with qualitative results that are categorized by themes and then provides results from the quantitative analysis conducted before ending with a summary of all findings. Finally, in the concluding chapter five, I provide implications of this present study by outlining its practicality for top-level university leadership and discuss in detail the limitations of this study that can be addressed in future iterations of such studies.

Chapter 2: Literature Review

This chapter addresses higher education institutions' (HEIs) role in knowledge production through IDR. To do this, the literature review will first gather the definition, historically documented benefits, contribution and challenges of practicing IDR. Then it will review research about the use of IDR in a global scene. In addition, the discussion of IDR with respect to rankings and prestige discourse will be examined via current literature. Next, as this study utilizes strategic plans as a source of data, part of the literature review will also highlight the reasons contributing to the increased reliance on strategic plans to assess institutional progress. Finally, the application of the theory of boundary spanning and the theory of middle status conformity are introduced to further understand how institutional strategies pertaining IDR practice/activities advance the institutional positionality in terms of ranking.

IDR Definition

The committee on facilitating interdisciplinary research, from the National Academy of Sciences, offers a definition of the IDR approach. They define IDR as:

Interdisciplinary research (IDR) is a mode of research by teams or individuals that integrates information, data, techniques, tools, perspectives, concepts, and/or theories from two or more disciplines or bodies of specialized knowledge to advance fundamental understanding or to solve problems whose solutions are beyond the scope of a single discipline or area of research practice. (National Academy of Sciences, National Academy of Engineering and Institute of Medicine, 2004, p 2).

The definition of IDR is easily confused with collaborative or co-operative projects. IDR inherently is the convergence of two distinct perspectives disciplines to foster our understanding and contribute to a novel perspective that would otherwise not be possible via the examination of the phenomena through a single discipline. While it could be collaborative, it can also be practiced by a single author who has the expertise in two or more fields. However, transdisciplinary research is used to define IDR that not only spans disciplines but also combines knowledge from beyond university, community and national boundaries (Repko, 2008, p.15). This distinction is of particular importance to this study as universities may be in a position to commit to both IDR as well as transdisciplinary activities to bridge their internal members with external organizations.

Approaching research by combing knowledge from different fields is not new (Strober, 2010), in fact its origins can be traced to have started in the late 1930s (Ledford, 2015). More institutions today are setting agendas that are in support of interdisciplinary research.

IDR Benefits

At the National Academy of Sciences, the committee on facilitating IDR is comprised of engineers, doctors, professors and thought leaders from various fields who express that they have

benefited profoundly from IDR as they recognize that the future of research lies beyond the purview of their respective disciplines. This is an important factor that distinguishes IDR practice and its rising popularity among educational institutions. Researchers' from various fields around the world laud IDR as a necessity to advance our scientific knowledge of the world (Pray, 2002; Rhoten & Parker, 2004) as the solutions to the problems we face lie beyond the scope of a single discipline.

Although the approach of IDR is not new (Abbott, 2001; Strober, 2010; Apostel, 1972), it is reported that it is "rapidly becoming an integral feature of research" as IDR "catalyzes the integration of disciplines" (National Academies of Science, National Academy of Engineering and Institute of Medicine, 2004, p 2). The National Science Foundation has also recognized IDR as a practice that furthers science by generating new knowledge that leads to innovation. The foundation supports and highly prioritizes the promotion of IDR by facilitating a variety of workshops, conferences and education programs. IDR is now promoted not only in tertiary education within the United States (US) but there is also evidence of it around the world as universities are viewed as sources of knowledge (Saunders, Kolek, Williams, & Wells, 2016) generated not just via isolated practice but through collaborative research.

There are many documented benefits of IDR, such as promoting collaborative learning, opening new avenues of thinking, connecting new cohorts of scientists across disciplines (Callard & Fitzgerald, 2016). The benefits are so rewarding that institutions are allocating spaces to create IDR focused centers. Pray (2002) states that to be considered as world-class, one must surely participate in interdisciplinary research. There has also been an overwhelming emphasis on the part of universities to create research centers focused on facilitating IDR (Berman, 2012; Leahey & Moody, 2014; Ledford, 2015) in the pursuit of innovation. Despite the numerous

documented benefits to the researcher as well as to the institution, the practice of IDR can also be very challenging.

IDR Criticism and Challenges

The practice of IDR has become an increasing feature in the natural sciences (Rhoten & Pfirman, 2007) and to other fields as well such as medicine, health and social sciences (Jacobs & Frickel, 2009; Pagliari, 2007). Despite its numerous benefits, Leahey, Beckman, and Stanko (2017) point out that engaging in IDR reduces scientist's level of productivity as it consumes more time as IDR projects would need to meet the demands of two or more fields' research standards and publication requirements. Ledford's (2015) recent article also suggests that IDR may well be in an experimental stage, wherein universities are still not convinced of IDR's benefits or not yet reaping its rewards if they are already participating. An article in the *Guardian* urges the academic community to rethink jumping into overly positive conclusions about IDR, as interdisciplinary work is not as simple as it is touted out to be particularly because people do not have uniform levels of access to influence, power and money (Callard & Fitzgerald, 2015). In the United States (U.S), it is said that faculty who are most successful in acquiring funding support 'tend to have greater bargaining power' with the top leaders of their institution (Camacho & Rhoads, 2015, p. 297). These scholars also warn that faculty researchers who negotiate successfully and gain funding support also tend to be scholars who generate wealth for the institution. Such faculty could also shape the direction of an institution's research agenda. The same logic can also be applied to ranked institutions from around the world as well because each institution exists with varying levels of resources, and the more highly ranked ones could potentially leverage their position to engage in more risky ventures such as IDR. This raises the

question then of the ways in which tier three institutions engage in the production of creative ways of thinking, production of novel knowledge and innovation. Another challenge of studying IDR stems from the numerous terminologies that exist to describe the practice. IDR has been interchangeably referred to as ‘cross-disciplinary, multidisciplinary and transdisciplinary research’ (as cited in Bromham, Dinnage, & Hua, 2016, p. 684). The challenge of referring to IDR in these many ways is that in some ways it restricts and confuses the development of a uniform understanding of IDR in the field. The benefit of having a clear metric for IDR, just as in single discipline research, would help to create a reputation for itself that warrants funding allocations (Bromham, Dinnage, & Hua, 2016; Rylance, 2015). It must be made clear that while the numerous terms keep intact the definition of IDR, other terms such as ‘collaborative’ or ‘intersectional’ are not sufficient to describe the scope of IDR. The movement towards encouraging multidisciplinary research should promote innovation (Cummings & Kiesler, 2005; Feller 2006). Considering this, institutions around the world reorganize their research priorities to include cross-disciplinary initiatives by channeling funds to create centers that assist the campus in facilitating not just within department collaborations but also research projects that connect scholars across colleges (Biancani, McFarland & Dahlander, 2014; Pray 2002). The sharing of funds between departments is one way that institutions can show their support for IDR as it better facilitates IDR projects and the coming together of scholars (Ledford, 2015).

Despite the challenges of coordination when it comes to IDR practice across institutions, scholars report that institutions that employ and facilitate the most amount of coordination mechanisms, such as face-to-face interactions, tend to be the most successful at IDR (Cummings, & Kiesler, 2005). Feller (2006) points out another challenge in practicing IDR has to do with how complex it becomes to assess its quality because it is derived from multiple organizations.

As the benefits outweigh the challenges, for institutions to become more willing to partake in IDR, Feller calls on federal agencies to promote the changes needed in organizations to be able to facilitate IDR. He urges that even if it means that institutions must change their structures and culture to accommodate IDR efforts, the prospects for richer data acquired through IDR would be worth their effort. In 2016, the Global Research Council (GRC) addressed Feller and other scholars' urgency in creating better policy and practice when it comes to assessing interdisciplinary studies by highlighting this as the headline topic of discussion at their annual meeting. The GRC has commissioned a team to put forth a report that would gather worldwide evidence of the ways in which institutions are stimulating and funding IDR practice (Rylance, 2015). The recently released report acknowledges that funding agencies do not support IDR as they may have a lack of policy with respect to IDR (Gleed & Marchant, 2016). Such a report would be a step in the direction of creating policy that better facilitates interdisciplinary research around the world.

Despite the numerous documented benefits of IDR, scholars also highlight the various challenges associated with IDR participation. For instance, Rylance, (2015) writes that other than securing funding, the practice of IDR is perceived to take away from more focused and nuanced research inquiry. He also warns that it is viewed as an inferior form of inquiry when compared with single discipline inquiries. To advance the practice of IDR, Rylance like Bromham, Dinnage, and Hua, (2016) also call for the need to have reviewers who are equipped to evaluate IDR proposals as they are often rejected due to the lack of expertise on the part of the reviewer(s). The GRC's efforts in creating better policy for IDR would facilitate and foster the growth of IDR practice around the world and potentially impact funding structures that could better serve interdisciplinary research agendas.

IDR in the Global Scene

Across the world, there is evidence of scientists from different fields coming together to pursue research via interdisciplinary methods. However, Kretschmer, Liming and Kundra (2001, p. 553), highlight ‘the insufficient theoretical and practical evidence’ of IDR and point out that there is a notion that ‘interdisciplinary collaboration is necessitated to overcome institutional barriers and specialization.’ Overcoming barriers such as creating novel solutions to research conundrums or challenging problems and facilitating the development of innovation is driving the promotion of IDR globally.

Institutions of higher education employ various strategies to advance research and teaching goals as evidenced by their strategic plan’s emphasis on maintaining or striving for global status on ranking lists such as the Times Higher Education's World University Rankings and Shanghai Jiao Tong University's Academic Rankings of World Universities (Stensaker, Lee, Rhoades, Ghosh, Castiello, et al., 2017). They employ international faculty, top researchers and students to generate new perspectives and facilitate the production of novel knowledge. The Global Talent Competitiveness Index demonstrates strong correlations between economic performance and talent competitiveness (2018). Universities could be responding to this finding by increasing global recruitment to generate collaborative IDR projects and publications. Worldwide, researchers are increasingly producing collaborative work that enhances the field of science and technology. But collaborative work is not understood along the same vein as the principle of IDR. The key contribution of IDR is the joint work created by two (or more) separate disciplines. To remain relevant, institutions strategize to stay abreast of global competition by increasing their participation in interdisciplinary activities to contribute to innovative ways of thinking (Kretschmer, Liming & Kundra, 2001; Smith, 2016). Engaging in

IDR could be a step for institutions to counter homogeneity as it would allow for them to leverage their positionality as they produce innovative ways of thinking, products or concepts. However, the ways in which they choose to then commercialize the new knowledge and innovations created would then open them up to homogeneity. It is important to investigate how globally ranked institutions, through their strategic plans, visualize the utility and practice of IDR to maintain or advance their status to remain competitive for students and faculty. It is also important to understand if there are differences in emphasis of IDR across ranks to be able to assess if IDR can only be practiced or promoted by specific institutional agents who are from a specific ranked institutions, country or region.

Global Rankings

Increasingly, institutions heavily rely on their positionality on higher education ranking lists such as the Times Higher Education's World University Rankings list, Shanghai Jiao Tong University's Academic Rankings of World Universities and the Quacquarelli Symonds (QS) World University Rankings. In the US, scholars report an ‘unprecedented focus on US news rankings’ (Campbell, Corbin & Cabrera, 2011, p. 79). However, Pusser and Marginson (2013) argue that studies that seek to understand tertiary education often lack a good understanding of rankings and neglect its influence on institutional behavior. These scholars say that realizing the impact of rankings would allow for an understanding of its implications on policy formation. Furthermore, Pusser and Marginson also point out that rankings are quickly becoming a key indicator of relations of power and the ways in which states, countries and regions organize their tertiary institutions even though some of these ranking lists are generated utilizing webometrics. Similarly, Sauder and Espeland (2009), also argue that rankings produce immense pressure on

organizations and influence university administrator behavior as they respond with “superficial changes” (p.64) in the form of creating committees to tackle challenges associated with their rank. These scholars argue that rankings further influence members of institutions to publically announce their rankings. The danger of falling prey to the demands of ranking lists is that internal members of an institution change the way they manage, lead and form expectations or goals for the university. When it comes to IDR and its relation to rankings (if any), current ranking criteria do not explicitly measure it. Instead, they measure research volume, industry income, citation impact, international diversity and teaching. None of the ranking lists explicitly include the measurement derived from the impact of interdisciplinary research.

However, even though the well-known ranking lists such as QS and others assess innovation, ranking lists do not assess innovation derived from IDR and if IDR publications make an impact on ranking positionality on any of these lists. Globally ranked institutions have increasingly been prioritizing emphasis on IDR even though IDR itself ‘struggles for prestige’ (Rylance, 2016, p.314) in the eye of scholars and researchers. Rylance also documents that to derive a common, globally recognized position about IDR, recently the Global Research Council has selected IDR as a focus of discussion. Arriving at a common consensus about IDR would potentially overcome the alleged funding barriers. Presently, institutions mention their interdisciplinary research goals or ambitions via their strategic plans.

Strategic Plans

Universities around the world utilize strategic plans to articulate their organizational goals, values and achievements (Mueller, 2015). Such plans are made available publicly via their institutional websites as way to position and perhaps even distinguish themselves from other

institutions that may share similar values. Strategic plans showcase the ‘long-term sustainability’ actions required by an institution and serve as a blueprint that would guide institutions to ‘manage the complexities of a competitive environment’ (Aleong, & Aleong, 2011, p. 17). At the time of writing this dissertation, the University of Arizona’s (UA) president announced a year’s commitment to reshaping their strategic plan by engaging faculty, staff and students across campus in a dialogue about what they value and what they would like their university to represent (University Communications, 2017). Through this methodological procedure of revamping their strategic plan, each college was instructed to create a list of priorities and several common themes emerged from dialogue sessions, focus groups and strategic planning meetings. Through this effort, “increase collaborations across college and university” was found to be the number one theme from the college of education (College of Education, Strategic Plan- Phase 2, 2018). The process of strategic planning at the UA is fueled by the demands of the forth industrial revolution that is promising a shift towards education that is largely guided by mechanistic and digital spheres. This example from the UA illustrates why strategic plans are useful in understanding the ways that an institution envisions tackling the demands of the future, staying current and ensuring that its students graduate ready to meet the needs of a local or global economy. Similarly, scholars have documented that institutions are changing the ways that they educate their students particularly because of the shift in focus towards representing more entrepreneurial ambitions (Deschamps & Lee, 2015; Slaughter & Leslie, 1997). These shifts are captured by strategic plans and as it serves as a master plan of institutional goals, values and aspirations. With this description, they become sources of data as it provides rich details of the ways in which institutions prioritize long term goals, create concrete plans to manage the

financial aspects of their institution, address the needs of their community, respond to global competition as well as meet the demands of academic rigor.

Despite the positive attributes of strategic plans such as showcasing what an institution values and its aid in forming public consensus of an institution, Abdallah and Langley (2014) question the actual utility of strategic plans by institutions as they largely fail to provide a comprehensive take on institutional strategies and reveal few tangible and implementable solutions. They also point out that the ambiguity of strategic plans can often lead to various interpretations of an institution's strategic vision. Still, strategic plans provide more than just a glimpse into an institution's research priorities, political agendas, initiatives for socioeconomic contributions, funding allocation and vision statements that help to distinguish and position institutions from around the world (Morphew, Fumasoli, & Stensaker, 2016). Given its strong relevance, this study utilizes strategic plans as a data source to gather evidence of institutional commitments to IDR. Although strategic plans can serve to distinguish institutions, they can also provide evidence of homogenous organizational behavior.

Theoretical Framework

This research examines if various institutions around the world support IDR practice and when they do, the influence of institutional power, status and conformity will also be analyzed. The second aim is to map the various similarities and differences between global institutions ways of practicing, stimulating and promoting IDR. In this study, 'practicing' IDR refers to ways members of an institution are producing interdisciplinary projects through publications or other activities. The act of 'stimulating and promoting' IDR is understood by how members of universities express IDR goals through the text of strategic plans. To aid in tracing these patterns

in a nuanced method, this study applies two distinct frameworks to conceptualize and better make sense of the findings.

First, the theory of Boundary Spanning is invoked to conceptualize the utility, relevance and origins of IDR in institutions around the world. In general, this theoretical approach is useful to make sense of objects, people and ideas that move between spaces. In the case of global practice of IDR, the theory of boundary spanning is used to place emphasis on the behavior of organizations that allow for collaborative practices both internally and with external organizations. Boundary spanning is used to understand the practice of IDR at an organizational level and to understand the people who engage in IDR. Through the literature we understand that the practice of IDR makes contributions to the scientific field by producing new knowledge. Beyond that, it also enhances the scholarly visibility of the researcher who engages in IDR (Leahey, Beckman & Stanco, 2017) and contributes to the positive reputation of their respective institutions as they facilitate the production of new knowledge (Feller, 2006; Strober, 2011; 2010). In noting this, several organizational agents are recognized in the creation of novel knowledge. The first agency is held by the institution in the role of facilitator of advancing IDR agendas. The second set of agents in the production of new knowledge are researcher/members who as individuals also benefit from the involvement in IDR. In recognizing the various dimensions that IDR impacts, this theory assists in understanding the benefits, contribution and limitations of the practice of IDR.

