Investigations of Non-Vertical Collaborations by Small Firms: Two Empirical Studies

DISSERTATION

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Abstract

Small firms, a crucial segment of the US economy, face internal resource constraints that hinder their ability to survive and grow. Access to external resources through collaborations with external parties can be a viable way for small firms to overcome such constraints. While there is an abundance of literature examining vertical collaborations with customers or suppliers, non-vertical collaborations with external organizations have been under-investigated. In this dissertation, I investigate two types of non-vertical collaborations to generate insights for small firms trying to leverage external resources from non-vertical partners.

The first type is collaboration with non-profit research institutions for research and development (R&D). While accessing outside resources through external R&D initiatives paves the path to commercialization, such external collaborations heighten the risk of intellectual property (IP) leaks as proprietary knowledge becomes shared. I examine how the decision to conduct R&D projects internally or externally is determined and the factors that affect subsequent commercialization success. I assemble a unique longitudinal dataset of 1,374 SBIR/STTR awards received by 933 small firms between 2009 and 2010 for this inquiry. My analyses suggest a small firm's R&D path decision

depends on its previous success, as well as its competitors' success, but in opposite ways. I also find that possessing formal IP rights is not always beneficial. Specifically, this can decrease the likelihood of commercialization success from 12.4% to 7.0% when project novelty for external R&D projects is high, ceteris paribus. This counterintuitive finding suggests an "IP lockup" problem during external R&D initiatives.

The second type is collaborations with non-profit Business Membership Organizations (BMOs) to enable sales growth. Through a survey of 113 minority suppliers affiliated with a BMO, I find that minority suppliers can expand social networks with other minority-owned firms through participation in BMO-sponsored activities. Such participation in turn leads to greater sales growth. Moreover, participation in connect-oriented activities is more effective in expanding social networks with other minority-owned firms than participation in develop-oriented activities. Surprisingly, my analysis suggests expanding social networks with large buying corporations, through collaborations with BMOs, is generally not positively associated with sales growth, except for extremely young and small minority suppliers. Insights from this study provide practical suggestions to minority suppliers on how to participate wisely in BMO-sponsored activities for increased sales growth.

Taken together, these two empirical studies highlight unique considerations for small firms engaging in non-vertical collaborations. Moreover, my studies demonstrate potential benefits and challenges of non-vertical collaborations for small firms that warrant more research.

Dedicated to My Parents, Ying and Mingfang

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Table of Contents

Abstract ii

Acknowledgments v

Vita vi

List of Tables viii

List of Figures ix

Chapter 1: Introduction 1

Chapter 2: When Should Small Firms Conduct R&D Projects Externally? 10

Chapter 3: Connecting Small Minority Suppliers to Large Corporations through Participation in BMO-sponsored Activities 63

Chapter 4: Conclusions 104

References 111

Appendix A: Chapter 2 Subset of Interview Questions 128

Appendix B: Chapter 2 NIH SBIR/STTR Review Criteria 132

Appendix C: Chapter 2 Literature Review 134

List of Tables

Table 1 Variable Definitions and Statistical Descriptions 35

Table 2 Predicting Likelihood to Conduct R&D Projects Externally (Choose STTR Program) 41

Table 3 Predicting Likelihood of Commercialization Success 44

Table 4 Managerial Implication: When to Conduct R&D Projects Externally 59

Table 5 Variable Descriptions 79

Table 6 Sample Descriptions 80

Table 7 Example Descriptions of Connect- and Develop-Oriented Activities 84

Table 8 Participation and Relationships 91

Table 9 Relationships and Sales Opportunities 93

Table 10 Moderation Effects of Age and Employment 97

Table 11 Chapter 2 Literature Review 135

List of Figures

Figure 1 Path to Commercialization Success 16

Figure 2 Moderation Effects of Formal IP Rights: A Internal R&D Projects, B External R&D Projects 46

Figure 3 Predicted Probability of Commercialization Success with and Without Correcting for the R&D Path Decision 49

Figure 4 Post-hoc Analyses: A External R&D Projects with Low Formal IP Rights, B External R&D Projects with High Formal IP Rights, C Internal R&D Projects with Low Formal IP Rights, D Internal R&D Projects with High Formal IP Rights 51

Figure 5 Robustness Check: Alternative Measure of Commercialization Success 54

Figure 6 Types of BMO-sponsored Activities 72

Figure 7 Interaction plot for types of activities participated and relationship building 95

Figure 8 Interaction plots for employment and age on sales opportunities 99

Chapter 1: Introduction

Small firms, defined as firms with fewer than 500 employees, are the driving force of innovation and economic prosperity. However, due to a lack of internal resources and experience, small firms often face significant challenges to survive and grow. Per a 2016 Mid-year Economic Report by the National Small Business Association (NSBA), 41 percent of small firms said lack of capital is hindering their ability to grow their business or expand operations, and 20 percent said they had to reduce the number of employees as they struggle with the costs of salaries, benefits, and trainings. Cost of technology was also cited by small firms among the most important challenges to the future of their businesses.

The Small Business Administration (SBA) was created in 1953 to aid, counsel, assist and protect the interests of small business concerns. Through the years, the SBA has not only coordinated government programs and funding for small firms but has also facilitated collaborations between small firms and various organizations. Per the Small Business Act, the SBA may "make grants [for small businesses] to enter cooperative agreements with any coalition of private entities, public entities, or any combination of private and public entities; and to expand business-to-business relationships between large and small businesses" (15 U.S. code § 637 (n)(1)). After all, collaborations with external

organizations provide small firms access to external resources and experience that complement their limited internal prowess.

For decades, influenced initially by Japanese operational practices, vertical collaborations within supply chains have become popular approaches to improve cost savings and efficiency (Cao & Zhang, 2011; Malhotra, Gosain, & Sawy, 2005). Formal supplier development programs are designed in almost all large corporations for improved supply chain performance with small firms. Small firms have also been encouraged to utilize vertical collaborations with large buying or supplying corporations for mentorship and opportunities (Wee, Thoo, Sulaiman, & Muharam, 2016; also, see a literature review by Street and Cameron (2007)). However, powerful large corporations also tend to exploit small suppliers by restricting their number, the price paid to individual suppliers, and the quantity purchased from each supplier (Wyld, Pugh, & Tyrrall, 2012).

In fact, many small firms, though less advocated, also collaborated non-vertically to access external resources with such external organizations as federal agencies, non-profit organizations, universities and other research institutions, firms from different supply chains, and so on. The definition of non-vertical collaborations may vary among practitioners and researchers. In this dissertation, non-vertical collaborations are defined as commercially oriented connections between small firms and other organizations from different supply chains with the intent of accomplishing mutually compatible goals for greater success (Barratt, 2004; Simatupang & Sridharan, 2005).

Per the Institute of Supply Management (ISM), non-vertical collaboration allows firms in the same industry to share resources for cost savings and improved customer service. Such non-vertical collaborations occur in almost all aspects of small firm operations. For example, one study was found that non-vertical collaborations among firms for innovation were well developed in Italy, where small food manufacturers are mainly involved in producer consortiums (Gellynck & Kühne, 2010). Another recent study showed about 30 percent of small innovative firms had R&D collaborations with universities or public research institutions (Chun & Mun, 2012). Regarding sourcing, non-vertical collaboration in purchasing was reported as the most common used inter-firm collaboration among small firms in which they join a strategic alliance to gain bargaining power over suppliers (Ghaderi & Leman, 2013). For selling, non-vertical collaboration within supplier networks was considered to mark the emergence of a "collective strength" that improves individual small suppliers bargaining position towards their customers (Björnfot & Torjussen, 2012). Non-vertical collaborations, as such, do exist and are becoming increasingly relevant in practice.

Literature Review

Many studies on small firm collaborations did not segment in their sample whether collaborations were vertical or non-vertical (BarNir & Smith, 2002; De Jong & Freel, 2010; Dickson & Weaver, 2011; Haahti, Madupu, Yavas, & Babakus, 2005; Hoffmann & Schlosser, 2001; Miles, Preece, & Baetz, 1999; Nakos & Brouthers, 2008; Spriggs, Yu, Deeds, & Sorenson, 2013; Thorgren, Wincent, & Boter, 2012; Welbourne & Pardo-del-

Val, 2009; Yang, Zheng, & Zhao, 2014). Instead, they investigated impacts of various success factors on external collaborations conducted by small firms regardless of partner type. The literature also includes studies that do not discuss specific insights with regard to non-vertical collaborations even when such collaborations are modelled in analyses (Arita, Fujita, & Kameyama, 2006; M. Freel, 2000; M. S. Freel & Harrison, 2006; Lee, 2007; Okamuro, 2007). For instance, a study of regional small Japanese firms suggested that non-vertical collaborations have a more positive influence on firm growth than vertical collaborations (Arita et al., 2006). This study did not investigate further as to why this difference exists. Below, I review literature that investigated specific issues related to non-vertical collaborations.

Golden and Dollinger (1993) defined three types of non-vertical collaborations: confederations are for firms that compete with each other but maintain some contractual functional activities (like advertising and shipping) in common; agglomerate collectives are for firms that compete within the same industry but have no contractual "business" arrangements like Cartels and trade organizations; organic collectives are for firms that engage in traditional networking such as board memberships or other voluntary organizations. Later, researchers also extended the types of non-vertical partners beyond firms to include organizations like government and research institutions (J. Chung, Bae, & Kim, 2003; Sadler-Smith, Gardiner, Badger, Chaston, & Stubberfield, 2000). In this dissertation, non-vertical collaborations are categorized into two primary types: one-to-

one collaboration (with research institutions, competitors, and government) and collaboration with membership-based organizations.

Small firms may establish one-to-one collaborations with non-vertical partners. Forrest (1990) discussed qualitatively how small technology-based firms may choose between non-vertical collaborations with research institutions, other small firms, or large firms for innovation. One key note from this study is that the strength of these small technology-based firms often lies in their technological prowess and technology leadership. The choice of collaborations thus depends upon the firms' overall growth strategy and management of competition. Another study suggested a small hotel's choice to develop cooperative relationships with other small hotels also depend on internet usage and the level of competitive moves (Domke-Damonte & Levsen, 2002). In a case study on small firms in the information technology and telecoms industry, findings suggested small firms can balance their relationship with large, powerful competitors through development of alliance portfolio management capabilities (Bengtsson & Johansson, 2014). Researchers also explored other specific factors influencing the success of non-vertical collaborations. Chung, Bae, & Kim (2003) showed that usage and performance influences of vertical and non-vertical collaborations may vary across technology development stages and research innovativeness. Specifically, non-vertical collaborations are more favored at later technology development stages and with a higher level of innovativeness. Leiponen & Byma (2009) found empirical evidence that partner types greatly influence the choice of intellectual property strategy for small firms. Similarly,

incoming spillovers and appropriability were found to be crucial factors in determining R&D collaborations for smaller firms, especially in cooperation with research institutions and universities (Chun & Mun, 2012). Findings from this stream of literature highlight the tension between access to external resources and preservation of competency when small firms collaborate non-vertically. Further investigations into how small firms can manage this tension during non-vertical collaborations are needed.

Another stream of literature on non-vertical collaborations by small firms discusses issues related to collaborations with membership-based organizations where various parties come together in collections, often with the intent to improve joint power. Qualitative studies have observed many examples of such non-vertical collaborations. For instance, Sadler-Smith et al. (2000) found small firms in southwest UK collaborate with each other along with universities for joint learning. Similar collaborative membership organizations were also observed qualitatively for joint environmental management (Ammenberg & Hjelm, 2003), joint consulting (Q. Chung, Luo, & Wagner, 2006), and innovation (McAdam, McAdam, Dunn, & McCall, 2014). Research has also explored influences on firm performance from such collaborations. Small firms allied in some cooperatives for e-commerce adoption, for example, seemed to perceive fewer problems; but, at the same time, they perceive no additional benefits (MacGregor, 2004; MacGregor & Vrazalic, 2005). The researchers did not provide further suggestions regarding the factors that can improve performance. Potential relevant factors were later explored through a survey of Japanese cross-industry groups, which showed that dense

communication and a high level of commitment among members are correlated with initiating joint product development (Fukugawa, 2006). However, how dense communication and high level of commitment can be achieved remained unanswered. In summary, previous literature has shown that non-vertical collaborations are adopted by small firms in various forms and for various motivations. The unanswered question is how small firms can manage such non-vertical collaborations for greater success. Regarding one-to-one collaborations, the challenge is how small firms can manage the balance between access to resources and preservation of their own competency. Regarding collaborations with membership-based organizations, the question is how small firms can best exploit their membership for success. This dissertation thus aims to fulfill this literature gap and provide insights to how small firms can overcome challenges for success when managing their non-vertical collaborations.

Dissertation Research Overview

This dissertation aims to expand theoretical and practical understanding of non-vertical collaborations for small firms. Specifically, it intends to understand and propose solutions to operational challenges faced by small firms when collaborating non-vertically. In this dissertation, I report the results of two empirical studies investigating small firms and non-vertical collaborations. My first study (Chapter 2) examines collaborations with non-profit research institutions in the process of research and development (R&D). I first identify drivers of the decision to conduct non-vertical R&D collaborations given different motivations and corresponding operational challenges from carrying out the

R&D initiatives. With the knowledge of collaboration drivers, I then examine a trade-off between access to external resources and the costs of intellectual property (IP) protection faced by small firms when collaborating non-vertically. The findings from this study test the applicability of tenets from the resource based view of the firm (RBV) and from transaction costs economics to the contexts of non-vertical collaborations between small firms and research institutions.

My second study (Chapter 3) examines collaborations with non-profit Business Membership Organizations (BMOs) for minority suppliers to grow sales. This study is carried out with a sample of minority suppliers in collaboration with the Ohio branch of the National Minority Supplier Development Council (NMSDC). Per NMSDC president, most of the minority-owned businesses that NMSDC represents, including Asian-, African American-, Hispanic- and Native American-owned enterprises, are mostly small firms with an average of 25 employees. I first examine the effects of minority suppliers' participation in BMO-sponsored activities on expanding social networks with other minority-owned firms and with large buying corporations and the consequent effects on their sales growth. I then examine whether participation in connect- vs. develop-oriented activities moderates the effects of participation on expanding social networks. Insights from this study provides practical suggestions to minority suppliers on how to participate effectively in BMO-sponsored activities for increased sales growth, as well as recommendations for BMOs.

In summary, motivated by the practical relevancy and lack of empirical research related to non-vertical collaborations for small firms, my dissertation investigates two types of non-vertical collaborations (small firms with research institutions regarding R&D and small minority suppliers with BMOs regarding sales growth). Findings from these studies contribute towards a theoretically holistic understanding of non-vertical collaborations for small firms and generate practical insights as to unique operational challenges small firms face in these settings. I elaborate on these, as well as future research directions, in Chapter 4.

Chapter 2: When Should Small Firms Conduct R&D Projects Externally?

Introduction

Small firms, defined as organizations with fewer than 500 employees, are the innovation engines of today's economy. Compared to larger firms, they have significantly higher R&D productivity, especially in the science and technology industry context (Breitzman & Hicks, 2008). They also have limited access to capital and other resources, which can be a challenge when developing and transforming their innovative ideas into commercially successful products. One such example is Modista, a startup that built an impressive e-commerce website based on an object recognition technology (Geron, 2011). Based on industry reports, Like.com – a larger and venture capital-backed firm – had a similar, arguably inferior product offering but owned a patent on its underlying technology. Like.com eventually leveraged its patent to shut Modista down.