Next, to further understand patterns of stratification and institutional characteristics across the institutions sampled, I discuss the theory of middle status conformity and its utility for this study. Then criticisms of both frameworks are addressed to arrive at a unique consensus that is more suitable to the present study.

Theory of Boundary Spanning. Predominantly used in social sciences, the theory of boundary-spanning describes individuals who utilize internal organizational resources to create new contributions (Levina & Vaast, 2005) by working with external individuals or organizations (Aldrich & Herker, 1977; Leifer & Huber, 1977). In this theory, the boundary is described as the parameters of an organization. Spanning refers to actions lead by members, also known as boundary-spanners of an organization, who engage with other members beyond the parameters or boundaries of their own organization in the pursuit of new knowledge or creation that leads to innovation. The organizational practice of boundary-spanning and the role of the boundary-spanner has been documented within marketing research as a successful strategy to expand both domestic and global networks (Hult, 2011).

Boundary-spanners have also been documented to include the people ‘who operate at the nexus of higher education institutions’ (Mull, 2016, p. 157). In the context of interdisciplinary research (IDR), an institution’s top leaders, such as deans, provosts and presidents would not be the only *boundary spanners* but would also include researchers, faculty and students who could all engage in activities that expand the network of the institution. These activities would include projects that transcend the scope of an individual’s own discipline or area of expertise. They could utilize their agency to either work independently or with other scholars from a different field of study to create research projects that produce new and novel ways of thinking and knowledge. Essentially, boundary spanners are individuals who through the influence of their organization, venture out to create projects that are cross-disciplinary. Boundary-spanners utilize their agency to work collaboratively with other organizations from all over the world, across disciplines to contribute to the creation of new knowledge and innovation.

Hargadon (2002) astutely points out that for organizations to create innovation, it's not about what information or knowledge they are already in possession of, it is instead, about the ways in which they can harness their knowledge to 'make sense of new situations and how they use new situations to make sense of what they already know' (p. 80). Through the model of innovation, Hargadon explains that organizations are most successful when its members can recognize their knowledge and choose to couple it with knowledge learned from others, they naturally create the potential of innovation.

Integral to innovation and the creation of new knowledge is also an institutions' ability to anticipate market trends with respect to research. An institution's ability to foster organizational anticipatory behavior through its members would be pivotal in promoting and cultivating the practice of IDR. If an institution becomes a place that emphasizes the freedom to produce interdisciplinary - cross-college – multidisciplinary research, individuals can be easily motivated to exercise their agency to pursue interdisciplinary approaches in their own research. When institutions can facilitate such processes, they are bound to benefit from it as boundary-spanning has been documented to be advantageous (Singh & Fleming, 2010) as they increase the networks of both domestic and global scientists working together towards innovation.

Despite the benefits, the theory and practice of boundary-spanning does not make an organization immune to isomorphic pressures but also does not make its effects long-lasting. As Hult points out:

“should resource heterogeneity develop, it will likely be temporary, given that market resources are highly mobile. As such, homogeneity of marketing strategies among organizations competing in the same industry exists since, for example, marketing actions taken by an organization are easily observable and duplicated by other organizations. As such, we can speculate that perhaps this also means that a theory of the boundary-spanning marketing organization, with its primary stakeholders (i.e., customers, employees, suppliers, shareholders, communities, and regulators) and secondary stakeholders (e.g., media, special interest groups), ultimately will include each other as stakeholders (i.e.,

competitors internal and external to the marketing organization's primary industry)." (2011).

This example from Hult illustrates that IDR practice could assist institutions in mitigating isomorphic pressures in the long run. Given this, it is essential that an institution's boundary spanning capacity is analyzed to be able to understand how connected they are to other global institutions. The concept of boundary spanning has been applied in different ways by several researchers. While it is mostly used to examine management and organizational activities research also shows that the concept can be used to make sense of how people build relationships to navigate between the boundaries. For instance, in an ethnographic study determining how students with refugee status are supported by their school districts, Koyama and Ghosh (2018) report that refugee mentors can be viewed as 'boundary spanners' (p. 96) as they help to bridge the school-community-family boundaries that refugees have to navigate as they transition into a new country. In this study, the emphasis is on individuals who have the agency to navigate between boundaries.

In another study that investigates how engineers work to solve problems, the emphasis is placed on boundary objects. The authors examine how engineers focus on boundary objects such as knowledge gained through progress reports, emails and calendars to form collaborations with other experts across the boundaries to solve complex problems (Hsiao, Tsai, & Lee, 2012). In their study, Birkinshaw, Ambos and Bouquet (2017) apply the concept to understand how corporate executives located at various headquarters (HQ) engage in boundary spanning activities to improve their company's overall effectiveness. The authors report that the HQ leaders engaged in four types of boundary spanning activities. First they made connections with other organizations and simultaneously they also engaged in activities that spanned the

boundaries of their organization to mitigate differences between their organizational views and external views. The authors refer to this as the ‘spearheading’ activity (p. 433). They also distinguish and term internal spanning activities as ‘facilitating’ (p. 438). These researchers further suggest that leaders engage in ‘reconciling’ (p. 436) where they assist stakeholders from their internal organization to effectively communicate with external organizations to successfully complete collaborations. Finally, they point out that leaders should also work with members across internal departments to ensure that they shed personal biases so that they can overcome preconceived notions that they may have about working with other departments. They refer to this as the ‘lubricating’ activity (p.439). This study employs the application of boundary spanning in the way that is described by Birkinshaw, Ambos and Bouquet’s study to identify the types of commitments made by university leaders to stimulate IDR. In doing so, it allows leaders to gain a more nuanced understanding of spanning activities that are necessary both internally and externally as they invest in IDR.

In addition to the theory of boundary spanning, adding the lens formed from the theory of middle status conformity helps to trace at what stage institutions conform to each other and which institutional characteristics proves to be more symptomatic to conformity behavior.

Theory of Middle Status Conformity. Besides understanding an organization’s boundary spanning efforts, another goal of this study is to trace patterns of conformity between institutions of varying status. It has been well established in the field of sociology and social psychology that there is a relationship between conformity and status (Phillips & Zuckerman, 2001). Middle status conformity theorizes that conformity is greatest in the middle and lower in cases of high status (Deephouse & Carter, 2005; Phillips & Zuckerman, 2001; Krohn, 1986; Harvey, & Consalvi, 1960). According to this theory, organizations/actors with low status will

have low conformity as they tend to be excluded from the forces that pressurize high and middle status organizations/actors. Low status organizations would choose to forge their own path by focusing on counter normative practices. Thus, this theory can be represented as an inverted U-shaped curve when mapped out graphically. The figure below illustrates how university status influences levels of conformity, wherein universities with middle ranking status would be theorized to have greater tendencies to conform to the goals of other institutions that they aspire to be like. In this study, I apply this theory to hypothesize that the practice of collaborating to produce more impactful publications through an interdisciplinary lens is normative. Given this, institutions with high status would be less likely to conform to this norm whereas institutions with middle status would be more likely to conform to this approach to producing publications. Institutions with low status would also not conform to the norm as they might not have the necessary resources to engage in IDR.

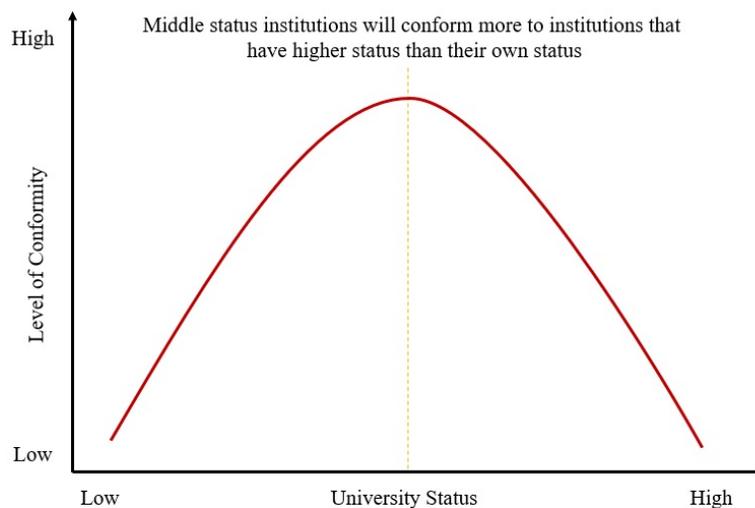


Figure 1: Middle Status Conformity for Universities

While this theory is useful in examining conformity in relation to status, it doesn't fully take into consideration regional differences in status. Furthermore, it strictly views status in three distinct categories which could be problematic as it could also be argued that conformity and status would show a curvilinear association. Investigating evidence of middle status conformity allows for a nuanced understanding of the ways in which global institutions strategize to participate in interdisciplinary research and if they are mirroring their strategic goals to other high status institutions within their region or to other international world-class institutions.

The following methodology provides a better understanding of the data used in this study, preliminary findings and research questions.

Chapter 3: Methods

In this study, I examine interdisciplinary research activity by analyzing text from university strategic plans from a total of 211 institutions. I focus on 170 institutions that have strategic plans, across six regions, stratified by their rankings to understand interdisciplinary commitments. The regions included in this study are Asia, North America, Oceania, Africa, Europe and the Middle East. To gather these strategic plans in an efficient and systematic way, Python codes was written to assist in collecting strategic plans from the university websites through web-scraping methods. Since the web-scraping codes did not return strategic plans for 41 institutions, simple searches on their website for IDR terms such as 'multi-disciplinary', 'transdisciplinary', 'cross-disciplinary' and 'IDR' is conducted and discussed along with the results of this study. Using qualitative and quantitative methodologies, this study aims to arrive at a deeper understanding of the ways that institutions commit to IDR and if there are similarities or differences in the way they express IDR commitments around the world. The qualitative

assessment allows for texts pertaining to IDR to be collected from strategic plans and examined for institutional support for IDR activity. They also provide a nuanced understanding of why institutional leaders pursue interdisciplinary research and other ID initiatives. To provide a snapshot of IDR commitments, this study also compares how institutions express IDR commitments between countries and across regions. This approach allows for analysis of trends in IDR practice between institutions as well as identify inter-regional similarities and differences. Preliminary analysis of strategic plans, as part of a separate research study guides this dissertation. They are discussed next to show relevance for this larger, global study to understand IDR commitments.

Preliminary Analysis

This study was partly motivated by another project I co-authored with several colleagues that examined strategic plans of institutions from around the world (see Stensaker, Lee, Rhoades, Ghosh, Castiello, et al. 2017). As I examined South-East Asian university strategic plans for that project, it became clear that IDR is a point of discussion for several institutions. My initial reading and discussion of 30 strategic plans showed that institutions were expressing ways that they engage their university members in IDR, and what impact they felt it would create for faculty, students and their community. For instance, one institution in Hong Kong prioritized in their strategic plan that ‘promoting interdisciplinary studies’ was essential for students to ‘acquire a strong entrepreneurial spirit and innovative thinking.’ Another institution in India, only briefly mentions having numerous interdisciplinary degree programs that are being offered to diversify its educational offerings. In Japan, one institution that aimed to broaden their research

scope mentions attending a contest that supported interdisciplinary research and that they submitted 100 research papers through this initiative.

Of the 30 institutional strategic plans that I analyzed for this class research project, about a third expressed detailed plans related to IDR commitments. The others ranged from no IDR commitments to brief mentions of IDR course offerings and that they wanted more faculty and students engaging in this area of research to be better equipped to tackle the challenges of the world. It was clear from this initial analysis that an in-depth study of more institutional strategic plans could reveal nuanced details of the kinds of institutions that choose to participate in IDR. More importantly, such a research study also shows if certain institutional characteristics or status makes a difference in their support of research agendas that include IDR. This dissertation is a response to this need of gathering a global understanding of the ways in which institutions express IDR commitments.

Research Questions

The following research questions guide this study.

Research Question 1: Through strategic plans, how are members of international institutions stimulating and expressing commitment to interdisciplinary activities?

Preliminary text analysis shows that strategic planning committees tend to highlight IDR goals in their strategic plans to tackle global challenges. In this way, through IDR, universities are projected as organizations that work to solve real-world problems. Moreover, they also discuss strategies to improve faculty lead IDR projects to both stimulate new forms of revenue and produce innovative ways of thinking. The practice of IDR or the expressed intention of increasing participation in IDR could be one way that institutions position themselves to attract

more global talent. From the preliminary reading of strategic plans, it was also found that institutional research goals vary depending on the institutional characteristics. For instance, institutions focused on science and technology field programs lay out specific discipline focused research goals within their strategic plans. To advance their research agendas, some explicitly state that they intend to increase IDR efforts to create innovation in a specific field or to solve a specific problem that requires the coming together of two or more fields of inquiry. Others specify the need for increasing IDR to stimulate new forms of revenue for research. In answering this research question, it is predicted that interdisciplinarity will not only be discussed as a research activity but also a method for institutions to produce other forms of collaborative practices. For instance, preliminary analysis found that universities provide campus wide workshops on various topics that is often lead and designed by faculty coming from different disciplines.

Research Question 2: What are quantifiable determinants that drive IDR?

It is hypothesized that institutions with higher faculty populations would have more research activity. Universities with larger student populations have also been known to have more resources to allocate towards research. Some studies have found that university prestige or ranking can determine the amount of research activity produced (Collyer, 2013; Bornmann, & Daniel, 2006). To account for this, I use average ranking positionality as a proxy for reputation in this study. In addition to this, funding support from industries could mean that researchers have more incentives to participate in collaborative research that involves members of external organizations. Given this, faculty and student population and industry income are included as independent variables. Number of collaborative publications is used as a dependent variable as it is used as a proxy for IDR. To answer this research question, additional variables of interest from

the CWTS Leiden Ranking (2018) dataset are utilized. This publicly available dataset 'is based exclusively on bibliographic data from the Web of Science database', (Leiden Ranking Methodology Report, 2018, p. 2). In this edition of the university publication data, 938 universities from around the world are included. I match my sample with the Leiden Ranking list to obtain publication specific data for each case.

Research Question 2a. From the regression results (2), how are the top-performing institutions expressing IDR commitments through their strategic plan?

This question differs from RQ1 as it aims to first quantitatively identify institutions with high rates of IDR publications (given their characteristics as specified in the regression model) and then understand how their leaders discuss IDR commitments within strategic plans. It is hypothesized that IDR is practiced predominantly by tier 1 institutions. Tier 2 institutions that outline specific ambitions of improving their ranking positionality may also project IDR goals in their strategic plans. Mentions of IDR goals may decrease when it comes to strategic plans from tier 3 institutions. To answer research question 3, text analysis will be conducted to analyze how top ten performers with high collaborative publications discuss IDR in their strategic plans.

All strategic plans were collected using Python and data were cleaned and analyzed using R version 3.5.2.

Procedure and Data Source

The data for this study were gathered through a convenience sampling strategy. First, ranking scores from the Times Higher Education's World University Rankings (THE; N=1258); QS World University Ranking (N=959); and the Academic Ranking of World Universities - Shanghai Jiao Tong University Ranking (ARWU; N=500) were collected into an excel

spreadsheet. Next, a new ranking score is calculated by taking an average across the scores from all three university ranking lists. Ranking positionality was then sorted by university name across all three lists. Institutions were grouped by the following order: Tier 1 = top 200 institutions, Tier 2 = 201- 400 and Tier 3 = all institutions ranked below 400. This revealed, as an example, for “University of Arizona, the ranking on list A, list B and List C” and an average ranking score for this study. When a university appeared on all three lists, it was accepted into a separate dataset to be used as a list for web-scraping to obtain the strategic plans via an automated Google search. Given ranking list’s notoriety and problematic methodology (Filinov, & Ruchkina, 2002; Hazelkorn, 2007) an average score across the three lists helps to avoid an over emphasis on any single ranking list.

A total of 335 universities appeared on all three lists. Next, for each university from this list, Python codes were used to collect and record the first ten Google search results that had the words “strategic plan” linked to the website of the universities. Even though universities do not all use the term “strategic plan” to refer to their vision or goals document, the automated search codes were written to provide search results for all plans available in a portable document format (PDFs). If PDFs were not specified in the codes, the automated search would result in large quantities of word documents or text files that are not strategic plans. An example of the search results is provided in appendix 2.

For each institution’s search results, only the relevant and most recent strategic plans were downloaded, excluding institutions that only had college specific plans. For example, web-scraping codes specific to the University of Arizona yields links for strategic plans at the college level, annual reports and older versions of strategic plans. A manual check of the links for

each institution was done to accept the web address extension that was most meaningful for this project. An example of web-scraping for a single institution is provided:

1. http://...../5_year_strategic_plan (Accept)
2. http://...../school_of_social_sciences.pdf (Reject)

Institutions with plans from 2010 onwards were accepted and the automation allowed for their strategic plan PDFs to be populated into a folder to serve as a database that contained all strategic plans. The lifespan of each strategic document depending on the institution, but most are mostly five, ten or twenty year plans.

Through this process, a final list of universities that had PDF versions of their institutional strategic plans (N=211) was collected. It is also important to note that the study criteria also included only strategic plans published in English. The average length of a strategic plan is between 25 to 30 pages. The shortest plan had only 1 page and the longest plan had 335 pages. Anecdotal experience from working on research studies that utilize strategic plans as its source of data informs that universities without PDF strategic plans are mostly unranked institutions or have features of a strategic plan, such as a vision or mission statement, published on their website as opposed to having it available on a separate document. To improve the overall external validity of this study, several institutions from different countries and regions are included. The sample selected comprises 23 institutions from Asia, 24 from Oceania, 3 from Africa, 82 from North America, 6 from the Middle East and 73 from Europe. Figure 2. provides a pie chart to show the countries represented for each of the six regions.

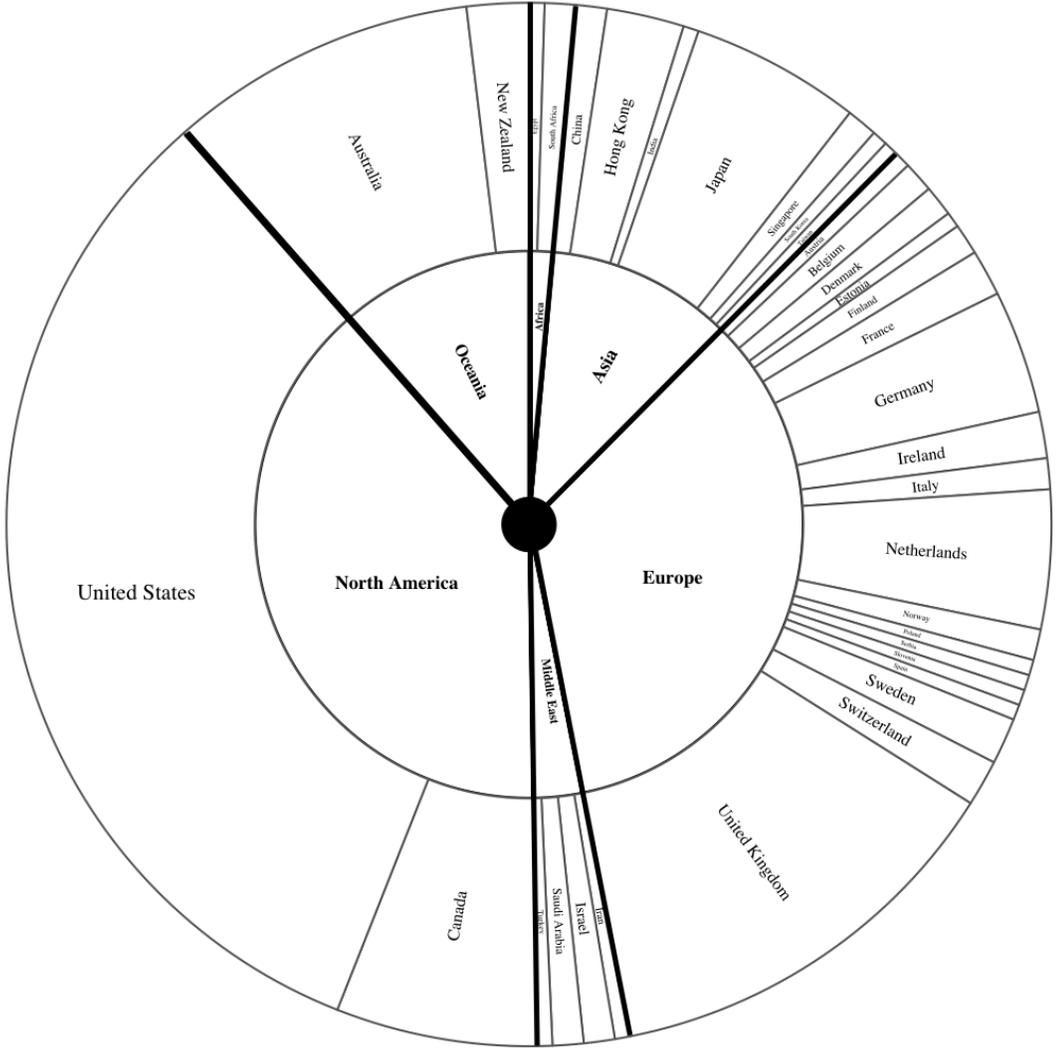


Figure 2. The center of the pie chart shows the six regions. The second layer provides all countries represented within each region.

More descriptive statistics for the institutions included in this study are provided in Table 1. The oldest university in the sample is University of Bologna and the largest by student population is Cairo University (233,999) which is included in the African region. There is a total of 30 institutions with private status and 180 universities that are of public status in this sample. One

institution from France did not have enough information to be categorized as public or private. A total of 59 institutions are also classified as research-intensive according to their websites.

Table 1
Sample Descriptive Statistics

| Region | Mean # Faculty | Faculty SD | Mean Student | Student SD | Mean Institution Age | Institution Age SD |
|------------------|-------------------|---------------|-----------------|---------------|----------------------------|-----------------------|
| Africa | 2670 | 2521 | 97812 | 118092 | 108 | 5.77 |
| Asia | 1964 | 994 | 23364 | 11490 | 125 | 125 |
| Europe | 1483 | 831 | 25994 | 16100 | 240 | 220 |
| Middle East | 2114 | 1444 | 35031 | 30358 | 74.8 | 21.2 |
| North America | 2081 | 1136 | 27847 | 14560 | 153 | 55.9 |
| Oceania | 1066 | 451 | 26941 | 11552 | 86.1 | 48.2 |

Text analysis of each PDF revealed 41 strategic plans that have no mention of interdisciplinary, cross-disciplinary, trans-disciplinary or multi-disciplinary research and/or IDR related activities. This includes plans that do not discuss IDR activity without using the various terms to refer to it. These 41 institutions are not used to answer the first research question but are later used for research questions two and three. For research question one, a total of 170 universities from 32 countries and six regions were included for text analysis to understand institutional members' commitment to IDR. Two universities from this subset had statements within their strategic plans that do not grant permissions for its text to be reproduced. For these two universities, only the content of IDR commitment is interpreted and none of its textual content are quoted in this study.

To answer research questions 2, information from strategic plans was populated into a spreadsheet with variables such as university, country, region and ranking positionality according to each of the ranking lists. Then, for each university, I use the average rank score to provide a

continuous variable for ranking¹. These and other institutional variables from Leiden's ranking list provided much of the data needed for the study. Calculating an average ranking with scores from each ranking list was done to provide greater credibility to the various ranking positionalities since each ranking list uses a different methodology. It is important to note that none of the ranking lists methodology incorporates interdisciplinary activity. These ranking lists also provide additional institutional characteristics. Institutional characteristics are defined as a university's faculty and student ratios, international student population, range of programs and degrees awarded, facilities and tuition costs.

To answer this study's first research question, the codes generated from the preliminary analysis were used to analyze and categorize the text from strategic plans. Over a period of six months, I analyzed the text pertaining to these codes to answer the research questions. To access and retrieve the plans easily, text related to the IDR specific codes were documented separately by institution.

To answer the second research question, I utilize institutions' publication-related data from the 2018 Leiden Ranking list for the period 2013-2016. I matched my study sample (N=211, this includes institutions without mention of IDR in their strategic plans) list of universities to the Leiden ranking list and extract data for the 209 universities in common. Two tier 2 institutions, one from the U.S and the other from France were not found in the Leiden ranking list. For the second research question's analysis, these two institutions were dropped. The 2018 Leiden Ranking list defines each of the variables in their data. The variable labels

¹ The average ranking position for each institution that appeared in all three lists (N=211), Times Higher Education's World University Rankings (THE; N=1258); QS World University Ranking (N=959); and the Academic Ranking of World Universities - Shanghai Jiao Tong University Ranking (ARWU; N=500) is calculated by taking an average across the scores from each list.

provided below are directly from the Leiden ranking list. The following variable was used in this study from the Leiden list and its definition is as follows:

Variables from 2018 Leiden Ranking List

1. *Total collaborative publications or P(collab)*: The total number of a university's publications that have been co-authored with one or more organizations.

All collaboration indicator variables are provided in the full counting method. The full counting method in Leiden's ranking list gives a full weight to each collaborative publication from a university.

Next, contingent on results from research question 2, I provide more qualitative analysis of the top performing institutions in terms of IDR publications in answering research question 2a. I highlight these top performing institutions' IDR commitments from their strategic plans to show if they are engaging in unique behaviors that are different from universities with low collaborative publications.

Finally, since the Leiden ranking list's variables used in research question two are from the years 2013-2016, I collect more current data to study institutional tier effects in IDR publications. Research question three answers how many interdisciplinary publications universities in this study produce for the year 2018. I examine total publications for each university on the Web of Science (WoS) database for the year 2018. A single calendar year is a reasonable sample to measure publication output from a university as it is indicative of the kind of research being conducted by a university in current times. For each university in my sample, I search its name within WoS database and narrow the results by year 2018. Once WoS produces the results of this search, I then narrow it further by selecting only articles. This filter helped to remove other WoS document types such as 'proceeding paper', 'editorial material', 'biographical

item’, ‘news item’, ‘reprint’, ‘review’, ‘book chapter’ and ‘meeting abstract.’ I then save all references in ‘full record with cited references’ format. This total number of publications for a specified university is saved into a designated folder. Using python code, I then extract subject categories (SC) for each journal. Subject categories allow each publication to have a subject label. For instance, a publication in the field of education and engineering would be labeled “Education” and “Engineering” under the WoS SCs. When publications combine knowledge from two or more fields, it is considered as an interdisciplinary publication. I specify code to count publications that have two or more SCs to signify IDR. I also separately count those publications that are labeled by the WoS as being ‘*multidisciplinary*’. Aside from SCs, the WoS labels publications as ‘multidisciplinary’ if the article combines subject categories. Moving forward, I refer to these two variables as follows:

1. IDR measured using two or more subject categories are labeled as IDR-SC.
2. IDR measured using WoS category of ‘*multidisciplinary*’ are labeled as interdisciplinary research – WoS Category or IDR-WC.

Once this process was repeated for all 211 universities, I then calculate total proportion of 2018 publications that are IDR-SC from the total percentage of article publications per university. I also collect proportion of those publications that IDR-WC as well. These scores reveal how many publications in the year 2018 integrated more than one discipline in total publications for each university.

To help visualize the disciplines network for each university, I provide subject category maps for each institution to show links between disciplines. Each node in the map represents a discipline or subject category. Each link or connector represents one or more publications that brings two disciplines together (See figs 4 – 6). The SC maps allow us to understand which field

in a university has the most number of interdisciplinary publications and reveal fields that have the least number of integrative publications according to the data collected through WoS for the year 2018. These maps will be discussed further in the results section.

Text Analysis

Using the strategic plans, terms related to IDR were identified through manifest coding from the preliminary analysis conducted in 2017. Aside from IDR terminology, other examples of codes include terms such as “across disciplines”, “Innovation” and “Partnership”, “Collaboration”. The assistance of an inter-coder was enlisted to confirm these themes from their initial read of the strategic plans. These codes along with various terms used to refer to IDR were used to identify text from all strategic plans used in this study. Text results for each corresponding term from each institution was then populated into a separate spreadsheet. It is important to note that the texts that were collected using the mentioned codes also needed to signify a commitment or a goal made by the leaders who worked on the strategic plan for it to be accepted in this study for further analysis. For example, a commitment to IDR would be when members of an institution states that in order to facilitate IDR, “At faculty level, the process involved inspiration from experts, visits to universities abroad, and consolidating a team management to foster a true interdisciplinary vision among heads of departments and centres, vice-deans, and the dean”². While this example is directed at top level leadership, other examples of IDR to support faculty and students are also accepted. Using the assistance of an inter-coder, IDR text analysis from the strategic plans was coded to ensure inter-coder reliability. This procedure provided high levels (93%) of inter-coder reliability. To visually represent the

² This quotation is taken verbatim from a strategic plan as an example to illustrate the process of text analysis conducted in this study.

various stages of this is a mixed methods study, a flow chart representing the data analysis stages is presented in Figure.2.

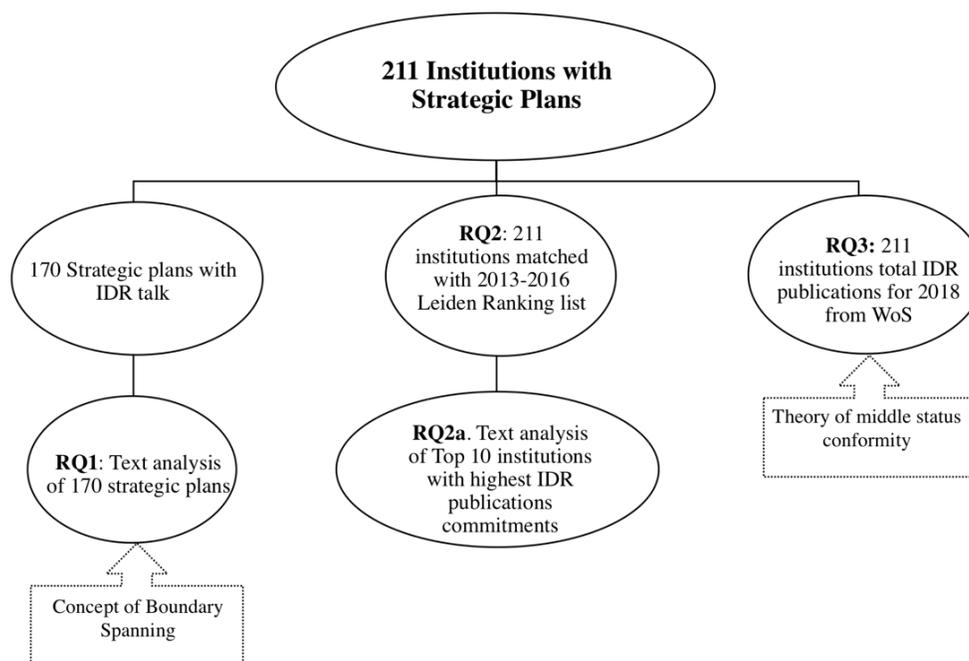


Figure 3: Flow chart describing data source, sample size and analysis methodology for each research question of this study. The concept of boundary spanning guides research question one and the theory of middle status conformity is applied to research question three.

In summary, the first stage involved qualitative text analysis of n=170 strategic plans that express commitments to IDR. Using university names, country and region from stage one, additional data from THE ranking list and the 2018 Leiden ranking list are added to understand and capture more institutional characteristics as well as co-authored publications output by institution. As an example, if I conducted regular regression analysis, it would provide the effect of a unit change in student enrollment number on the dependent variable. Instead, using log-log regression provides the percentage change for dependent variable for every 1% increase in the independent variables. As institutions operate on large scale changes, log-log regression

interpretation is more useful for institutions as it gauges and predicts more discernable changes in variables of interest by providing percentage change or increase as opposed to a value or number. I then utilize the log-log regression results from the second stage to identify universities in the sample with the most collaborative publication based on the residuals calculated from research question two. According to the residuals, the top ten institution's IDR strategic priorities are analyzed in more depth to understand if they engage in unique behaviors that may be associated with or even drive collaborative publications. Finally, through web-scraping methods, I collect publication data for all institutions from the year 2018 via the Web of Science database to quantify the total number of publications by university, proportion of publications that is of two or more subject categories and proportion of publications that is classified by the database as being multidisciplinary. Through this final step, I provide network maps for three universities, each from a separate tier to illustrate how well their disciplines are connected to produce collaborative publications. These discipline network maps were selected from several maps I developed for each tier to show a single example that best represents each tier.

Chapter 4: Results

The results are provided in two sections: study aim 1 (qualitative analysis) and 2 (quantitative analysis). It was found that to stimulate IDR, top university leaders who propose university strategic priorities do so for five main reasons. Their rationales are categorized in five themes, 1) attract faculty to facilitate IDR, 2) IDR to benefit students, 3) university infrastructure to support IDR, 4) boundary spanning goals and 5) increasing diversity and global connection. Overall, the text gathered from the strategic plans shows that university leaders employ various transdisciplinary strategies as opposed to only committing to interdisciplinary research.

Transdisciplinary activities include actions that bring two or more disciplines together but it may not always be for the sake of conducting research. For instance, an example of a transdisciplinary activity would be to provide seminars on campus from world-renowned scholars that is accessible to all members of the campus. Such initiatives help raise the collective aptitude of an institution and stimulate cross disciplinary dialogue. While university leaders prioritize and associate IDR goals with senior faculty and scientists from all over the world, they emphasize boundary spanning transdisciplinary activities to bridge industry and key stakeholders from their community to their students and faculty. University leaders from tier 1 and 2 institutions reason that engaging in transdisciplinary activities ensures that all members of an institution are better poised to respond to the needs of the current economy and produce innovation. The first part of this study uses text analysis with direct evidence from strategic plan quotes to support each of the five themes.