The Like.com/Modista case illustrates two key challenges common to small firms. First, and most critically, Modista was unable to legally protect its intellectual property (IP). Second, the company lacked the adequate financing to obtain external expertise for website improvements, unlike its competitor. Based on 2015 NSBA Year-End Economic Report, more than 27% of U.S. small firms were unable to receive adequate financing. In fact, only 1% of small firms attracted external funds from venture capitalist or angel

investors. Thus, these firms must access external talent, equipment, and facilities through external R&D projects, defined here as activities wherein most value creation (e.g., product design and testing and process development) occurs in collaboration with a research institution. Science and technology firms increasingly rely on external partners to develop core technologies because a clear majority of relevant knowledge resides in nonprofit research institutions such as universities (Motohashi, 2005). For internal R&D projects, by contrast, a clear majority of value creation occurs within firm boundaries, with only limited external interactions.

While small firms access new resources through external R&D projects, they also risk IP leaks. And with fewer complementary assets such as marketing and manufacturing savvy, firms that failed to protect their IP are likely to lose against large, established firms (Coff, 1999). Furthermore, the risk of IP leaks can increase along with project novelty, defined as the degree to which the innovation is new and discontinuous from existing technologies (Anderson & Tushman, 1990; Ettlie, Bridges, & O'keefe, 1984; Henderson & Clark, 1990). Research shows firms can reduce these leaks by relying on formal IP rights (Graham, Merges, Samuelson, & Sichelman, 2009) or any legal means they have to negotiate for and prove invention ownership (e.g., patents, copyrights) (Reitzig & Puranam, 2009). Obtaining these rights, however, might be expensive, which in turn increases small firms' coordination costs. Therefore, for small firms to succeed with external R&D projects, they must manage the tradeoffs between the need for external resources and the risk of IP leaks.

Our research seeks to understand this issue by asking the following two questions: 1) *what factors affect small firms' R&D path decision (i.e., their decision to involve external partners or conduct R&D internally)?* And 2) *what factors affect small firms' commercialization success considering the R&D path decision?* We define commercialization success as the extent to which a firm can launch products from its innovation (Gatignon, Tushman, Smith, & Anderson, 2002; Mansfield & Wagner, 1975). Previous studies on R&D path decisions (Arora, Belenzon, & Rios, 2014; Cassiman & Veugelers, 2006) have primarily focused on large, resource-rich firms likely less susceptible to resource constraints and IP issues. Some studies have examined IP-related issues at small firms (Gans, Hsu, & Stern, 2000; Huang, Ceccagnoli, Forman, & Wu, 2013), but they focus on R&D path decisions at later, post-product development innovation stages. In addition, previous studies have failed to simultaneously estimate R&D path decisions and commercialization success, leading to potentially biased conclusions induced by sample selection and endogeneity.

We investigate these research questions by assembling a unique longitudinal dataset of 1,374 National Institutes of Health (NIH) Small Business Innovation Research (SBIR) and, Small Business Technology Transfer (STTR) Phase I awards that 933 small medical research firms received in 2009 and 2010. Our estimation technique uses the generalized Heckman selection model (Heckman, 1979), which accounts for sample selection and endogeneity issues. With respect to our first question, we used arguments from the learning myopia (March, 1991) and vicarious learning literature (Baum, Li, & Usher,

2000) to hypothesize that a small firm's R&D path may depend on its previous success – and that of its competitors. Our analyses suggest these two factors affect small firms' R&D path decisions, but in opposite ways. Specifically, the average likelihood a small firm will conduct R&D projects externally increases from 11.8% to 27.4% when it has been successful with such projects in the past, ceteris paribus. That likelihood falls from 18.7% to 10.4% when its competitors have achieved success by doing so, ceteris paribus. Small firms' likelihood of conducting internal R&D projects has a similar relationship with previous success but no significant relationship with competitors' success. Together, these findings suggest small firms react differently to their own previous success than to competitors' when making R&D path decisions, in direct contrast to arguments from the vicarious learning literature.

Regarding our second research question on commercialization success, our analyses suggest possessing formal IP rights is not always beneficial. Specifically, we find this drops the likelihood of commercialization success from 12.4% to 7.0% at high project novelty for external R&D projects, ceteris paribus. This counterintuitive finding is because small firms are likely to enter "IP lockup" mode and not share important technical knowledge during external R&D activities. The results also suggest the initial R&D path decision, formal IP rights possession, and degree of project novelty interact in interesting ways to affect commercialization success. Specifically, counterfactual analysis shows that small firms at high project novelty may be better off conducting R&D projects internally, regardless of formal IP rights. At low project novelty, however, small firms

with formal IP rights may conduct R&D projects externally. Finally, our results are robust across several different operationalization of variables. Taken together, our findings offer new insights on how small science and technology firms make R&D path decisions.

Background

Small Business Industry

Coordinated by the United States Small Business Administration (SBA), the highly competitive SBIR and STTR programs require the NIH to set aside a certain portion of its R&D budget to support domestic small-firm innovation. To better understand these programs, we examined the program policies and interviewed eleven research applicants (some of them also served as NIH reviewers) and three NIH administrators (e.g., program coordinator, Office of the Director). Appendix A contains a subset of questions used during these interviews. This preliminary screening offered rich insights on the SBA context, which we chose for this research based on the following observations.

First, U.S. government funding plays an increasingly important role in fueling small-firm innovation. SBIR and STTR program funding in 2013 exceed $2.1 billion[1] and encompassed 5,204 grants, compared to 218 venture capitalist or angel investor seed-stage deals. Second, the nature of SBIR and STTR programs allow for observation of small firms' R&D path decisions. Per SBA study, *Small Innovative Company Growth:*

[1] Statistics for SBIR&STTR program are available from SBA analytical dashboard (https://www.sbir.gov/analytics-dashboard?view_by=Year); statistics for seed capital from venture capital are available from PricewaterhouseCoopers/National Venture Capital Association MoneyTree™ Report (https://www.massmedic.com/wp-content/uploads/2014/03/PwC-Medtech-Presentation.pdf).

Barriers, Best Practices, and Big Ideas, both programs help small firms overcome resource scarcity by funding early R&D development stages. The application and evaluation process is identical for SBIR and STTR programs, except for the R&D path. The SBIR program requires small firms to conduct more than 70% of R&D project activities internally, while the STTR program requires small firms to partner with a non-profit research institution (NIH guide 2013). Indeed, only a small portion of SBIR-funded R&D activity (≤33%) can be outsourced, and based on our interviews this work often is transactional and structured under a fee-for-service arrangement. Based on a 2016 study by the National Research Council (NRC), the university connection, by comparison, was much deeper and richer for STTR projects. Finally, the competitive funding process ensures awarded SBIR and STTR projects are comparable, which helps isolate the decision to the R&D path.

The funding process for the SBIR and STTR programs flows as follows. At the beginning, small firms submit their proposals to either program. The NIH's Center of Scientific Review then assigns each proposal to its institute centers (IC) and their study sections, where lead researchers recruit the reviewer panel. This panel then assesses both SBIR and STTR proposals, starting by independently scoring each proposal based on five criteria: significance, investigator, innovation, approach, and environment (Appendix B provides more NIH criteria descriptions). A peer review panel meeting then finalizes the proposal's overall impact score, after which the IC director makes the funding decision based on its percentile ranking. As the process is highly competitive and structured, all

Phase I SBIR and STTR projects are initially comparable in terms of scientific merit and commercial promise, which helps reduce uncontrolled disturbances to final R&D success. Based on the above consideration, we believe the SBIR and STTR programs serve as an excellent setting for our study.