Study Part 1

Research Question 1: Through strategic plans, how are members of international institutions stimulating and expressing commitment to interdisciplinary activities?

Across the 211 institutions included in this study, 81% (or 170 institutions) of the strategic plans outlined institutional goals to stimulate IDR in various ways. Before developing undergraduate and graduate IDR degree programs, leaders who develop strategic plans point out that attracting faculty from around the world who work on a diverse array of research projects as the first step in developing an institutional portfolio that supports IDR. Eighty-six percent (86%) of strategic plans also express ways that students will benefit from partaking in multidisciplinary programs, courses, internships and other activities that include overseas exchange and

connection with scholars from around the world. While faculty talent and equipping students with the necessary skills required for the current economy are prioritized, there is also a notable emphasis on developing institutions' physical infrastructure and design to better stimulate IDR efforts. To support each theme, I provide direct quotes from the strategic plans.

Text analysis also reveals that institutions' efforts in stimulating and expressing IDR often resulted in activities that spanned their community (38%), country (12%) and international (70%) boundaries. Finally, as the leaders expressed their collective vision for supporting and promoting interdisciplinary research and collaborative interactions, deeply philosophical rationales were also included to substantiate their reasons for wanting to commit to IDR. The expressions of IDR by the members of universities reveal a desire to increase diversity, serve their immediate society, connect to the world around us by playing an active role in solving today's greatest problems and they also convey that in its undertaking, no one institution alone can generate solutions. A clear majority (93%) express that IDR is achieved when institutions and its members are interconnected and have access to each other both through internal infrastructure and with external organizations. Findings under each of these themes are detailed further with evidence from strategic plans.

Attract Faculty for IDR. Hiring faculty from all over the world who work on unique research is frequently cited but how universities intend to support them is also clearly articulated. A tier one European institution (Erasmus University Rotterdam), a tier one Asian university (City University of Hong Kong), two tier two universities (Florida State University and Aalto University) and two tier three universities (University of Central Florida and University of Belgrade) cite that they provide 'incentives for their [professors] to conduct multidisciplinary research' that lead to innovation. Several U.S based tier one institution express that hiring faculty

from different disciplines helps to develop ‘clusters of interdisciplinary excellence.’ One tier 2 U.S university (Brandeis University) acknowledges that providing funding supports for faculty who work on ‘cutting-edge’ IDR will not only prove to be beneficial to their students and university but that it will also make a difference around the world. The same university also places an emphasis on ‘cluster hiring’, which is a practice of hiring faculty into more than one department. It is aimed at increasing diversity in terms of IDR interests within a department and create opportunities for faculty to collaborate across departments and institutions. This practice is further supported by a recent report that highlights an increase in institutions choosing to participate in cluster hiring practices in the hope that it will lead to greater faculty diversity, community engagement and multiple perspectives being represented in teaching, learning and via collaborative projects (Flaherty, 2015). Similarly, to this effect, another top North American (Cornell University) institution plans to ‘include faculty from more than one discipline or college’ on hiring committees to encourage recruitment that that will lead to impact beyond the hiring department. One tier 3 North American institution (Drexel University) also plans to diversify their hiring committees to recruit new faculty who would conduct research that “engage[s] multiple units across the university.’ 12% of strategic plans refer to the practice of ‘cluster-hiring’ to describe their plans to diversify faculty hiring practices. Of these 12%, majority are tier 1 institutions and 4% are from tier 2.

Two top-ranked North American institutions’ (University of California, San Diego and Duke University) strategic plans states that providing more ‘seed grants’ to faculty and students would help stimulate IDR. One institution from the African region (Cairo University) acknowledges that capacity-building in junior faculty can be achieved by hiring ‘distinguished senior faculty.’ Such a practice, they hope, will not only lead to meaningful IDR collaborations

but also increase international connections. The presence of distinguished faculty is frequently mentioned by tier 1 and 2 institutions as a reason for why they can make greater strides in achieving research that transcends the boundaries of disciplines. A leading U.S institution (Cornell University) has pledged funds to support untenured faculty who participate in IDR with a promise that such participations will be taken into consideration in ‘renewal, tenure and promotion decisions.’ Promoting greater awareness of research that is being conducted across the campus is two leading North American institutions’ (Carnegie Mellon University and University of British Columbia) strategy to build greater faculty and student capacity that could then drive IDR. They organize ‘research retreats, seminars, presentations and workshops’ between departments to provide faculty of all levels formal and informal opportunities to learn about each other’s research areas. Such interactions are thought to encourage cross-disciplinary initiatives.

Overall, findings reveal that attracting members of universities around the world favor faculty who can demonstrate to a university search committee that they are actively participating in cutting-edge research that is both inclusive and collaborative when it comes to stimulating IDR within their institution. While IDR produced by faculty and support for faculty who have the potential to conduct IDR is prioritized in terms of strategies, students are also discussed in as university members describe their commitment to IDR.

IDR to Benefit Students. A little over half of the institutions included in this study express IDR goals that are aimed to improve the education and research opportunities for their students. While there is less talk of students conducting interdisciplinary research, institutions place a heavy emphasis on providing students with degrees, courses, internships and exposure to international connections to provide them with ample experiential opportunities to learn across disciplines. One leading North American university and several European tier one and tier 2

institutions state that they make efforts to ensure their students work on IDR projects. One tier one institution (Technical University of Denmark) states that their students ‘are challenged to further improve their learning outcome by focusing on core academic skills combined with an interdisciplinary and application-oriented perspective.’ To promote research across disciplines for students to engage in, graduate and doctoral programs are designed so that students can acquire skills in more than one field by the time they graduate. A leading North American university (Dartmouth College) states that “[we] must provide additional support for interdisciplinary courses, the culminating experience, and off-campus programs’, recognizing that these programs expose students to transdisciplinary learning opportunities. Another tier one European institution (Delft University of Technology) highlights in their strategic plan that providing their students with interdisciplinary skills is a way to ‘prepare students to contribute to solving societal challenges.’ A tier 3 U.S institution (Drexel University) states that the curriculum designed for their engineering students should reflect an ‘integration of engineering and life sciences’ to meet their goal of stimulating interdisciplinary research. Similarly, another top-ranked North American institution (Duke University) state in their strategic plan that they want to ‘encourage students to seriously explore’ curricular offerings outside of their majors so that they can ‘meaningfully integrate [these] modes of inquiry’ into their scholarship. Additionally, they also express their support for students who want to engage in IDR by setting aside funds for graduates who ‘propose IDR projects, training or experiences.’

Several universities across all tiers from both Europe and the U.S outline strategies for developing doctoral programs that allow for cross-disciplinary collaboration and research that will widen their learning possibilities. They also outline ways that colleges can connect their students to their community to stimulate multidisciplinary collaborations. One top-ranked North

American university (University Of Southern California) have prioritized a goal of recruiting graduate students who can demonstrate that they are engaged in ‘interdisciplinary research of distinction.’ They express a rigorous process for recruiting graduate students because they have positioned themselves as a ‘leader in addressing interdisciplinary problems of importance’ to the society. This institution also states that overcoming ‘disciplinary barriers’ would allow them to mobilize various research teams that include faculty of all levels, graduate and postdoctoral students to tackle challenges that are of relevance to their community and the world. Similarly, another tier one institution in Europe (University of Birmingham) plan to ‘welcome more high quality students’ so that they can continue to deliver interdisciplinary learning experiences. They also state that they aim to provide curriculum that is interdisciplinary to their online students as well. Only eight other universities from the North American, European and Asian regions describe plans to extend their interdisciplinary focused curricula to their online students. A top ranked European institution (University of Vienna) states that expanding their IDR efforts across the campus is one way to be ‘an attractive location for the best academic and students.’ A tier 3 institution (Victoria University of Wellington) from the Oceania region describes their academic strength as being ‘multi-disciplinary’ and one that has an ‘outlook that goes beyond disciplinary...boundaries’ which ultimately allows their students to succeed academically. Another top-ranked Asian university (City University of Hong Kong) describe that participating in ID learning increases students’ ‘analytical skills’ and while it allows them to learn about another discipline, it simultaneously provides them ‘with a solid training in their subject disciplines.’

While universities around the world express their support for IDR and multi-disciplinary learning to enable their students a better chance at addressing critical global challenges, the

strategies also include clear goals aimed at improving the physical infrastructure of the university to increase IDR.

University Infrastructure. A total of 36 tier 2 and tier 3 institutions discuss plans to build and/or upgrade their facilities, shared resource spaces such as libraries and computer laboratories, digital platforms, classrooms and improve overall accessibility to connect more people together and aspire to be like globally recognized institutions that they too view as being titans of the terrane. On the other hand, tier 1 institutions commit to continue making investments to improving their existing research centers and shared resource spaces. The most common rationale behind the detailed goals of infrastructure changes, as one tier 2 European institution (University College Cork) puts it, enhancing ‘infrastructural support’ allows their university to be more prepared to support IDR projects. It is also thought to enable more collaborative projects as professors, international scholars and students are more easily connected because the university’s physical and cyber spaces allow it. A tier 3 middle-eastern institution (Amirkabir University of Technology) places an emphasis on being able to connect with ‘global counterparts’ so that they can successfully ‘direct their academia towards transdisciplinary research.’ While detailed commitments as to what they plan to change or upgrade are not mentioned, university leaders do acknowledge that they must continually invest in upgrading their university infrastructure to provide faculty and students a space to support their cross-disciplinary interactions.

A top-ranked North American institution references their ‘new collision spaces’ that have enabled more collaborative avenues for research teams to come together to conduct ‘interdisciplinary, data-driven, digitally reliant, and team-based research.’ Like this institution, another top-ranked North American institution (New York University) is dedicating research

funds to build a center where junior faculty can be mentored and provide a space to ‘bolster emerging areas of interdisciplinary research’ projects. More importantly, the research center also strives to develop and promote science education programs specifically for local K-12 schools. Building and maintaining research centers that is accessible by all colleges within a university is an increasingly key design feature of universities that want to stimulate IDR. A tier 2 North American institution (Florida International University) aims to achieve the highest ‘Carnegie-related classification for research’, and to achieve this goal, they plan to develop an ‘interdisciplinary solutions center’ that would allow members of the community and the university to interact and facilitate IDR. Besides establishing research centers that facilitate IDR, a tier 1 regionally prominent Asian university (City University of Hong Kong) describes in detail a campus-wide effort to upgrade their ‘cyber infrastructure to support interdisciplinary research’ and specify that as they modernize their technology platforms, they will make way for ‘large bandwidths for massive data handling.’ Details of how these upgrades will be funded are not discussed but they are prioritized and budgeted for as up to date infrastructure is thought to inspire creativity. Keeping up with modern technology and consistently upgrading university infrastructure is also one way for universities to position themselves on a global stage to attract distinguished faculty and talented students from around the world. Evidence of boundary-spanning strategies were closely tied to university infrastructure developments.

Boundary-Spanning. Evidence of boundary-spanning was not just limited to domains of knowledge or subject fields. To enhance IDR, boundary-spanning activities including goals to engage in partnerships with members of the community, industry experts, other universities, local and international organizations and indigenous communities were expressed by the university leaders in the strategic plans. As Jemison’s (1984) study highlights, spanning

boundaries is a necessary strategy that organizational leaders must employ to survive external changes. As found in his study, specific initiatives through international collaborative projects were often cited in institutional plans as a method to stimulate IDR.

Furthermore, boundary spanning categories according to Birkinshaw, Ambos and Bouquet's 2017 study was also found across the tiers. Table 2, 3 and 4 show evidence from strategic plans pertaining to each boundary spanning category. Applying the categories of boundary spanning reveal that tier 1 institutions propose to engage mostly in spanning activities that are categorized as *spearheading* as they strategize ways to collaborate with external organizations to stimulate IDR activity. This finding was true across regions in tier 1. Also, there are a few instances of institutions (20%) in tier 1 that showed evidence of *facilitating*, *reconciling and lubricating* boundary spanning commitments to steer IDR. Evidence from strategic plans to support these categories for tier 1 are described in Table.2. Tier 2 institutions state more commitments to IDR that fall under the *spearheading category*. This finding in tier 2 institutions could be a response to external pressures to be more like tier 1 institutions. Examples of tier 2 strategic plan commitments with boundary spanning categories are provided in Table 3. Tier 3 institutions show the least commitments that could have been categorized as *spearheading*. Instead, a clear majority of their commitments to IDR are categorized as *reconciling and facilitating*, revealing that majority of their efforts are directed at developing better communication between members of their internal organization as well as with members of external organizations. This signals that to realize their IDR commitments, tier 3 institutions may have increase efforts in establishing networks of researchers and scholars who understand the research goals and strengths of their institution before they can engage in collaborative

projects. Table 4. Provides text evidence from strategic plans to support tier 3 boundary spanning commitments.

Table 2

| Tier 1 Institutions | | |
|--------------------------------|--|-------------------------------|
| University | Strategic Plan Quotations | Boundary Spanning Category |
| Aarhus University | <i>'visits to universities abroad, and consolidating a team management to foster a true interdisciplinary vision among heads of departments and centres, vice-deans, and the dean'</i> | Spearheading and facilitating |
| University of Bristol | <i>'To seek further collaborative and multidisciplinary opportunities, both within the University and externally, including partnerships with leading overseas institutions where there are complementary research strengths and synergies.'</i> | Spearheading |
| Boston University | <i>'We need to assess our current interdisciplinary or cross-departmental initiatives and entities, and reorganize them as necessary to include larger numbers of faculty and students.'</i> | Facilitating |
| Carnegie Mellon University | <i>'Invest/organize informal gatherings as well as focused research retreats and workshops to form/maintain/grow research initiatives within the department and across the university.'</i> | Facilitating and Lubricating |
| Australian National University | <i>'partnership with Indigenous communities and a commitment to novel and multidisciplinary approaches to our work.'</i> | Spearheading |

| | | |
|---------------------------------|--|------------------------------|
| Chinese University of Hong Kong | <i>'Through engagement with the public we will better articulate, develop and communicate an identity consistent with our visions in order to facilitate the community in understanding our goals and recognizing our achievements' to facilitate interdisciplinary collaboration.</i> | Spearheading and Reconciling |
|---------------------------------|--|------------------------------|

Table 3

Tier 2 Institutions

| University | Strategic Plan Quotations | Boundary Spanning Category |
|-------------------------|--|----------------------------|
| Hokkaido University | <i>'we strive to create new research bases with interdisciplinary projects, provide lectures in foreign languages, and accept competent international students to further our development into a university open to the world and a global center for education and research.'</i> | Spearheading |
| Pompeu Fabra University | <i>'....to further strengthen our internationalization, to foster interdisciplinary and multidisciplinary learning, to update the process both in and outside the classroom, and to promote innovative forms of governance and management.'</i> | Spearheading |
| Deakin University | <i>'capacity-building reflects this global awareness as we endeavor to foster collaboration and partnerships with universities, civil society organisations and government agencies around the world... and actively pursues collaborative</i> | Spearheading |

interdisciplinary research with many partners in these regions.'

| | | |
|------------------------------|--|-------------------------------|
| George Washington University | <i>'Cross-disciplinary research institutes will expand the university's capacity to contribute creative and valuable solutions to the most pressing issues facing society... such institutes will also open up new research opportunities for our students.'</i> | Spearheading and Facilitating |
|------------------------------|--|-------------------------------|

Table 4

| Tier 3 Institutions | | |
|----------------------------|---|------------------------------|
| University | Strategic Plan Quotations | Boundary Spanning Category |
| University of Saskatchewan | <i>'If we are to realize the full potential of an engaged, collaborative, solutions-focused university with the courage to tackle humanity's greatest challenges, we need to harness scholarly strength, creativity and inventiveness across our campus—which means that we will need to acknowledge and tackle unevenness in the quality of research.'</i> | Reconciling |
| University of Kentucky | <i>'Technology has allowed us to greatly expand how we connect with community partners, near and far. Our efforts are based in the disciplinary strengths of our 16 colleges and centers, the libraries, our network of extension offices, and in the creative and innovative interdisciplinary work of our students and staff in Student Affairs.'</i> | Reconciling and facilitating |

| | | |
|-----------------------------|---|------------------------------|
| University of Ljubljana | <i>‘Encourage formation of large interdisciplinary research groups with a sufficient concentration of human resources, competences, equipment and funds for obtaining large international projects; equal participation should lead to superior results.’</i> | Reconciling and Lubricating |
| Tokyo University of Science | <i>‘[A center on campus] has been based on an interdisciplinary, globally-minded approach aimed at training not only specialized researchers but also highly-advanced professionals who can contribute to the practical world.’</i> | Reconciling and Facilitating |

Other text from strategic plans also show that global connection commitments were highest in tier 1 institutions but evidence of crossing boundaries is also found in tier 3 institutions. For instance, a tier 3 institution (Amirkabir University of Technology) states in their strategic plan that they plan to ‘direct [our] academia towards trans-disciplinary research’ and they will ‘develop open connections with global counterparts.’ Another tier 3 institution (Cairo University), aims to ‘strengthen our international research collaborations’ to increase their IDR collaborations. Rutgers, The State University of New Jersey, a tier 2 North American university aims to stimulate ‘[B]oundary-crossing scholarly initiatives that transcend departments, disciplines, colleges, and external stakeholders’ to facilitate the production of new knowledge and enable their faculty and students to tackle global problems. Boundary spanning collaborations are so strongly advocated by Tufts University, a tier 1 institution that they have promised to investigate and remove any ‘obstacles to collaborations.’ Drexel University, a tier 3 U.S university explains in their strategic priorities that engaging in IDR is pivotal in enabling students to succeed in ‘today’s industry’, academic, research and public environments.’ For their

students to engage in meaningful IDR that brings about innovation, their strategic committee state that the university setting should be one that ‘pierces disciplinary silos, transcends boundaries.’ Aalto University, a tier 2 European institution aims to produce research that makes a positive impact on their society by ensuring that they facilitate ‘multidisciplinary research platforms’ by connecting their students and faculty to industries. A concrete case for boundary-spanning to facilitate IDR is provided by the University of Oslo, a top-ranked European institution. They point out that the world’s grand challenges transcend both ‘disciplinary boundaries [and] geographic borders.’