Figure 1 presents success rates for SBIR/STTR awards along the path to commercialization success. The program consists of three phases, where Phase I awards fund feasibility study and Phase II awards fund further technology development. The firm then must work to attract venture capital for commercialization. Of all Phase I awards between 2000 and 2013, only 27% reached commercialization. This success rate increases dramatically, however, among Phase II awards (284 out of 384 or 74%), suggesting that receiving Phase II funding is a strong signal of final commercialization success. In this study, we focus on the R&D path decision and its influences for the Phase I awards, which are R&D projects at their very early stages.

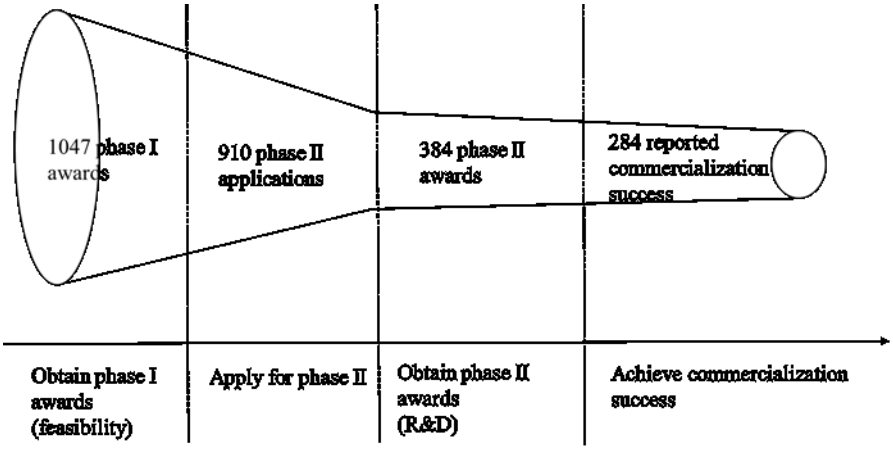


Figure 1 Path to Commercialization Success

R&D Path Decision

Scholars in R&D and innovation management have extensively studied how firms make R&D path decisions (Alcácer & Zhao, 2012; Arora & Gambardella, 1990; Arora & Gambardella, 1994; Lavie & Rosenkopf, 2006). Researchers also have examined how this decision affects R&D performance (Belderbos, Cassiman, Faems, Leten, & Van Looy, 2014; Dechenaux, Goldfarb, Shane, & Thursby, 2008; Gesing, Antons, Piening, Rese, & Salge, 2015; Hsu, 2006; Okamuro, 2007; Zahra & Nielsen, 2002). Appendix C summarizes previous studies. We review the existing literature, identify literature gaps, and discuss how our study attempts to address them.

Inferences on how firms make R&D path decisions originate mostly from studies of larger organizations. Factors shaping their decisions include internal resources and organizational structures (Arora & Gambardella, 1994; Arora et al., 2014; Lavie & Rosenkopf, 2006) and environmental characteristics (Alcácer & Zhao, 2012; Pisano, 1990; Zhao, 2006). Generalizing these conclusions to smaller firms, however, is problematic because of key differences. Larger firms, studies have found, have a greater incentive to conduct R&D projects externally because they – unlike smaller firms – have adequate resources (e.g., patent officers, technology entrepreneurs, process technology) to manage associated coordination issues (Sinha & Cusumano, 1991). Small firms, by contrast, may be comparably more influenced by behavioral factors because a single individual or small group – typically the CEO or owner – often make strategic decisions

(Cooper, 1981; Ling, Simsek, Lubatkin, & Veiga, 2008). Unfortunately, previous studies shed little light on how these issues affect firms' R&D path decision.

There do exist a few studies that have focused specifically on small firms' R&D path decisions. For example, formal IP rights possession was found to increase the likelihood of collaboration with larger companies (Gans et al., 2000; Huang et al., 2013), though this occurs at later innovation-cycle stages amid lower uncertainty. Chun and Mun (2012) argued for legal IP rights as an effective driver for R&D cooperation with universities, but their industry-level measure of this factor turned out to be insignificant. Also, small firms with venture capital backing have been deemed more likely to conduct external R&D projects (Hsu, 2006). Inferences from these studies, however, were all made at the aggregate firm level and may not apply to individual project decisions. As small firms evolve, their R&D path decisions may depend on their previous experience and competitors' actions as well as certain project-specific factors. Our knowledge on the project-level decisions remains underdeveloped, a gap we address in this study.

Factors Affecting R&D Project Performance

A number of studies have identified factors affecting commercialization success (Arora et al., 2014; Gesing et al., 2015; Hsu, 2006; Rothaermel & Alexandre, 2009; Zahra & Nielsen, 2002). One stream of literature on this topic argues from a resource-based perspective that high-novelty projects can leverage external resources for increased success (Rothaermel & Alexandre, 2009). A parallel stream, using a transaction cost perspective, argues that small firms can struggle to manage external R&D projects due to

the limited bargaining power of minimal manufacturing or scale-up resources (Arora & Ceccagnoli, 2006). Consequently, these firms may not be able to derive value from their external R&D projects and may even risk losing them to their partners.

It is important to note that the above insights come from research on for-profit external partners. Working with research institutions presents unique challenges few studies have explored. One such challenge is whether to protect or publish IP generated through collaborative efforts (Belderbos et al., 2014; Zahra & Bogner, 2000). In a case study of Siemens and its university partner, managers were found to spend the initial years monitoring PhD students involved in R&D activities to ensure they progressed consistent with company innovation processes (Cui, Loch, Grossmann, & He, 2012) – in other words, that they were not leaking IP. Without accounting for such IP conflicts, small firms are at risk of making incorrect R&D path decisions.

Finally, most existing research when evaluating performance has failed to consider the selection bias the R&D path decision may introduce. Okamuro (2007), for example, found that implementing a fair rule of outcome sharing between partners is positively associated with success for small firms, yet this conclusion is based on a sample of firms that conducted external R&D. These firms could have chosen their path under existing fair agreements with their partners, exaggerating the positive results. Ignoring sample selection and endogeneity issues, indeed, can falsely exaggerate or underestimate factors driving performance, yet no existing studies to our knowledge have addressed either. Our

study aims to fill this literature gap by using a simultaneous model estimating the R&D path decision together with factors influencing commercialization success.

Theory and Hypothesis Development

Own Previous Success with External or Internal R&D Projects

We argue for the following reasons that small firms' previous success influences their R&D path decisions. An individual, typically the CEO or owner, often makes strategic decisions in these firms (Ling et al., 2008). Learning myopia arguments (Duncker & Lees, 1945) based on the psychology literature suggest that when individuals succeed with certain strategy, they are more likely to repeat it to solve new problems and avoid alternative approaches. Audia and Goncalo (2007), for instance, found that successful inventors in the disk-drive industry focused more on incremental innovation in previously successful areas, ignoring other divergent ideas (i.e., radical innovation). This learning myopia also has applications at organizational-level decision making (Levinthal & March, 1993; March, 1991). Therefore, if a small firm has a successful history of conducting R&D externally (or internally), it is more likely to rely on this experience when making an R&D path decision.

Second, required internal R&D resources may differ from those for external R&D. From the asset specificity argument (Williamson, 1996), high switching costs of acquiring new resources can drive these firms to align with previously successful strategies. For instance, studies show that small firms during external collaboration invested more on resources such as value chain integrators and boundary spanners able to coordinate

research and design work (Kale & Singh, 2007; Parker & Anderson, 2002). In contrast, the same firm during internal R&D may develop other capabilities by hiring more technological experts and sales and marketing personnel (Romijn & Albaladejo, 2002; Yeoh & Roth, 1999). Switching between these decisions, therefore, requires additional resources typically unavailable to small firms. As an illustrative example, consider Biosurfaces Inc., which historically has developed a nano-fibrous polyester cuff in collaboration with Beth Israel Deaconess Medical Center. Biosurfaces mostly relied on Beth Israel for costly electrospinning technology, thus conducting similar R&D projects internally would require a significant investment. Considering this, firms unsurprisingly prefer to a successful previous strategy. We summarize this through the following hypothesis.