A tier 1 university from Oceania (Australian National University), another from Europe (Leiden University), North American (University of Alberta) and a tier 2 Asian university (Hokkaido University) all state that it is very important to create university ‘partnerships with Indigenous communities’ and cultivate novel transdisciplinary research and methodologies. They also recognize their own ‘Indigenous research leaders’ and through them want to ensure that meaningful collaborations are made with Indigenous communities. Across all the strategic plans that place an emphasis on pushing organizational boundaries to reach communities and connect to the world around us, universities state that ultimately they are in service of their societies. Overall, spanning boundaries and remaining receptive to the needs of the environment surrounding an institution is a way to foster research creativity and create synergies between various faculty, students and stakeholders. Beyond these findings, there is also evidence from strategic plans that boundary spanning activities are an initial step to increasing diversity and global connections.

Increasing Diversity and Global Connection. Top ranked institutions recognize that their faculty and student body diversity increases when ID efforts are supported through

fellowships, scholarships and grants. They also acknowledge that there needs to be a greater evaluation of faculty's research from various disciplines that contribute to the production of creative research. To this effect, a top ranked North American university's (Duke University) strategic plan states that it is its goal 'to re-evaluate the criteria for tenure and promotion' to be able to record in greater detail the research activities done by scholars to improve their community. Another institution with similar ranking from Asia (City University of Hong Kong) has projected that efforts to 'deepen[ing] internationalization and global partnerships...to promote interdisciplinarity.' They also state that they continue to build global partnerships that help position their institution's researchers to 'address issues of critical significance' through interdisciplinary research.

The theme of global connection is critical to one tier 2 European institution (University of Bordeaux) as its leaders provide clear insight into why they need to 'promote multidisciplinary collaborations', they go on to state that 'the needs of students are changing' and it is the institution's responsibility to provide them with knowledge that will allow them to leave a 'meaningful impact in a larger self-governing citizenry.' Like this university's goal, another tier 2 U.S institution's (University of Connecticut) aim is to provide students a 'global education curricula' that is jointly developed by multiple faculty partnerships from various departments. This program is believed to provide students the necessary 'tools to understand the process of globalization and their consequences through different lens and methodologies.' While some institution's leaders address global connection via curriculum, others establish institutes within their universities that are specifically developed to conduct IDR in the hopes that it will 'regularly attract leading international researchers... to work with our students and staff' as stated by members of one tier 2 European institution (University of Cologne).

Stimulating IDR not only increased diversity in terms of faculty, scholar, and student populations, according to one top-ranked U.S institution (University of Michigan), it is also said to increase an institution's collective capacity to be able to address issues of 'complex diversity, equity and inclusion-related situations.' Similarly, one tier 3 North American institution (University of Saskatchewan) states that collaborative initiatives that bring colleges together allows them 'creative diversity to tackle some of the greatest challenges humanity faces', they also acknowledge that it their responsibility as an institution to take advantage of their diversity by engaging in scholarly work that utilizes 'the fullness of [our] interdisciplinary potential.'

Middle Status Conformity. As previous research on IDR has shown that conducting IDR requires high resources and funds, it could be thought that tier one institutions practice IDR the most and tier three the least. However, findings differ from the prediction. Tier 2 produces the most IDR when IDR publication output is measured. It was expected that institutions in tier 1 and 2 would have similar commitments to IDR and tier 3 institutions would have lesser or no IDR commitments as they would prioritize other practices that are more pressing for their university and community. However, findings from the strategic plans confirm the theory of middle status conformity specific to IDR goals for a handful of universities around the world. Rather than conformity per se, the variety of commitments by tier 2 institutions reveal that they are conforming to the rise of IDR by engaging in a range of IDR and transdisciplinary activities that are collaborative not just through research practice. For instance, two tier 2 universities from Europe, four from North America and one Asia all specify goals to develop 'world-class' interdisciplinary research centers that can compete with other regional and global universities who engage in IDR.

Overall, tier 1 institution's IDR specific goals did not mirror tier 2 or tier 3 institutions' goals as they were less detailed and more focused on forging a unique path and forming new standards of research that others could follow. For instance, one tier 1 institution (Boston University) states that '[we] set the standards—in many interdisciplinary realms.' Tier 3 institutions across the regions specified very few IDR goals and in many instances the goals do not necessarily promise a timeline or immediate commitment that would come to fruition. A rare instance of conformity from a tier 3 university from Asia (Kobe University) was found as it places importance on becoming like the top national university in their country by engaging in research and providing their students with 'world-class education' so that they can generate interdisciplinary research.

Text analysis results from the university strategic plans across the ranks indicate that there are a wide range of activities members of universities engage in to stimulate IDR. University leader's commitments via their strategic plans show that they engage various spheres of a university – including faculty, researchers, postdoctoral fellows and students, community, industry and the global world to promote and stimulate IDR. However, these commitments – even though they are detailed – still do not reveal if the research output generated by institutions with high IDR commitments are indeed interdisciplinary. One quantifiable way to understand if commitments to promote IDR translate to greater output of ID research is to measure it against the number of collaborative publications a university produces. While collaborative publications by authors of different fields may not be the only goal of interdisciplinary research, such publications are visible evidences of disciplines coming together to produce new knowledge. Other activities that are interdisciplinary such as workshops or seminars that engage members from different disciplines can't be easily measured. Hence, collaborative publications are used to

measure IDR. Research questions in this study's second part attempts to answer this.

Study Part 2

Research Question 2: What are quantifiable determinants that drive IDR?

I use the following variables to conduct an Ordinary Least Squared(OLS) regression:

1. *Collaborative Publications* (Dependent Variable): I use collaborative publications data as the dependent variable from the 2018 Leiden dataset as it provides total 'publications that have been co-authored with one or more other organizations' (Leiden Methodolgy, 2018). Total number of collaborative publications is an indicator of how much researchers in institutions are willing to work with other researchers or organizations. It has been documented by researchers to measure research productivity and found to have greater 'epistemic authority' than research that is produced individually (Beaver, 2004, p. 404; Howard, 2009). I use this variable as a proxy to quantify IDR activity. Although the total publications score could mean that authors from the same discipline are working together, collaborative work is documented to produce increased instances of IDR (Qin, Lancaster, & Allen, 1997; Qiu, 1992).

2. *Student Population* (Independent variable): From the Times Higher Education (2019) ranking list, I use the total student enrollments as an indicator of the size of university.

3. *Rank* (Independent variable): The average ranking position for each institution that appeared in all three lists (N=211), Times Higher Education's World University Rankings (THE; N=1258); QS World University Ranking (N=959); and the Academic Ranking of World Universities - Shanghai Jiao Tong University Ranking ((ARWU; N=500).) is calculated by taking an average across the scores from each list. A low score indicates a higher rank position and higher the score, the lower the rank. This average can be considered as more reflective of a university's reputation as it combines positionality from the three most widely recognized global

HEIs ranking list. Each list utilizes different methodologies to arrive at ranking categories.

Combining the three to create an average rank is one way to offset arbitrary weights that may be over emphasized in a list.

4. *Industry Income*: This variable is an indicator of institution's ability to secure industry funding in exchange for innovative research, consultancy and inventions. The income from industries provides an indication of institutions with high capacity to produce innovative research (THE, 2019). This variable is used as a proxy for funding to support multidisciplinary research.

5. *Region*: Gathered from the strategic plans, this variable includes Africa, Asia, Europe, Middle East, North America and Oceania. Each region has its own education system and its cultural and structural differences play a role in valuing collaborations differently.

6. *Faculty Population*: From the Times Higher Education Ranking list (2019), faculty population is calculated from the student to staff ratio provided.

I use a log-log regression to predict the effect of size and rank on quantity of co-published research from universities around the world. The ordinary least squared regression equation for this model is as follows:

$$\log Y_i = \beta_0 + \beta_1 \log Faculty_Population_i + \beta_2 \log Student_Population_i \\ + \beta_3 \log industry_income_i + \beta_4 \log AveRank_i + \beta_5 \log Region_i + \epsilon$$

The results of the log-log regression are presented in Table.5.

Results

Table 5
log-log Regression Results for Collaborative Publications

| Coefficients: | | | | | |
|------------------------|----------|------------|---------|----------|-----|
| | Estimate | Std. Error | t value | Pr(> t) | |
| (Intercept) | 3.91 | 0.54 | 7.25 | 8.90E-12 | *** |
| Faculty Population | 0.39 | 0.05 | 7.55 | 1.55E-12 | *** |
| Student Population | 0.21 | 0.05 | 4.23 | 3.54E-05 | *** |
| Industry Income | 0.40 | 0.07 | 5.46 | 1.43E-07 | *** |
| Rank | -0.38 | 0.02 | -16.51 | < 2E-16 | *** |
| Asia (factor) | 0.50 | 0.17 | 2.87 | 4.52E-03 | ** |
| Europe (factor) | 0.55 | 0.17 | 3.31 | 1.10E-03 | ** |
| Middle East (factor) | 0.33 | 0.20 | 1.69 | 9.22E-02 | . |
| North America (factor) | 0.47 | 0.17 | 2.82 | 5.31E-03 | ** |
| Oceania (factor) | 0.51 | 0.17 | 2.99 | 3.18E-03 | ** |

Signif. codes: 0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1

Multiple R-squared: 0.811 Adjusted R-squared: 0.8025 n= 209

The results (Table 5.) from a log-log regression show that faculty and student population, industry income and average rank are significant indicators of the quantity of collaborative publications produced by universities. Findings show that the presence of high faculty population drives more research activity. For every 1% increase in faculty population, findings show that collaborative publications increase by 0.39%. Further, campuses with larger student enrollment may enjoy more diversity and have spaces allocated to facilitate interdisciplinary discussions. Results show that every 1% increase in student enrollment correlates with 0.21% increase in collaborative publications. Universities that are research intensive tend to fair better on global HEI ranking lists. Results also show that higher ranking (the smaller the rank value, hence the negative sign for the coefficient of average rank in the regression results) indicates more collaborative publications. For instance, a 1% improvement in average ranking correlates to 0.38% increase in collaborative publications. In this model, regions are used as control variables

and the African region is taken as the baseline. Regions are used as one of the controls because they vary in terms of resources, cultural differences and research priorities. The R-squared value of 0.8 shows that this model explains 80% of the variance in the data.

Research Question 2a. From the log-log regression results (RQ2- Table 5), how are the top performing institutions expressing IDR commitments through their strategic plans?

To answer research question 2a, analysis is conducted by examining the residuals for each university from the log-log regression equation. A positive residual reveals that the *collaborative publication* output for a university of its faculty and student population, ranking, industry income and region is still above the expected norm. The top ten performing universities from this dataset in terms of collaborative publications output have different characteristics. All top performers are from tier 1 and have an average ranking position score of 134. A total of 3 regions (North America, Europe and Oceania) and 6 countries (United States, Netherlands, France, Australia, Finland and Italy) are represented in the top performing institutions when it comes to collaborative publications. Two North American (Case Western Reserve University and University of Cincinnati) and one university from Oceania (University of Western Australia) included in the top ten did not have any discussion of IDR in their strategic plans. The remaining seven top performers (Two from Netherlands and one each from France, Australia, Finland, U.S and Italy) interestingly have very succinct statements to describe their commitments to IDR unlike other tier 2 and 3 institutions.

One European institution states that the compact size of their campus enables faculty and students to interact well and produce collaborative projects. Despite the overall size limitation, they emphasize that the presence of a very large laboratory has been very instrumental

in attracting faculty and researchers from all over the world to engage in research ‘across a range of disciplines.’ Another European institution (University of Amsterdam) states that they want to make IDR its ‘trademark’ by designing doctoral programs that are more interdisciplinary and want to ensure that their students can graduate with skills in data science and artificial intelligence so that they can be more ready to respond to current economic needs. Furthermore, their strategic plan also states that they are encouraging inter-faculty connections between fields such as ‘health systems, complexity economics, crime and terrorism, and urban complexity’ so that they are more ready to respond to the immediate needs of their environment. A top U.S institution (Brown University), states that they provide ‘trainings for young faculty and graduate students applying for grants’ to stimulate IDR projects. They also encourage students with research projects to approach it through an interdisciplinary lens. One university from Italy (Sapienza University of Rome) states that a key reason they encourage the practice of IDR is because it provides ‘life-long learning projects’ for their students as they engage in studies that cross more than one discipline. They also emphasize that the practice of IDR is reserved for their ‘top-level students.’ This could mean that IDR is viewed as a practice for more senior students as it is a rigorous form of research. For instance, an Asian university (Hong Kong Polytechnic University) states that they plan ‘to recruit more interdisciplinary research postgraduate students with supervisory teams and topics spanning different faculties’, thus indicating that IDR projects can be tackled by senior students such as postgraduates. These findings help to confirm that a focus on university infrastructure, faculty development and graduate degrees designed to be interdisciplinary for students are fundamental commitments institutions must make to achieve research activity that is not only one dimensional.

Given that the Leiden ranking list only provides composite scores for collaborative publications, research question 3 utilizes more current publication data from the Web of Science to find out how many collaborative publications institutions produce.

WoS Database Findings

Research Question 3. Are IDR publications only produced by members of tier 1 institutions?

I collect publication information for Results from the 2018 WoS database for all universities in this sample to describe total publications, their proportions of publications that have two or more subject categories and proportion of publications that are categorized by WoS classification as multidisciplinary.

In the following tables (Table 6, 7 and 8), I provide total publications and ratios of publications that are IDR-SC and IDR-WC for all institutions separated by tier. For tier 1, the City University of Hong Kong produced the highest IDR-SC ratio (0.56) of publications for the year 2018. This means that 56% of City University of Hong Kong's total publications for the year 2018 are categorized as having two or more subject categories, thus indicating it as an interdisciplinary publication. For Tier 2, Northeastern University produced the highest IDR-SC ratio (0.58) of publications and for tier 3, Tianjin University has the highest IDR-SC ratio (0.55) of publications.

Table 6
Tier 1 institutions with publication statistics from WoS for year 2018

| University Name | Country | WoS Total Publications | WoS IDR SC ratio | WoS IDR WC ratio |
|-------------------|---------|------------------------|------------------|------------------|
| Aarhus University | Denmark | 5186 | 0.39 | 0.13 |

| | | | | |
|--|----------------|------|------|------|
| Arizona State University | United States | 3866 | 0.44 | 0.18 |
| Australian National University | Australia | 3668 | 0.37 | 0.17 |
| Boston University | United States | 4384 | 0.39 | 0.13 |
| Brown University | United States | 3351 | 0.39 | 0.13 |
| California Institute of Technology | United States | 3557 | 0.28 | 0.25 |
| Cardiff University | United Kingdom | 2945 | 0.38 | 0.16 |
| Carnegie Mellon University | United States | 2065 | 0.45 | 0.2 |
| Case Western Reserve University | United States | 2724 | 0.41 | 0.13 |
| Chinese University of Hong Kong | Hong Kong | 3659 | 0.43 | 0.15 |
| City University of Hong Kong | Hong Kong | 2941 | 0.56 | 0.26 |
| Cornell University | United States | 4806 | 0.39 | 0.18 |
| Dartmouth College | United States | 1097 | 0.36 | 0.17 |
| Delft University of Technology | Netherlands | 3379 | 0.51 | 0.25 |
| Duke University | United States | 6654 | 0.38 | 0.12 |
| Durham University | United Kingdom | 2184 | 0.34 | 0.21 |
| Emory University | United States | 4812 | 0.4 | 0.09 |
| Erasmus University Rotterdam | Netherlands | 4147 | 0.39 | 0.06 |
| Ghent University | Belgium | 5884 | 0.41 | 0.15 |
| Hebrew University of Jerusalem | Israel | 2564 | 0.36 | 0.18 |
| Heidelberg University | Germany | 4531 | 0.35 | 0.15 |
| Hong Kong Polytechnic University | Hong Kong | 3720 | 0.55 | 0.2 |
| Hong Kong University of Science and Technology | Hong Kong | 2058 | 0.53 | 0.3 |
| Imperial College London | United Kingdom | 6515 | 0.4 | 0.21 |
| Indiana University, Bloomington | United States | 2531 | 0.37 | 0.13 |
| King Abdulaziz University | Saudi Arabia | 3918 | 0.39 | 0.24 |
| King's College London | United Kingdom | 5553 | 0.35 | 0.1 |
| KU Leuven | Belgium | 6741 | 0.4 | 0.15 |
| Kyoto University | Japan | 6547 | 0.36 | 0.26 |
| Leiden University | Netherlands | 4609 | 0.33 | 0.11 |
| London School of Economics and Political Science | United Kingdom | 1354 | 0.38 | 0.05 |
| Lund University | Sweden | 4683 | 0.39 | 0.15 |
| Maastricht University | Netherlands | 2938 | 0.39 | 0.08 |

| | | | | |
|--|----------------|-------|------|------|
| Massachusetts Institute of Technology | United States | 6947 | 0.39 | 0.28 |
| Mcgill University | Canada | 6130 | 0.39 | 0.13 |
| Mcmaster University | Canada | 3409 | 0.38 | 0.13 |
| Michigan State University | United States | 4700 | 0.41 | 0.12 |
| Monash University | Australia | 7351 | 0.41 | 0.14 |
| Nagoya University | Japan | 3839 | 0.34 | 0.22 |
| Nanyang Technological University | Singapore | 5226 | 0.52 | 0.3 |
| National Taiwan University | Taiwan | 4420 | 0.44 | 0.25 |
| National University of Singapore | Singapore | 6503 | 0.47 | 0.23 |
| New York University | United States | 5970 | 0.34 | 0.1 |
| Northwestern University | United States | 5989 | 0.39 | 0.2 |
| Ohio State University | United States | 7137 | 0.4 | 0.12 |
| Osaka University | Japan | 4751 | 0.37 | 0.26 |
| Pennsylvania State University | United States | 6678 | 0.43 | 0.19 |
| Princeton University | United States | 3574 | 0.33 | 0.23 |
| Queen Mary University of London | United Kingdom | 3031 | 0.36 | 0.15 |
| Radboud University | Netherlands | 4186 | 0.38 | 0.13 |
| Rice University | United States | 1747 | 0.42 | 0.28 |
| Seoul National University | South Korea | 8402 | 0.4 | 0.2 |
| Sorbonne University | France | 5880 | 0.35 | 0.22 |
| Technical University of Denmark | Denmark | 3131 | 0.51 | 0.23 |
| Technical University of Dresden | Germany | 3107 | 0.42 | 0.26 |
| Technical University of Munich | Germany | 5016 | 0.42 | 0.2 |
| Texas A&M University, College Station | United States | 6039 | 0.4 | 0.17 |
| Tohoku University | Japan | 4949 | 0.4 | 0.3 |
| Trinity College Dublin, The University of Dublin | Ireland | 1867 | 0.39 | 0.19 |
| Tufts University | United States | 2054 | 0.39 | 0.12 |
| University College London | United Kingdom | 11145 | 0.37 | 0.15 |
| University of Aberdeen | United Kingdom | 1547 | 0.36 | 0.17 |
| University of Adelaide | Australia | 3584 | 0.41 | 0.17 |
| University of Alberta | Canada | 6024 | 0.42 | 0.15 |
| University of Amsterdam | Netherlands | 5026 | 0.36 | 0.11 |
| University of Arizona | United States | 4464 | 0.37 | 0.13 |
| University of Auckland | New Zealand | 3350 | 0.4 | 0.14 |

| | | | | |
|---|----------------|-------|------|------|
| University of Basel | Switzerland | 2567 | 0.37 | 0.18 |
| University of Bern | Switzerland | 3527 | 0.37 | 0.16 |
| University of Birmingham | United Kingdom | 4001 | 0.37 | 0.16 |
| University of Bristol | United Kingdom | 4079 | 0.35 | 0.2 |
| University of British Columbia | Canada | 7483 | 0.41 | 0.12 |
| University of California, San Diego | United States | 7165 | 0.38 | 0.18 |
| University of California, Santa Barbara | United States | 2617 | 0.41 | 0.28 |
| University of Colorado, Boulder | United States | 4044 | 0.37 | 0.24 |
| University of Edinburgh | United Kingdom | 5195 | 0.36 | 0.15 |
| University of Exeter | United Kingdom | 2636 | 0.41 | 0.18 |
| University of Florida | United States | 7089 | 0.41 | 0.13 |
| University of Geneva | Switzerland | 2821 | 0.35 | 0.18 |
| University of Glasgow | United Kingdom | 3454 | 0.35 | 0.15 |
| University of Gottingen | Germany | 1772 | 0.35 | 0.21 |
| University of Groningen | Netherlands | 4456 | 0.38 | 0.14 |
| University of Helsinki | Finland | 4705 | 0.36 | 0.14 |
| University of Hong Kong | Hong Kong | 4180 | 0.44 | 0.15 |
| University of Leeds | United Kingdom | 3799 | 0.39 | 0.17 |
| University of Liverpool | United Kingdom | 3308 | 0.41 | 0.16 |
| University of Manchester | United Kingdom | 5957 | 0.37 | 0.18 |
| University of Melbourne | Australia | 8366 | 0.39 | 0.12 |
| University of Michigan | United States | 10515 | 0.4 | 0.13 |
| University of Minnesota, Twin Cities | United States | 7725 | 0.4 | 0.13 |
| University of New South Wales | Australia | 5509 | 0.42 | 0.17 |
| University of North Carolina, Chapel Hill | United States | 8066 | 0.4 | 0.11 |
| University of Oslo | Norway | 4498 | 0.36 | 0.13 |
| University of Oxford | United Kingdom | 10046 | 0.36 | 0.19 |
| University of Pennsylvania | United States | 8998 | 0.39 | 0.11 |
| University of Pittsburgh | United States | 6549 | 0.42 | 0.11 |
| University of Queensland | Australia | 7211 | 0.42 | 0.15 |
| University of Rochester | United States | 2651 | 0.35 | 0.13 |

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|-----------------------------------|----------------|-------|------|------|
| University of Sheffield | United Kingdom | 3558 | 0.42 | 0.17 |
| University of Southampton | United Kingdom | 3953 | 0.4 | 0.18 |
| University of Southern California | United States | 4798 | 0.43 | 0.13 |
| University of Sydney | Australia | 7539 | 0.37 | 0.11 |
| University of Tokyo | Japan | 9152 | 0.34 | 0.26 |
| University of Toronto | Canada | 11242 | 0.38 | 0.11 |
| University of Vienna | Austria | 2140 | 0.37 | 0.1 |
| University of Virginia | United States | 3713 | 0.41 | 0.12 |
| University of Warwick | United Kingdom | 3135 | 0.38 | 0.15 |
| University of Waterloo | Canada | 3120 | 0.49 | 0.18 |
| University of Western Australia | Australia | 4127 | 0.39 | 0.14 |
| Uppsala University | Sweden | 4538 | 0.39 | 0.2 |
| Utrecht University | Netherlands | 6097 | 0.4 | 0.15 |
| Vanderbilt University | United States | 4513 | 0.39 | 0.11 |
| Washington University, St. Louis | United States | 4916 | 0.39 | 0.1 |
| Yale University | United States | 5429 | 0.38 | 0.15 |

Table 7

Tier 2 institutions with publication statistics from WoS for year 2018

| University Name | Country | WoS Total Publications | WoS IDR SC ratio | WoS IDR WC ratio |
|------------------------------------|----------------|------------------------|------------------|------------------|
| Aalto University | Finland | 1984 | 0.49 | 0.27 |
| Colorado State University | United States | 2624 | 0.41 | 0.16 |
| Curtin University | Australia | 3066 | 0.42 | 0.15 |
| Dalhousie University | Canada | 2129 | 0.41 | 0.11 |
| Deakin University | Australia | 2777 | 0.4 | 0.15 |
| Eindhoven University of Technology | Netherlands | 1582 | 0.53 | 0.25 |
| Florida State University | United States | 2389 | 0.41 | 0.18 |
| George Washington University | United States | 2242 | 0.4 | 0.09 |
| Griffith University | Australia | 2709 | 0.41 | 0.13 |
| Heriot-watt University | United Kingdom | 929 | 0.5 | 0.2 |
| Hokkaido University | Japan | 3472 | 0.38 | 0.23 |
| Indian Institute of Science | India | 2078 | 0.45 | 0.33 |

| | | | | |
|---|----------------|------|------|------|
| Iowa State University | United States | 2961 | 0.43 | 0.21 |
| James Cook University | Australia | 1476 | 0.44 | 0.13 |
| King Saud University | Saudi Arabia | 3660 | 0.4 | 0.19 |
| La Trobe University | Australia | 1964 | 0.4 | 0.09 |
| Lancaster University | United Kingdom | 2046 | 0.42 | 0.14 |
| Macquarie University | Australia | 2546 | 0.39 | 0.12 |
| Northeastern University | United States | 3102 | 0.58 | 0.34 |
| Oregon State University | United States | 2465 | 0.43 | 0.17 |
| Pompeu Fabra University | Spain | 1406 | 0.38 | 0.12 |
| Queensland University of Technology | Australia | 2376 | 0.4 | 0.16 |
| RMIT University | Australia | 2178 | 0.48 | 0.2 |
| Rutgers, The State University of New Jersey | United States | 4567 | 0.41 | 0.15 |
| Sapienza University of Rome | Italy | 2367 | 0.39 | 0.12 |
| Stellenbosch University | South Africa | 1685 | 0.36 | 0.12 |
| Sun Yat-sen University | China | 8265 | 0.4 | 0.16 |
| Swinburne University of Technology | Australia | 1330 | 0.43 | 0.19 |
| University College Cork | Ireland | 1359 | 0.41 | 0.14 |
| University College Dublin | Ireland | 2285 | 0.36 | 0.15 |
| University of Bath | United Kingdom | 1601 | 0.42 | 0.19 |
| University of Bergen | Norway | 2492 | 0.34 | 0.17 |
| University of Bologna | Italy | 4435 | 0.38 | 0.15 |
| University of Bordeaux | France | 2774 | 0.38 | 0.21 |
| University of Calgary | Canada | 4179 | 0.39 | 0.11 |
| University of California, Riverside | United States | 2350 | 0.4 | 0.23 |
| University of California, Santa Cruz | United States | 1685 | 0.32 | 0.19 |
| University of Canterbury | New Zealand | 1116 | 0.4 | 0.18 |
| University of Cincinnati | United States | 2774 | 0.43 | 0.11 |
| University of Cologne | Germany | 2310 | 0.32 | 0.18 |
| University of Connecticut | United States | 2853 | 0.44 | 0.15 |
| University of Delaware | United States | 1921 | 0.46 | 0.2 |
| University of Duisburg-Essen | Germany | 1792 | 0.38 | 0.19 |
| University of Gothenburg | Sweden | 3177 | 0.35 | 0.11 |
| University of Iowa | United States | 3547 | 0.36 | 0.1 |
| University of Konstanz | Germany | 859 | 0.36 | 0.28 |
| University of Miami | United States | 3019 | 0.39 | 0.09 |

| | | | | |
|------------------------------------|----------------|------|------|------|
| University of Munster | Germany | 2002 | 0.36 | 0.22 |
| University of Notre Dame | United States | 1812 | 0.39 | 0.17 |
| University of Otago | New Zealand | 2292 | 0.32 | 0.11 |
| University of Ottawa | Canada | 3704 | 0.36 | 0.12 |
| University of Reading | United Kingdom | 1465 | 0.37 | 0.16 |
| University of South Florida, Tampa | United States | 2568 | 0.46 | 0.15 |
| University of St Andrews | United Kingdom | 1559 | 0.37 | 0.24 |
| University of Surrey | United Kingdom | 1522 | 0.45 | 0.13 |
| University of Tartu | Estonia | 1133 | 0.4 | 0.21 |
| University of Tasmania | Australia | 1973 | 0.4 | 0.13 |
| University of Technology, Sydney | Australia | 2708 | 0.45 | 0.13 |
| University of York | United Kingdom | 2042 | 0.39 | 0.18 |
| Victoria University of Wellington | New Zealand | 1103 | 0.37 | 0.17 |
| Washington State University | United States | 2250 | 0.44 | 0.18 |
| Western University | Canada | 1690 | 0.39 | 0.15 |

Table 8

Tier 3 institutions with publication statistics from WoS for year 2018

| University Name | Country | WoS Total Publications | WoS IDR SC ratio | WoS IDR WC ratio |
|------------------------------------|---------------|------------------------|------------------|------------------|
| Amirkabir University of Technology | Iran | 1921 | 0.46 | 0.19 |
| Bar-Ilan University | Israel | 1379 | 0.38 | 0.21 |
| Cairo University | Egypt | 3138 | 0.31 | 0.13 |
| Chiba University | Japan | 1608 | 0.34 | 0.17 |
| Drexel University | United States | 1577 | 0.45 | 0.17 |
| Flinders University | Australia | 1596 | 0.39 | 0.13 |
| Florida International University | United States | 1612 | 0.41 | 0.14 |
| George Mason University | United States | 1350 | 0.4 | 0.13 |
| Istanbul University | Turkey | 2045 | 0.29 | 0.08 |
| Kansas State University | United States | 1746 | 0.4 | 0.13 |
| Keio University | Japan | 2244 | 0.35 | 0.17 |
| Kent State University | United States | 850 | 0.39 | 0.15 |

| | | | | |
|--|---------------|------|------|------|
| Kobe University | Japan | 1939 | 0.36 | 0.13 |
| Oklahoma State University, Stillwater | United States | 1399 | 0.41 | 0.13 |
| Temple University | United States | 2097 | 0.43 | 0.11 |
| Texas Tech University | United States | 1993 | 0.38 | 0.14 |
| Tianjin University | China | 5668 | 0.55 | 0.3 |
| Tokyo University of Science | Japan | 1102 | 0.37 | 0.28 |
| University of Belgrade | Serbia | 3340 | 0.36 | 0.14 |
| University of Central Florida | United States | 1925 | 0.43 | 0.16 |
| University of Guelph | Canada | 1921 | 0.46 | 0.14 |
| University of Houston | United States | 2203 | 0.45 | 0.19 |
| University of Kentucky | United States | 2852 | 0.43 | 0.14 |
| University of Ljubljana | Slovenia | 2271 | 0.38 | 0.18 |
| University of Lorraine | France | 2151 | 0.43 | 0.23 |
| University of Manitoba | Canada | 2351 | 0.39 | 0.11 |
| University of Oklahoma | United States | 2409 | 0.39 | 0.12 |
| University of Pretoria | South Africa | 2173 | 0.34 | 0.11 |
| University of Saskatchewan | Canada | 2045 | 0.39 | 0.16 |
| University of Vermont | United States | 1279 | 0.45 | 0.11 |
| University of Warsaw | Poland | 2023 | 0.36 | 0.2 |
| Waseda University | Japan | 1500 | 0.38 | 0.21 |
| Wayne State University | United States | 2204 | 0.41 | 0.1 |

Application of Middle Status Conformity. Using the ratios gathered from Table 6, 7 and 8, I provide a visual representation of IDR-SC ratio (y-axis) in terms of average rank (x-axis) in a scatterplot. I fit a second-degree polynomial curve on the WoS two or more subject category proportions for all universities. The fitted curve shows that there is higher IDR-SC activity in tier 2 institutions compared to tier 1 and 3. The difference in IDR-SC ratio between the highest point (0.415) of the curve and the beginning of the curve (0.375) shows a difference in IDR-SC ratio of 0.04. An increase of 0.04 IDR-SC ratio indicates an increase of 10.7% in IDR-SC publications ($0.04/0.375 \times 100 = 10.7\%$). This can be interpreted that an institution at the start of the curve produces 10.7% fewer IDR-SC publications when compared to an institution in the center of the curve. This plot also illustrates and confirms the theory of middle status conformity. Institutions

in the middle of the distribution have higher IDR-SC ratio than institutions at higher and lower ends of the curve. The presence of more data points at the start of the curve represents the higher sample of all the tier 1 institutions in this study. Majority of institutions in tier 3 are not conforming to the norm of producing more IDR publications.