Hypothesis 1 (H1): A small firm's success in external (internal) R&D projects is positively (negatively) associated with its decision to conduct new R&D projects externally, ceteris paribus.

Competitors' Previous Success with External or Internal R&D Projects

Competitors' previous success also may be relevant in small firms' R&D path decisions. Learning from competitors – defined as other small firms from similar industry settings in nearby regions facing similar problems (Baum et al., 2000; Ingram & Baum, 1997) – has been empirically observed at both the individual and organizational levels (Baum et al., 2000; Baum & Dahlin, 2007; Greve, 2000; KC, Staats, & Gino, 2013; Kim & Miner, 2007). Research shows, for example, that firms are more likely to follow industry

competitors into new markets (Henisz & Delios, 2001), especially when they lack experience. Many small firms are relatively new, with limited to no experience (based on 2013 U.S. Census Bureau statistics, 57.7% of small firms are less than five years of age), thus they are more likely to learn from their competition on R&D path decisions. The literature, however, differs on how this knowledge comes into play.

One stream of research suggests firms often replicate neighboring firms' successful decisions due to geographic closeness and structural similarities (Haunschild & Miner, 1997; Kim & Miner, 2007). Social cognitive scholars refer to this as vicarious learning, or social learning from imitation (Bandura, 1962). This is especially true for smaller firms with limited resources poised to converge on competitors' success (Zahra & Filatotchev, 2004). Small high-tech firms perceiving higher strategic uncertainty, for instance, were found to rely more on external information sources. This is because they lack the internal resources to adequately evaluate the strategic environment (McGee & Sawyerr, 2003). Institutional theorists also have suggested that resource-constrained firms frequently engage in mimetic isomorphism (Haveman, 1993; Powell & DiMaggio, 2012). These firms are likely to conduct outcome imitation, replicating the success of others (Haunschild & Miner, 1997). Lu (2002), for example, found that small firms were more likely to establish wholly owned foreign subsidiaries over joint ventures if more industry competitors had made the same choice. All these arguments suggest small firms may replicate their competitors' successful strategic actions.

The extant literature also sheds light on how firms may, by contrast, avoid competitors' success strategy. When nearby small firms are successful with external R&D, they typically have long-term relationships with external research institutions (Laursen & Salter, 2006). This can reduce or eliminate similar opportunities for other firms. On the other hand, when neighboring firms have a track record of internal R&D, competing firms may choose to avoid it and access research institution resources untapped by competitors. Young, small semiconductor manufacturers, for example, were found to perform better with external alliance partners than otherwise comparable firms lacking such partners (Stuart, 2000). These arguments suggest a small firm is more likely to avoid replicating competitors' strategies. Given the arguments above, we propose two competing hypotheses:

Hypothesis 2A (H2A): Competitors' success in external (internal) R&D projects is positively (negatively) associated with small firms' decision to conduct new R&D projects externally, ceteris paribus.

Hypothesis 2B (H2B): Competitors' success in external (internal) R&D projects is negatively (positively) associated with small firms' decision to conduct new R&D projects externally, ceteris paribus.

Factors Affecting Commercialization Success

Studies have found that the novelty of the development effort is an important predictor of commercialization success (Carrillo, Druehl, & Hsuan, 2015; Garcia & Calantone, 2002). Moreover, research suggests that the payoff from collaboration depends on project

novelty and the choice of interfirm governance mode (Gesing et al., 2015). Based on this evidence, we argue for the following relationships between project novelty and commercialization success depending on R&D path, a decision made even before choosing governance mode.

When small firms conduct R&D internally, we argue that their likelihood of commercialization success increases with project novelty. For low-novelty projects, the firm likely faces competition from similar products or solutions. Working alone with low production capabilities and a lack of complementary assets, these firms stand less of a chance against large, established competitors (Damanpour, 1992; Teece, 1986). As project novelty increases, they can differentiate their product and service offerings from the market's limited comparable products. As the source of novel products, small firms have a greater chance of success through first-mover advantage. Thus, commercialization success increases with project novelty for internal R&D projects.

When small firms conduct R&D externally, we argue their likelihood of commercialization success decreases with project novelty. From a resource-based view, collaborative R&D can equip a small firm with additional resources (Arora & Ceccagnoli, 2006) such as lab experiments, clinical trials, and subject recruiting. Access to these resources better positions small firms to face established competitors for later-stage commercialization success. From a transaction cost perspective, however, collaborative R&D for small firms is associated with costs (Bhaskaran & Krishnan, 2009), particularly higher coordination costs during early-stage innovation activities

(Okamuro, 2007). Collaboration with research institutions could be even more costly due to distinct culture and goals small firms and research institutions possess (Bruneel, d'Este, & Salter, 2010).Therefore, the likelihood of commercialization success also can depend on the cost of coordination.

Depending on the project novelty level, in fact, the relative negative effects of coordination cost for external R&D may even counter the positive benefits of accessing external resources. At low project novelty, small firms can exploit external resources with relatively low coordination costs, given low uncertainty in product development. By contrast, engaging external partners at high project novelty can heighten the focal firm's coordination effort due to many potentially cost-increasing factors: design cycles, the time until the final design is frozen, the need for prototype building, the extent of testing, and the intensity of communication (Lakemond, Berggren, & Weele, 2006). Costs might become so overwhelming at high project novelty that small firms may not be able to keep up, leading to failures in the path to commercialization. Thus, commercialization success decreases with project novelty for external R&D projects. In summary, we propose the following hypothesis:

Hypothesis 3 (H3): Commercialization success increases (decreases) with project novelty for internal (external) R&D projects.

Research also suggests small firms are more likely to lose to established competitors when unable to protect their IP (Teece, 1986). Without sufficient marketing and manufacturing expertise, these firms' capability to protect their new products and

processes through formal IP rights, we argue, moderates the relationship between project novelty and commercialization success. Researchers have found formal IP rights block competitors from mimicking the technology for similar products (Blind, Cremers, & Mueller, 2009; Cockburn & MacGarvie, 2011). To maintain first-mover advantage as project novelty increases, this becomes even more crucial. For internal R&D activities, losing proprietary knowledge in the absence of IP protection can create a huge challenge. Here, small firms rely primarily on constrained internal resources to compete against imitators who release similar products by stealing leaked IP. A firm with a history of formal IP rights has the experience and knowledge to legally protect its innovation and is resultantly more likely to follow suit with new projects. Therefore, for internal R&D projects, the positive association between project novelty and commercialization success is more accentuated when firms previously possessed formal IP rights.

Formal IP rights also have been used to settle IP issues and obtain better terms during negotiations with external parties (Cohen, Nelson, & Walsh, 2000). Thus, firms conducting external R&D can leverage formal IP rights to reduce coordination costs that arise due to conflicting objectives. Research institutions by nature are more inclined to publish and share newer knowledge, in stark contrast to small firms' goal of protecting knowledge (Van de Ven, Andrew H & Johnson, 2006). Indeed, based on an extensive case study of U.S. industry-university collaboration, most major disputes arose from concerns over confidentiality and preventing competitors from accessing potentially important information and technologies (Kneller, Mongeon, Cope, Garner, & Ternouth,

2014). To address these concerns, firms often must negotiate multiple IP agreements with universities, which can be time-consuming (in one case, the first agreement alone took more than a year). Formal IP rights possession can simplify the negotiation process and ensure knowledge disclosed during collaboration is protected, which in turn can alleviate conflicts and foster commitment from both parties (Gans, Hsu, & Stern, 2008). Such commitment is even more crucial at high project novelty because increased complexity and uncertainties often increase the need for coordination (Mihm, Loch, & Huchzermeier, 2003). In the presence of formal IP rights, therefore, the negative association between project novelty and commercialization success can be attenuated for external R&D projects. Altogether, we propose the following relationship between project novelty and formal IP rights for internal and external R&D projects' commercialization success.