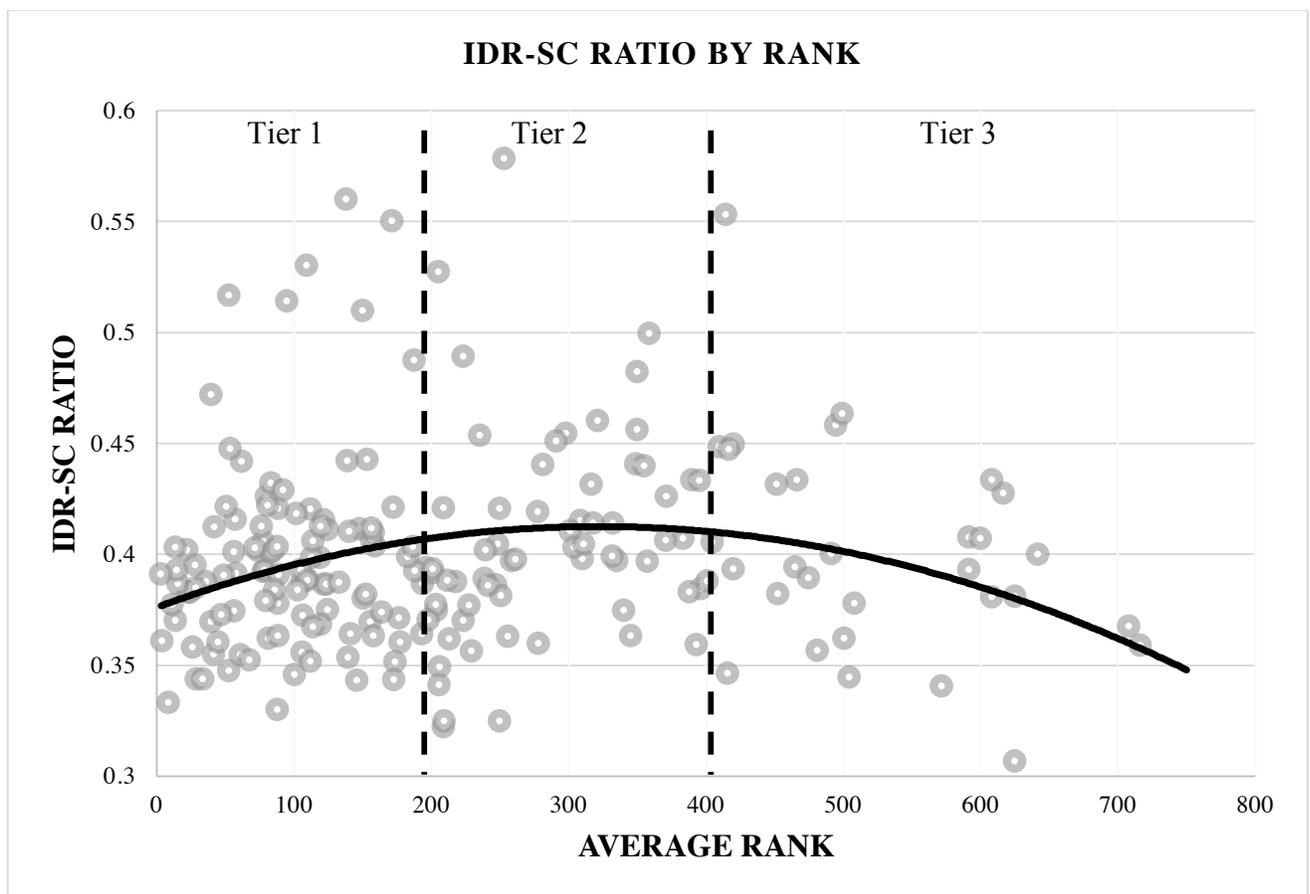


Figure 4. IDR-SC ratio versus average rank. This figure illustrates that institutions in tier 2 produce more collaborative articles when compared to tier 1 and 3.

Next, I examine IDR-SC network maps for an average institution from each tier represented in in Table. 6, 7 and 8. The IDR-SC network maps paints a clearer picture of the

subjects that are engaging in the most collaborative publications. For figures 5 to 7, I examined network maps for several institutions within each tier and provide here the most representative sample of each tier. Figure 5 and 5.1 illustrate the IDR publication network for a tier 1 university in Asia. The size of the colored nodes corresponds to the number of publications and the colors represent the number of connections. On a color scale, red indicates low, yellow is mid and green is high volume of publications. The isolated nodes that are not linked show disciplines that have not collaborated with another discipline. For the tier 1 university, the network map shows the discipline of engineering (dark green node) produced the most volume of IDR publications. A close second is from the field of material science (light green node). Fig 5.1 provides a closer look at the other disciplines that are linked with engineering to produce IDR publications at this tier 1 university. The numerous links or connections indicates that there are several combinations of disciplines coming together to produce publications. Even though tier 2 institutions produced more collaborative publications as a proportion of their total publications when compared to tier 1, it must be highlighted that there are fewer combinations of disciplines coming together to produce IDR publications in tier 2 institutions.

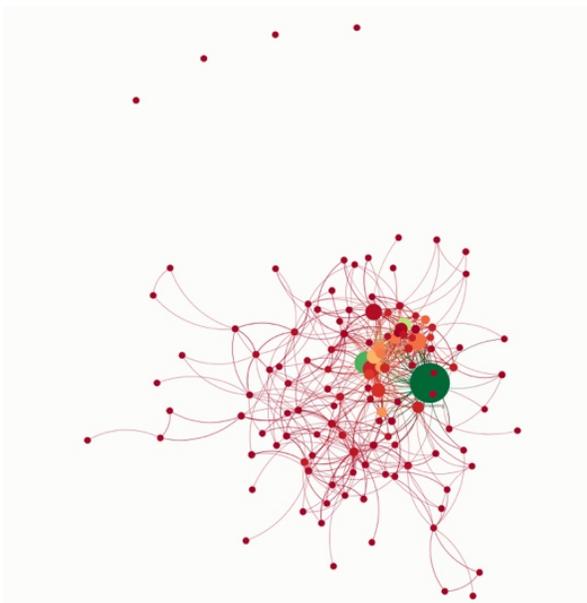


Figure 5. An example of a tier 1 institution's IDR-SC network map

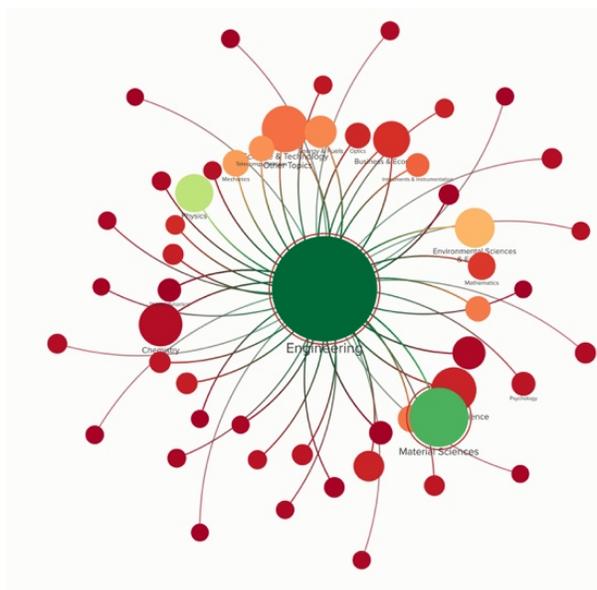


Figure 5.1. This image zooms in on the discipline with the most IDR-SC collaborations for the same tier 1 institution as in fig.5

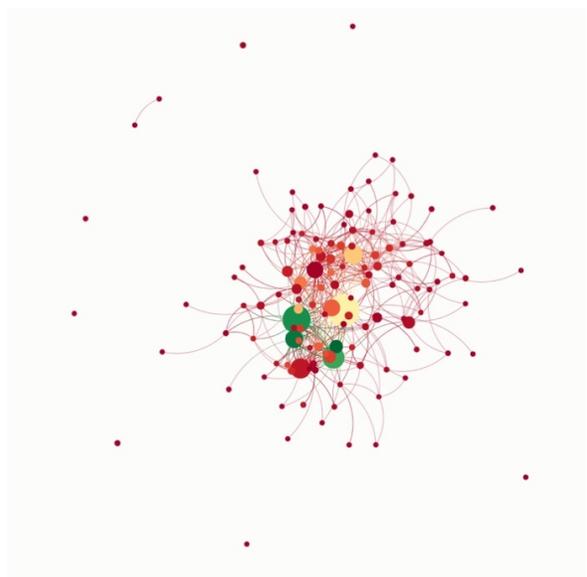


Figure 6. An example of a tier 2 institution's IDR-SC network map

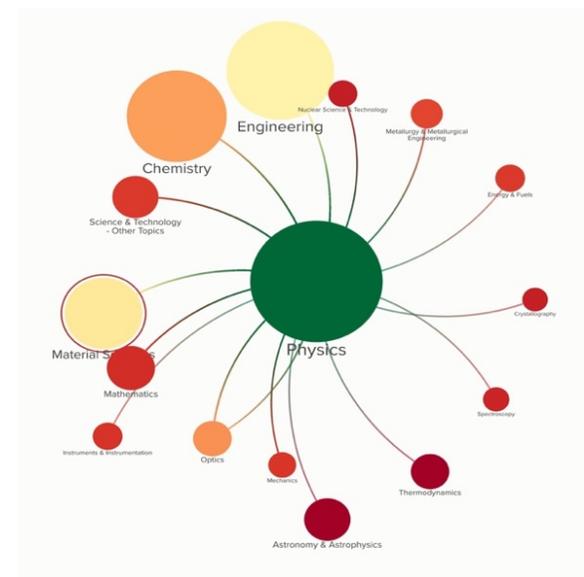


Figure 6.1. This image zooms in on the IDR-SC discipline with the most collaborations for the same tier 2 institution as in fig.6

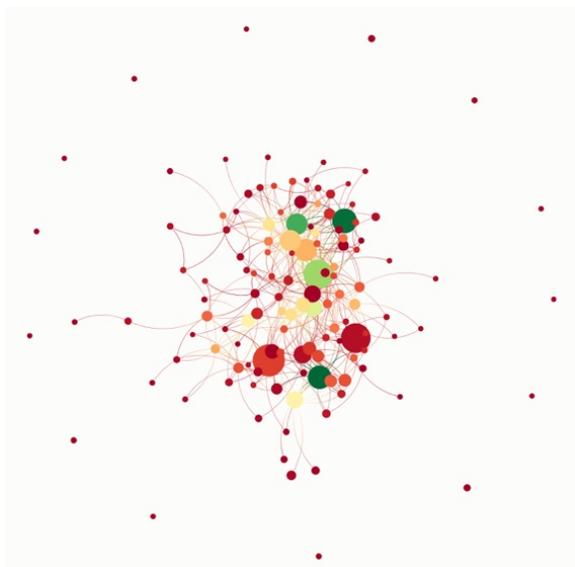


Figure 7. An example of a tier 3 institution's IDR-SC network map

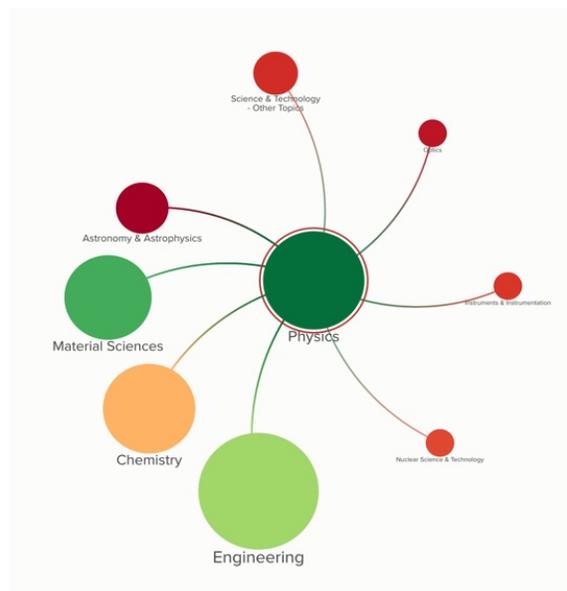


Figure 7.1. This image zooms in on the discipline with the most IDR-SC collaborations for the same tier 3 in fig.7. The highest IDR is from the physics discipline indicated by the dark green node. The larger light green node represents more overall publications from the field of engineering.

Figure 6 illustrates the publication network for a tier 2 institution from the middle east region. A closer look at its highest IDR producing discipline (fig 6.1) shows that there are fewer combinations of disciplines coming together to produce IDR. However, total count of IDR publications is comparable to a tier 1 institution. A publication network map of a tier 3 institution from Europe (fig 7) illustrates that there are more disciplines that are not connected. This is identified by the free-floating nodes in the network map. A closer view of this network map (fig 7.1) reveals that while engineering (largest in diameter, light green node) produces the most number of overall publications, the discipline that is producing the highest number of IDR publications is physics (dark green node). Fewer connections in this network also signals fewer combinations of disciplines coming together.

Summary

To summarize, the findings of this study reveal a more nuanced picture of global university IDR commitments. First, the qualitative text analysis findings from this study show that members of universities around the world set a wide range of goals to promote and stimulate interdisciplinary research. Further, text from tier 1 and 2 institution's strategic plans also point to activities committed to by members of the universities to attract global scholars through the interdisciplinary research centers to facilitate IDR projects. The strategic plans' text also highlight the challenges in not having a single definition of IDR that is used world-wide. Referring to IDR with different terminology such as multidisciplinary or cross-disciplinary makes it more challenging to identify, quantify and review IDR projects. As previous studies on strategic plans have pointed out the challenges associated with equating actual institutional behavior from the goals expressed in the text, the second part of this study uses quantitative analysis to understand drivers of IDR.

The log-log regression results indicate that the drivers of IDR publications include faculty and student population, the amount of industry income received by institutions and average rank. I assessed the ratio of IDR publications output for tier 1 institutions and found that it matched their overall level of IDR commitments in their strategic plans. While tier 3 strategic plan text did have examples of "IDR talk", the quantitative analysis shows that actual IDR publication output of tier 3 institutions is lower when compared to tier 1 and 2.

Overall, for the year 2018, quantitative analysis using the WoS publication output data show that total volume of IDR publications is highest for tier 1 institutions. However, this study highlights that when the ratio of IDR-SC³ is calculated, tier 2 institutions have the highest ratio

³ According to WoS, IDR-SC is measured using two or more subject categories. See page 43 for full definition.

of IDR-SC publications. This means that while IDR publications are produced by institutions from all tiers, tier 2 institutions have the highest proportion of IDR publications that are categorized as having two or more subject categories by the Web of Science database.

Chapter 5: Implications

Findings of this study, guided by the framework of Boundary-Spanning and the theory of middle status conformity provide several practical implications for university leaders who want to promote or increase IDR participation. Through the first part of this study, text analysis of strategic plans demonstrates that there is value in strategic recruitment of faculty and students – particularly postdoctoral students and international scholars – from different backgrounds to facilitate collaborative research practices. Several examples of global connections with faculty and researchers from other universities and industry experts were prioritized by universities to promote interdisciplinary projects and develop solutions for challenges that no one discipline can alone address. There are also numerous examples of universities committing to developing IDR centers that would be dedicated spaces, focused on developing specific types of IDR. Campuses that already had established IDR centers proposed further commitments for these spaces to provide their university members with an opportunity to learn from different fields. Interdisciplinary centers are found to be especially useful in promoting inclusive learning to develop IDR projects that are collaborative. Allocating space for interdisciplinary research centers within university campuses and ensuring that they are easily accessible by all colleges is also key to providing exposure to different disciplines and generating new research ideas that combine knowledge from various departments. In many cases, these centers also provide seminars and workshops open to the whole campus to generate cross-disciplinary discussions.

Aside from implications for university leaders to consider, this study also points to the prevalence of IDR practices from around the world. Universities across six global regions state at least one IDR specific goal that they are working towards. This signals that university members value IDR and have realized its impact on our ability to tackle global challenges collectively.

Another implication for leaders and education policy makers to consider is to promote more ways that IDR can bring together the arts and sciences as well as communities that are at the margins of society. As tier 3 institutions showed fewer commitments for IDR, this could mean that it is either not prioritized as a university goal or that it is viewed as a practice that only the elite universities can successfully execute given that IDR requires more resources. This study sheds light on the multifaceted cross-disciplinary activities a university can commit to given its location, size and resources to spur future projects that are interdisciplinary. For tier 3 institutions seeking to increase IDR commitment, perhaps it may not make sense to commit to building research centers, instead engaging their community in campus seminars and research projects could be the start of pushing the boundaries of knowledge production.

Text analysis for boundary spanning categories also reveal that top performing institutions for collaborative publications also tend to have high *spearheading* and low *lubricating* boundary spanning activities. These behaviors help to explain the high collaborations we see in tier 1 and 2 subject network maps (fig.5.1 and 6.1). It could be argued that these institutions leverage their resources and funds to develop both local and global networks to ensure that the members of their institution can have opportunities to interact with members from external organizations. Further, the absence of *lubricating* boundary spanning in tier 1 institutions could indicate that they have overtime worked on building trust between departments and colleges internally so that they can overcome any preconceived notions or hesitations of

working with each other on collaborative projects. Whereas, institutions with high *lubricating* or *reconciling* boundary spanning activity and low collaborative publications could indicate that the leaders of their institution need to focus on initiatives that will alleviate biases so that faculty and students from different colleges can work together. Leaders of tier 3 institutions may also need to engage in more effective *reconciling* boundary spanning activities so that external members can understand the strengths, goals and abilities of members within their institution. Before engaging in *spearheading* boundary spanning activities such as developing global connections, they may choose to prioritize engaging in *lubricating* and *reconciling* boundary spanning to resolve communication, infrastructure and internal challenges associated with working across disciplines.