Hypothesis 4(H4): For internal R&D projects, formal IP rights moderate the relationship between project novelty and commercialization success such that the positive association becomes more positive (accentuated) as formal IP rights increase.

Hypothesis 5(H5): For external R&D projects, formal IP rights moderate the relationship between project novelty and commercialization success such that the negative association becomes less negative (attenuated) as formal IP rights increase.

Empirical Methodology

Sample and Data Collection

We used multiple sources to compile the data for our study. First, we used the NIH dataset RePORTER to retrieve information on all 1,601 Phase I NIH SBIR/STTR awards

granted in 2009 and 2010. We chose this period as it allowed for five years[2] to collect information on project outcomes. Then, to construct our dependent and independent variables, we tracked all projects and firms backward (to 1991, when the program fully launched at NIH) and forward (to 2015) using RePORTER to obtain a full history of each project's corresponding firm, primary investigator (PI), and project outcomes (e.g., subsequent awarding, publications, patents, and clinical trials). We also used RePORTER to obtain information on the top 100 NIH projects similar to each project in our sample, as identified through the NIH's matching system.

Second, for each STTR award application, we identified the partnering research institution from sbir.gov. Matching these research institutions with their RePORTER records yielded their NIH grant history. Third, we used DUNS number to extract company demographics like employment size and age from the Dun & Bradstreet Million Dollar dataset. Fourth, we used Google and LinkedIn to search for PIs' personal and professional backgrounds.

[2] A five-year window is sufficient to capture whether a Phase I project succeeds in transitioning to the second phase of NIH funding. Per NIH SBIR/STTR policy, Phase I award performance should not exceed half a year. Upon completing the Phase I award, as stated by NIH personnel, firms can submit their phase II proposal within six solicitation receipt date (equivalently two years). The issuance of the Phase II award must be no more than 180 days after the closing of the solicitation, which adds up to 2.5 years between Phase I completion and Phase II granting. In total, the Phase II award usually comes within three years after the Phase I award. Then, taking into consideration that some Phase I award may exceed the normal half-year performance period, we extend the time window from three to five years (extending the Phase I completion window from six months to 2.5 years). This minimizes cases where the Phase II award came after our observation window. On average, our sample Phase I award completed that round within 1.5 years; only 48 of 1,374 grantees took more than 2.5 years. We tried to estimate all our models excluding these 48 awards, yielding consistent results.

After handling duplicates[3] and records with missing values, we obtained a final sample of 1,374 awards that 933 firms received. Missing values surfaced for two reasons. The first is a lack of records in the D&B Million Dollar dataset for some firm-level demographics, such as year established (age), employment, and founder name. We removed 211 records due to missing values. As a robustness check, we reran all our analyses including these records but dropped the associated firm-level control variables, yielding consistent results. The second reason was limited information regarding the primary investigator (PI)'s academic experience when searching online. We decided to use mean-replacement for these missing values to maximize information usage. Robustness checks with alternative methods to account for the missing value showed consistent results, as described later.

Our final sample consists of 181 STTR (162 firms) and 1,193 SBIR awards (771 firms). NIH SBIR/STTR grant policy has remained consistent over time in terms of awards granted, STTR award proportion, and success rates of Phase I awards proceeding to phase II: 1) On average, a firm typically applies for 1.254 awards per year, to a maximum of six. Of the 1,374 awards, there are 693 in 2009 and 681 in 2010. 2) STTR award proportion remained statistically similar in 2009 and 2010 ($p>0.1$), estimated at 12.7% and 13.6%, respectively. The proportion of STTR projects in our sample also is not statistically different from the proportion of STTR awards granted in the last five years

[3] Of the full population of 1,601 new Phase I SBIR/STTR awards in 2009 and 2010, 16 projects have two separate records in the system as they are funded jointly by 2 NIH institutes. For these records, we combined them into one award by summing up the grant amounts and recording the combined award under the administering NIH institute, reducing our sample to 1,585 records.

(2004 – 2008, p>0.1), estimated at 13.17% and 15.2%, respectively. 3) The rate of Phase II over Phase I grants also was statistically similar across both years (both at 0.252, p>0.1).

In terms of small-firm location, final data came from 48 U.S. states (including Washington, D.C., and Puerto Rico), excluding Alaska, Hawaii, North Dakota, and West Virginia. In terms of total SBIR/STTR awards and the total number of small firms, the top five states are California (CA), Massachusetts (MA), Maryland (MD), New York (NY) and Pennsylvania (PA). In terms of STTR awards, the top five states are CA, NY, MA, MD and Oregon (OR). In terms of SBIR awards, the top five states are CA, MA, MD, NY and PA.

Variables

Dependent Variables

Dvsttr is a dummy variable valued at 1 if an STTR award and 0 if SBIR. This is used to examine the R&D path decision, where choosing the STTR program implies most R&D activity was conducted with an external partner. Choosing SBIR implies a clear majority of R&D was conducted internally.

Dvphase2 is a dummy variable that measures commercialization success probability, valued at 1 if a Phase II award was obtained within the five-year window, 0 otherwise. While Phase I grants allow small firms to test feasibility and establish scientific merits, Phase II grants are competitive for projects with high commercialization promise. Based on our interviews with NIH administrators, commercialization promise is NIH reviewers'

highest-weighted criterion when evaluating Phase II applicants. Based on a 2015 NIH survey conducted by NRC, about 75% of Phase II awardees reported actual or expected sales by successfully commercializing their project. Moreover, more than 80% of Phase II awardees said their project clinched investors, third parties' acknowledgement of project technologies' marketable value. For all these reasons, we used the Phase II award as a measure of commercialization success probability. We also used an alternative measure of commercialization success, as described in the robustness check.

Independent Variables

OwnSTTRsuccess is a measure of a small firm's previous external R&D success. We calculate by log-transforming the number of new Phase II STTR awards the focal firm has received from 1991 to the award year. Log transformation is used to normalize the independent variable (Manning & Mullahy, 2001; Zarembka, 1990). Similarly, o*wnSBIRsuccess* is a measure of a small firm's previous internal R&D success, calculated by log-transforming the number of new Phase II SBIR awards received from 1991 to the award year.

O*therSTTRsuccess* is a measure of competitors' previous external R&D success. We calculate by log-transforming the average number of new Phase II STTR awards firms within 20 miles of the focal firm received from 1991 until the award year. We chose the 20-mile radius as the NIH also uses this in identifying nearby projects. Similarly, o*therSBIRsuccess* is a measure of competitors' previous internal R&D success, calculated by log-transforming the average number of new Phase II SBIR firms within 20 miles of

the focal firm received from 1991 until the award year. We performed a sensitivity analysis of our results by changing the definition of nearby firms by increasing it to 40- and 60-mile radius, finding our results robust to various operationalization.

Projectnovelty measures the degree to which the innovation in the Phase I project is new and discontinuous from existing technologies (Anderson & Tushman, 1990; Ettlie et al., 1984; Henderson & Clark, 1990). This is operationalized as a continuous variable, calculated as the difference between 1,000 and the average "match scores[4]" of the top 100 similar projects the NIH matching system identified, divided by 1,000. A "match score" of 1,000 means a project is almost identical to the award candidate, thus the higher the average "match score", the lower the project's novelty level. For ease of interpretation, we reverse-coded this measure by using 1000 minus the average, such that the higher the value, the higher the project novelty. We also ran robustness checks using maximum match score value of the top 100 similar projects, which yielded consistent model results.

$$projectnovelty = (1000 - \overline{MatchScores})/1000$$

FormalIPR is a measure of formal IP rights, calculated by log-transforming the number of patents the corresponding PI had obtained before the award year. This approach is consistent with previous studies measuring formal IP rights (Cockburn & MacGarvie,

[4] For each NIH project, NIH calculate a set of match scores for all other NIH projects in the database about the project of interest. The NIH uses the Elsevier Fingerprint Engine (https://www.elsevier.com/solutions/elsevier-fingerprint-engine) to create a "fingerprint" and calculates the match score by cross-multiplying the weights of all terms common to both projects' fingerprints, then summing these cross-products across all common terms. Thus, the match score indicates a project's relative degree of similarity to all other NIH-funded projects. We can extract information on the top 100 projects with the highest match scores to the project of interest.

2011; Huang et al., 2013). A patent, first and foremost, denotes a (property) right the state confers to an (agglomerate of) inventor(s). The granted patent allows its holder to exclude third parties from the use of its protected technology. The grant of a patent also represents an applicant's ability to convince a patent examiner of sufficient novelty, inventive step (non-obviousness), and commercial viability (Reitzig & Puranam, 2009). Firms can then build around issued patents to block competition and facilitate the IP agreement negotiation process.

Control Variables

We included several controls in the models to account for other sources of explanation. For the first research question, we included following: 1) Formal IP rights the small firm's investigator possesses (*formalIPR_firm*). Research shows firms are more likely to enter external relationships when they feel protected by formal IP rights (Arora & Ceccagnoli, 2006; Gans et al., 2008; Huang et al., 2013). We used the firm's investigator rather than the PI because in some STTR projects, he or she may come from the research institution (this is determined after the decision to conduct the R&D project externally). Similarly, we included project novelty (*projectnovelty*) to assess if small firms considered this when making the R&D path decision. 2) Total SBIR/STTR awards the corresponding firm received for each award (*own_total*); this serves as a base control for our measure of the firm's previous success in receiving these awards. Similarly, we included the average total of SBIR/STTR awards competitors received (*other_avgtotal*). 3) Project-level controls, including award year (*award_year*) and R&D outcome types (*outcome_d*). We

identified the two types of R&D outcome using NIH criterion[5] of intangible (theoretical concepts, approaches or methodologies) or tangible (instrumentation, or interventions) products. Arguably, certain innovation outcome types may require specialized resources a small business may not possess internally. As such, this can increase the likelihood the firm will conduct external R&D. 4) Age (*age*) and number of employees (*employment*), which control for firm demographics. We controlled firm age as previous research suggests startups are more likely to leverage universities in R&D development (Cohen, Nelson, & Walsh, 2002). Employee count controlled for resource availability.

For the second research question examining commercialization success, we also controlled for total awards (*own_total* and *other_total*), project-level characteristics (*award_year* and *outcome_d*), and firm demographics (*age* and *employment*). We also included a control for PI's academic experience, measured by log-transforming the PI's tenure at a research institution setting (*pi_research_year*), and a dummy variable measuring whether the PI founded the corresponding firm to account for possibly stronger motivation and input level (*pi_founder*). At the project level, we controlled for the average distance of the top 100 projects similar to the focal firm's (*avgdistance_similar*). Finally, to control for resources and time devoted to the project of

[5] See NIH definitions of Criteria and Considerations for Research Project Grant Critiques (Retrieved from https://grants.nih.gov/grants/peer/critiques/rpg.htm). Note that intervention is defined as a manipulation of the subject or subject's environment for modifying one or more health-related processes and/or endpoints. Examples include, but are not limited to: drugs/small molecules/compounds, biologics, devices; procedures (e.g., surgical techniques); delivery systems (e.g., telemedicine, face-to-face); strategies to change health-related behavior (e.g., diet, cognitive therapy, exercise, development of new habits); and treatment, prevention, and diagnostic strategies.

Variable name	Mean	Std. dev.	Variable definition
Dependent variables			
dvsttr	0.13	0.34	dummy=1 if the award is under STTR program
dvphase2	0.25	0.43	dummy=1 if second stage federal funding was obtained
Independent variables			
ownSTTRsuccess	-4.17	1.41	the log of (number of new phase II STTR awards obtained by the corresponding firm in the past +0.01)
otherSTTRsuccess	-1.64	1.44	the log of (average number of new phase II STTR awards obtained by firms within 20 miles in the past +0.01)
ownSBIRsuccess	-2.20	2.94	the log of (number of new phase II SBIR awards obtained by the corresponding firm in the past +0.01)
otherSBIRsucess	-0.23	1.17	the log of (average number of new phase II SBIR awards obtained by firms within 20 miles in the past +0.01)
formalIPR	-3.86	1.97	the log of (number of patents the primary investigator obtained in the past +0.01)
projectnovelty	0.64	0.12	(1000 minus average Match Scores among top 100 similar projects)/1000
Controls			
own_total	9.55	20.88	total number of total SBIR/STTR awards obtained by the corresponding firm in the past
other_avgtotal	3.70	2.87	average total number of total SBIR/STTR awards obtained by firms within 20 miles in the past
other_total	0.71	1.04	total number of total SBIR/STTR awards obtained by firms within 20 miles in the past (in thousands)
award_year	0.50	0.50	dummy=1 if the year of awarding is in 2010

Continued

Table 1 Variable Definitions and Statistical Descriptions

Table 1 Continued

age	8.95	8.32	age of the corresponding firm at the award year
employment	11.12	19.96	number of employees of the corresponding firm
outcome_d	0.26	0.44	categorical variables=0 if the phase I award under concern is creating some theoretical concepts, approaches or methodologies, =1 if instrumentation or intervention
formalIPR_firm	-3.85	1.97	the log of (number of patents firm-side investigator obtained in the past +0.01)
pi_research_year	6.05	6.80	the log of (number of years the primary investigator worked in a research institution setting +0.01)
pi_founder	0.43	0.49	dummy=1 if the primary investigator is also the founder of the firm
avgdistance_similar	1.37	0.49	average distance of the top 100 similar projects to the award under concern (in thousand miles)
amount	0.25	0.17	dollar amount granted for the phase I award under concern (in $1M)
period	1.56	0.61	length of the phase I award under concern in years (360 days per year)

concern, we included the Phase I grant amount (*amount*) and grant period (*period*). Table 1 summarizes variables and other statistic descriptions.

Methods

For the first two hypotheses, we used a probit regression with robust error clustered at the firm level to analyze the small firm's R&D path decision. For the hypotheses on commercialization success, we used a generalized Heckman selection model also with robust error clustered at the firm level to evaluate how project novelty and formal IP rights influence commercialization success, conditional on small firms' initial R&D path decision.

R&D Path Decision

The dependent variable, *dvsttr*, measures whether a small firm chooses to conduct R&D internally (valued at 0) or externally (valued at 1) for the project under investigation. Note that a firm can take on multiple projects, some external and others internal, in the same year or across years. To correct for this lack of independence, we used a probit regression (equation 1) with robust error clustered at the firm level along with an award year control for year effect. The model is specified as below:

$$dvsttr_i^{=1} = (a_0 + a_1 * OwnSTTRsuccess_i + \alpha_2 * OtherSTTRsuccess_i + a_3 * OwnSBIRsuccess_i + a_4 * OtherSBIRsuccess_i + \boldsymbol{z}_i\boldsymbol{\alpha} + u_{1i} > 0) \quad (1)$$

where

$\boldsymbol{z}_i$ *is a vector of controls for the likelihood of conducting R&D projects externally*

$\boldsymbol{\alpha}$ *is a vector of coefficients for control variables*

Commercialization Success

Our second research question investigates the relationship between project novelty and formal IP rights and commercialization success, conditional on the initial R&D path decision. Ideally, we would need performance observations for each project under both R&D paths or a fully randomized sample design, yet we only could observe outcomes after the decision had been made. This suggests a sample-selection issue. An endogeneity issue also is present as unobserved factors related to the project or to focal firm characteristics could influence the R&D path decision and likelihood of commercialization success.