The analysis conducted to understand middle status conformity reveals universities at the top have a lower ratio of IDR-SC publications when compared to tier 2 universities. Tier 1 universities can do more to leverage their resources, such as international partnerships, networks with global scholars and funding, to produce more interdisciplinary publications or commitments to match tier 2 universities. When universities stimulate IDR, they are not only creating unique academic opportunities but such initiatives have a deeper philosophical meaning in that they carry the potential of bringing people from various backgrounds, distant, remote and rural spaces together to engage in research and discourse that improves our collective lives.

This global study of university IDR commitments using WoS data also reveals that there are few instances of disciplines from the sciences combining knowledge from other non-traditional science disciplines. There were a handful of instances where publications had two or more subject categories to show that it combined knowledge from a social sciences field and a traditional science field. However, it is possible that this finding could be attributed to the type of

database used for this study since WoS is a predominantly science focused database. The fields leading IDR publications are Material Sciences, Physics and Engineering.

If we want to see IDR projects using a wider range of disciplines, I believe university leaders should reinvent university discipline networks to make room for interdisciplinary projects of all shapes and sizes. When universities establish more connections between disciplines, I call this network, an *Internal Discipline Symbiosis* (IDS). In the study of biology, symbiosis is achieved when two different organisms come together to form a mutually advantageous relationship. When universities facilitate more connections between disciplines within the institution, I would refer to this as a high IDS environment. Such an environment is beneficial to an institution because it brings scholars of different disciplines with different perspectives together to discuss ideas that lead to unique solutions to problems facing our current society. To extend this concept further, university leaders can implement boundary-spanning activities to increase a university's connections with members of external institutions and their discipline network. I call this, *External Discipline Symbiosis* (EDS). When an institution's internal disciplines can connect with members of external institution's discipline network, there is greater opportunity for researchers to receive exposure to other scholars and their research initiatives. Successful promotion of IDS and EDS environments positions an institution at a greater advantage of producing collaborative and interdisciplinary projects.

Limitations and Future Directions

Several limitations to this present study steer future projects with similar goals to increase knowledge about IDR. First the criteria to only accept institutions that appeared in all three ranking lists meant that there is no representation from South American institutions. This also

stems from fundamental challenge with ranking lists as their measures tend to serve as globally recognized norms which are imposed on universities from various countries with different educational systems. The ranking lists do not necessarily take a country's education system into consideration when it comes to developing its ranking methodology. Another reason several plans were rejected from this study was due to their strategic plans being published in foreign languages. Enlisting professional translators would have proved to be cost ineffective at this stage. In the future, similar studies with greater regional representation could be tackled by larger teams of researchers who have multiple language skills or with support from a grant.

Due to study design, it also meant having lower representation of university strategic plans from Africa and the middle east. In future studies of similar scope, perhaps additional sources of data such as annual reports, president speeches, budget reports and college specific strategic documents could be analyzed to get a deeper understanding of how much IDR or transdisciplinary activity is taking place between colleges as opposed to universities. This would allow for factors like size and age to not be as important when conducting comparison studies. The strict criteria in this study also means that there is a low representation of tier 3 universities. As the ranking lists' methodologies form their own global norm of what should be considered as a highly ranked institution, universities from several regions may not be presented as per each list's, often arbitrary, criteria. It was imperative to include universities present on all three ranking lists and match it against the Leiden ranking so that it would yield publication data for each case. This produced an untended exclusion of institutions from tier 3 and warrants a separate investigation into how and why tier 3 institutions would want to engage in IDR.

Another limitation of this study is the strategy employed to acquire its sample: *convenience sampling strategy*. This process does not allow for sufficient representation from all

regions included in this study and did not yield a balanced representation from all ranks of universities. Future studies should investigate how collaborative publications are stimulated and supported specifically in Africa and the Middle East.

I also acknowledge that there are several limitations to using publically available databases as I have done in this study. For instance, for each variable taken from a ranking list that is a composite score like the variable for international collaborations, no raw scores are provided to show how calculations were done to provide the final score for each university. These variables were accepted by the reasonable rationales provided in the methodology section for each ranking lists' developers. An important limitation of this study is in its use of only the WoS database to identify IDR publications. This database predominantly accepts publications from the science fields which results in IDR network maps highlighting IDR in mostly science fields. To truly understand if IDR publications exist in social sciences and the arts and humanities, other databases that accept a wider range of publications from all fields could be used.

Furthermore, in future iterations of such studies, more website content analysis would be helpful to understand the different IDR commitments and outputs universities discuss. In addition to this, future studies could also examine collaborative publications from universities with IDR focused centers and universities without such dedicated research spaces. Such a study would allow university leaders to make more realistic funding commitments to developing IDR centers. Further, as Hunter and Leahey (2008) point out, examining gender differences would be critical to examining collaborative publication behavior since their study found that more men overwhelming author publications. Extending such an analysis on publications from universities

outside the U.S could reveal if there are locations that foster more women or men to work on collaborative research.

Conclusions

There are considerable arguments that state that IDR is a threat to preserving the sanctity of disciplines. There remain challenges to evaluating and assessing IDR projects as well as securing funds to conduct IDR. The Global Research Council found that grants do not always last to see an IDR project complete (Global Research Council, 2016). They also stress that it is imperative that IDR should be recognized in the same vein as traditional discipline projects. While findings from the strategic plans reveal that universities around the world express commitments to IDR and ID activities, there is little to no commitment or support in terms of fund allocation for IDR. While an overwhelming majority of world universities (81% or 170 out of 211 institutions) express through their strategic plans goals to stimulate IDR through research centers, engage in global partnerships with international scholars, and partner with local and global industry experts. There is no evidence from strategic plans to show how institutional leaders would manage or assist in overseeing the needs of IDR projects that suffer from a shortage of resources.

This study points to the need for our higher education systems, no matter its location, to cater to a rising need for tackling the world's biggest and most complex problems through approaches that provide sustainable solutions for both their students and faculty as well as for their community. As evidenced by the rationales cited by university leaders of various ranks, IDR is fast becoming a fundamental and necessary feature of the higher education landscape. Disregarding its benefits is not only myopic but also narrows our potential for generating unique,

collective perspectives on issues that affect the world's population. Despite country level differences, leaders' express a desire to stimulate and promote IDR as it is found to be a rewarding method to nurture research creativity and promote diversity.

In response to criticism of practicing IDR, one university astutely points out that combining knowledge from two disciplines only 'strengthens and creates new opportunities for each.' A key contribution of this study is the analysis of the range of commitments to IDR provided by universities of various characteristics. They provide solutions for other universities who want to increase commitment to IDR and stimulate research projects between faculty and scholars from different disciplines. Findings also furthers our understanding of IDR and how institutional leaders can play a pivotal role in advocating for IDR not just through strategic plans but also through making connections with scholars from around the world who could collaborate with faculty and students to generate impactful publications. For instance, through IDR centers, institutions could host international scholars to present their research to campus members. Such events raise the knowledge capacity of an institution and allows for scholars to engage in dialogues that could stimulate interdisciplinary collaborative projects. Furthermore, partnerships with key industry experts was also found to support more interdisciplinary projects. Overall, university leaders should facilitate spaces where faculty and students can engage with various stakeholders of their immediate society and leverage international connections to support and facilitate IDR. As institutional leaders work to foster commitments to promoting IDR, their actions ultimately contribute to raising our collective aptitude as interdisciplinary research provides solutions to otherwise challenging problems that is beyond the scope of any one discipline.

Appendices

Appendix 1

List of Universities by region. From this list, 170 institutions mention commitments to interdisciplinary (ID) research and/or other ID activities.

Africa

1. Cairo University
2. Stellenbosch University
3. University of Pretoria

Asia

4. Chiba University
5. Chinese University of Hong Kong
6. City University of Hong Kong
7. Hokkaido University
8. Hong Kong Polytechnic University
9. Hong Kong University of Science and Technology
10. Indian Institute of Science
11. Keio University
12. Kobe University
13. Kyoto University
14. Nagoya University
15. Nanyang Technological University
16. National Taiwan University
17. National University of Singapore
18. Osaka University
19. Seoul National University
20. Sun Yat-sen University
21. Tianjin University
22. Tohoku University
23. Tokyo University of Science
24. University of Hong Kong
25. University of Tokyo
26. Waseda University

Europe

27. Aalto University
28. Aarhus University
29. Cardiff University
30. Delft University of Technology
31. Durham University
32. Ecole Des Ponts ParisTech
33. Eindhoven University of Technology
34. Erasmus University Rotterdam
35. Ghent University
36. Heidelberg University
37. Heriot-watt University
38. Imperial College London
39. King's College London
40. Ku Leuven
41. Lancaster University
42. Leiden University
43. London School of Economics and Political Science
44. Lund University
45. Maastricht University
46. Pompeu Fabra University
47. Queen Mary University of London
48. Radboud University
49. Sapienza University of Rome
50. Sorbonne University
51. Technical University of Denmark
52. Technical University of Munich
53. Technische Universitat Dresden
54. Trinity College Dublin
55. University College Cork
56. University College Dublin
57. University College London
58. University of Aberdeen
59. University of Amsterdam
60. University of Basel
61. University of Bath
62. University of Belgrade
63. University of Bergen
64. University of Bern
65. University of Birmingham
66. University of Bologna
67. University of Bordeaux
68. University of Bristol
69. University of Cologne
70. University of Duisburg-Essen

71. University of Edinburgh
72. University of Exeter
73. University of Geneva
74. University of Glasgow
75. University of Gothenburg
76. University of Gottingen
77. University of Groningen
78. University of Helsinki
79. University of Konstanz
80. University of Leeds
81. University of Liverpool
82. University of Ljubljana
83. University of Lorraine
84. University of Manchester
85. University of Munster
86. University of Oslo
87. University of Oxford
88. University of Reading
89. University of Sheffield
90. University of Southampton
91. University of St Andrews
92. University of Surrey
93. University of Tartu
94. University of Vienna
95. University of Warsaw
96. University of Warwick
97. University of York
98. Uppsala University
99. Utrecht University

Middle East

100. Amirkabir University of Technology
101. Bar-Ilan University
102. Hebrew University of Jerusalem
103. Istanbul University
104. King Abdulaziz University
105. King Saud University

North America

106. Arizona State University
107. Boston University
108. Brandeis University

109. Brown University
110. California Institute of Technology
111. Carnegie Mellon University
112. Case Western Reserve University
113. Colorado State University
114. Cornell University
115. Dalhousie University
116. Dartmouth College
117. Drexel University
118. Duke University
119. Emory University
120. Florida International University
121. Florida State University
122. George Mason University
123. George Washington University
124. Indiana University Bloomington
125. Iowa State University
126. Kansas State University
127. Kent State University
128. Massachusetts Institute of Technology
129. McGill University
130. McMaster University
131. Michigan State University
132. New York University
133. Northeastern University
134. Northwestern University
135. Ohio State University
136. Oklahoma State University
137. Oregon State University
138. Pennsylvania State University
139. Princeton University
140. Rice University
141. Rutgers, The State University of New Jersey
142. Temple University
143. Texas A&M University
144. Texas Tech University
145. Tufts University
146. University of Alberta
147. University of Arizona
148. University of British Columbia
149. University of Calgary
150. University of California, Riverside
151. University of California, San Diego
152. University of California, Santa Barbara
153. University of California, Santa Cruz
154. University of Central Florida

155. University of Cincinnati
156. University of Colorado Boulder
157. University of Connecticut
158. University of Delaware
159. University of Florida
160. University of Guelph
161. University of Houston
162. University of Iowa
163. University of Kentucky
164. University of Manitoba
165. University of Miami
166. University of Michigan
167. University of Minnesota
168. University of North Carolina
169. University of Notre Dame
170. University of Oklahoma
171. University of Ottawa
172. University of Pennsylvania
173. University of Pittsburgh
174. University of Rochester
175. University of Saskatchewan
176. University of South Florida
177. University of Southern California
178. University of Toronto
179. University of Vermont
180. University of Virginia
181. University of Waterloo
182. University of Western Ontario
183. Vanderbilt University
184. Washington State University
185. Washington University in St. Louis
186. Wayne State University
187. Yale University

Oceania

188. Australian National University
189. Curtin University
190. Deakin University
191. Flinders University
192. Griffith University
193. James Cook University
194. La Trobe University
195. Macquarie University
196. Monash University

197. Queensland University of Technology
198. RMIT University
199. Swinburne University of Technology
200. University of Adelaide
201. University of Auckland
202. University of Canterbury
203. University of Melbourne
204. University of New South Wales
205. University of Otago
206. University of Queensland
207. University of Sydney
208. University of Tasmania
209. University of Technology Sydney
210. University of Western Australia
211. Victoria University of Wellington

Appendix 2

A screenshot of the Python codes' execution that yields strategic plans' web addresses is provided below.

```

76 # pdf_url = fowlo
77 # r = requests.get(pdf_url)
78 # with open("python_logo.png", 'wb') as f:

```

PROBLEMS OUTPUT DEBUG CONSOLE TERMINAL 2: Python

```

4. https://s3.amazonaws.com/vu-news/files/20171204142850/International-Strategy-Report.pdf
5. https://tutech.de/wp-content/uploads/2018/11/Tutech_Flyer_How-to-develop-a-strategic-plan.pdf
6. https://www.cesifo-group.de/dms/ifodoc/docs/about/aboutifo/EURAXESS/HR54R_EURAXESS-Action_Plan.pdf
7. https://www.wi.tum.de/wp-content/uploads/2016/09/TUM_SoM_Strategy.pdf
8. http://www.benchmarkworks.com/wp-content/uploads/2018/02/WEST5935-LinkedInProfiles_02.pdf
9. http://www.doyoubuzz.com/var/f/w2/l0/w2l0t4_NbILnJVR36izWZP69HT0cmSwXRUdGpexhVf_master.pdf
10. https://www.wirtschaft-muenchen.de/publikationen/pdfs/Munich-City%20of%20Knowledge2005.pdf
Row IDs to collect(comma separated):
Yale University:
1. https://sustainability.yale.edu/sites/default/files/sustainability_plan_2025.pdf
2. http://environment.yale.edu/content/documents/00011710/Download-the-FES-Strategic-Plan.pdf
3. http://sustainability.yale.edu/sites/default/files/files/SOM%20Sustainability%20Action%20Plan%20-%204%2030%2015.pdf
4. https://sustainability.yale.edu/sites/default/files/sustainabilitystrategicplan2013-16_0.pdf
5. https://sustainability.yale.edu/sites/default/files/strategicplanupdatejune2011.pdf
6. https://facilities.yale.edu/sites/default/files/files/Design%20Standards/YALEFRMW.pdf
7. http://digitalcommons.law.yale.edu/cgi/viewcontent.cgi?article=1023&context=ylls
8. https://sustainability.yale.edu/sites/default/files/2016_progress_report.pdf
9. https://its.yale.edu/sites/default/files/imce/pdfs/Strategic_Plan_Final.pdf
10. https://sustainability.yale.edu/sites/default/files/files/Athletics%20Action%20Plan%20-%20FINAL%20DRAFT.pdf
Row IDs to collect(comma separated):1
East China University of Science and Technology:
1. https://www.bmbf.de/pub/China_Strategy_Longversion.pdf
2. https://www.jst.go.jp/crds/pdf/en/CN20160127_EN.pdf
3. https://www.albany.edu/~pm157/research/Technology%20Transfer%20Institutions%20in%20China.pdf
4. http://www.tillvaxtanalys.se/download/18.1af15a1f152a3475a818b62/1454505968936/China%E2%80%99s+fifteen-year+plan+for+science+and+technology-07.pdf
5. https://www.uscc.gov/sites/default/files/Research/Planning%20for%20Innovation-Understanding%20China%27s%20Plans%20for%20Tech%20Energy%20Industry%20and%20Defense%2006.pdf
6. https://www.phillydistrict30.com/s/DrexelStrategicPlan-qp06.pdf
7. https://peer.asee.org/an-exploration-on-the-reform-of-china-s-engineering-education-under-the-background-of-made-in-china-2025.pdf
8. http://library.acecondo.net/ebooks/HISTORY/Science & Technology in China_A Roadmap to 2050_Strategic_General_Report_of_the_20121130215622420.pdf
9. https://www.brookings.edu/wp-content/uploads/2016/06/29-science-technology-policy-china-campbell.pdf
10. https://www.swissnexchina.org/wp-content/uploads/sites/4/2014/07/Higher-Education-in-China-2014.pdf
Row IDs to collect(comma separated):

```

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