To account for these deficiencies, we tested H3 using a binary-outcome generalization of the Heckman selection model (Guajardo, Cohen, Kim, & Netessine, 2012; Heckman, 1979; King & Tucci, 2002). This approach uses a maximum-likelihood simultaneous estimation of the R&D path decision (effects of independent variables on choosing STTR program, usually called the choice model) (equation 2) and the effects of independent variables on commercialization success likelihood, correcting for the initial decision (also called the outcome model) (equation 3 and 4). Equations 5 and 6 specify that the error terms (u_1, u_2) of the choice and outcome equations are modeled as bivariate normal variables, with mean equal to zero and variance equal to 1. Equation 7 is the control function specification that allows the error terms to be correlated. The control function (CF) approach relies on the same kinds of specification conditions as the instrumental variable (IV) method. It is useful to account for endogeneity by assuming $u_2 = \rho u_1 + e$

and substituting u_2 by these two terms when estimating the outcome model. Because the new error term e is uncorrelated with u_1, thus uncorrelated with the endogenous variables, then we can estimate the outcome model using traditional method. We also used a robust standard error, clustering at the firm level. The complete specification of our model is shown below. To investigate H4 and H5, we modified equation 3, adding an interaction term between project novelty and formal IP rights.

$$dvsttr_i^{Select} = (a_0 + a_1 * OwnSTTRsuccess_i + \alpha_2 * OtherSTTRsuccess_i + a_3 * OwnSBIRsuccess_i + a_4 * OtherSBIRsuccess_i + \boldsymbol{z}_i\boldsymbol{\alpha} + u_{1i} > 0) \quad (2)$$

$$dvphase2_i^{dvsttr=1} = \beta_0 + \beta_1 * formalIPR_i + \beta_2 * projectnovelty_i + \boldsymbol{x}_i\boldsymbol{\beta} + u_{2i}$$

$$dvphase2_i^{dvsttr=0} = \gamma_0 + \gamma_1 * formalIPR_i + \gamma_2 * projectnovelty_i + \boldsymbol{x}_i\boldsymbol{\gamma} + u_{2i} \quad (3)$$

$$dvphase2_i^{Probit} = (dvphase2_i^* > 0) \quad (4)$$

$$u_1 \sim N(0,1) \quad (5)$$

$$u_2 \sim N(0,1) \quad (6)$$

$$corr(u_1, u_2) = \rho \quad (7)$$

where

$\boldsymbol{z}_i$ *is a vector of controls for the likelihood of conducting R&D projects externally*

$\boldsymbol{x}_i$ *is a vector of controls for the likelihood of commercialization success*

$\boldsymbol{\alpha}, \boldsymbol{\beta}, \boldsymbol{\gamma}$ *are vectors of coefficients for corresponding control variables*

Hypothesis Testing and Results

Model of R&D Path Decision

Table 2 gives results for the probit model (model 1) investigating the effects of a firm's success and its competitors' success on the likelihood of conducting R&D projects externally (i.e., choosing STTR) compared to the base group (i.e., SBIR).

Among the controls, we find that the estimate for *formalIPR_firm* is positive and significantly associated with the likelihood of conducting R&D externally ($p<0.05$). This is consistent with the literature (Huang et al., 2013), which finds firms are more likely to collaborate with a partner when formal IP rights possession reduces their expropriation concerns.

H1 suggests small firms are more likely to repeat a successful past strategy. Our estimate for the effect of *ownSTTRsuccess* on the likelihood of conducting external R&D externally is positive, indicating that, on average and ceteris paribus, *ownSTTRsuccess* significantly increases external R&D likelihood ($p<0.01$). For instance, when small firms had no success with external R&D projects before, the mean predicted probability of new-project external R&D is only 11.8% and increases to 27.4% with one successful project. Our estimate for the effect of *ownSBIRsuccess* on external R&D likelihood is negative, indicating that, on average and ceteris paribus, *ownSBIRsuccess* significantly decreases (increases) the likelihood a firm will conduct R&D externally (internally) ($p<0.01$). The mean predicted probability of internal R&D is 79.9% if small firms had no

such success before and increases to 93.0% with one success. Taken together, these results support H1.

	Probit regression
	(1)
Independent variables	
ownSTTRsuccess	.136(0.034)***
otherSTTRsuccess	-.088(0.041)**
ownSBIRsuccess	-.146(0.027)***
otherSBIRsucess	.008(0.060)
Controls	
own_total	.003(0.005)
other_avgtotal	-.018(0.040)
projectnovelty	-.183(0.344)
outcome_d (tangible)	.095(0.105)
formalIPR_firm	.045(0.022)**
award_year (2010)	.012(0.088)
age	-.006(0.007)
employment	.001(0.002)
constant	-.889(0.356)**
Log-likelihood	-490.84
Wald Chi2	70.11
Prob>Chi2	0.000
obs.	1374

*p<0.10 **p<0.05 ***p<0.01, two-tailed tests, standard errors (adjusted for clustering) in parentheses.

Table 2 Predicting Likelihood to Conduct R&D Projects Externally (Choose STTR Program)

For H2, we proposed two competing hypotheses. H2A suggests small firms are more likely to replicate competitors' successful strategy, while H2B suggests they will avoid it.

Our estimate for the effect of *otherSTTRsuccess* on external R&D likelihood is negative. This suggests that, on average and ceteris paribus, *otherSTTRsuccess* significantly decreases the likelihood of external R&D ($p<0.05$), supporting H2B. The mean-predicted probability of external R&D is 18.7% if competitors had no success with it and decreases to 10.4% if competitors averaged one success. The coefficient estimates for *otherSBIRsuccess* on external R&D likelihood had a positive sign as proposed by H2B but was not statistically significant. Overall, H2B is partially supported as competitors' previous success with external R&D projects negatively influences small firms' decision to conduct R&D projects.

Model of Commercialization Success

Table 3 provides results for the maximum-likelihood simultaneous estimation of R&D path decision and the effect of independent variables on commercialization success. We first specified a choice model predicting R&D path decision (using equation 2), which produces similar results about focal firm and competitor success, as above. Note that the choice model is estimated simultaneously for each observation but is reported here only for external R&D projects (projects under STTR program) to avoid redundancy. We reported the outcome model results separately for SBIR and STTR cases. Full results available from the authors. We analyze results for the outcome model below.

Regarding our controls, we find that project duration is negatively associated with commercialization success probability, i.e., projects spending longer time to complete Phase I are less likely to achieve commercialization success ($p<0.01$, model 3 and 4).

This is consistent with previous research (Dechenaux et al., 2008) that found commercialization success increases when firms move products to market faster. Second, the likelihood of commercialization success increases significantly with the amount granted for internal ($p<0.05$, model 4), but not external ($p>0.10$, model 3), R&D projects. This implies government support for firms pursuing R&D by themselves is crucial, less so for those with a partner. Third, for internal R&D projects, the likelihood of commercialization success decreases along with the average distance to entities conducting similar projects ($p<0.05$, model 4), implying knowledge spillover from nearby projects may have positive effects (Van Beers, Berghäll, & Poot, 2008). In contrast, distance to similar projects does not influence commercialization success for external R&D projects with formal research partnerships ($p>0.10$, model 3).

H3 suggests that project novelty increases (decreases) commercialization success for internal (external) R&D projects. As seen from models 3-4, we find that the coefficient estimates for project novelty are not significant for both external and internal R&D projects at base model ($p>0.10$). We resultantly find no support for H3.

	Simultaneous maximum-likelihood selection model				
	Choice model†: Chose STTR (probit)	Outcome models			
		Base		Interaction	
		External R&D projects (STTRs)	Internal R&D projects (SBIRs)	External R&D projects (STTRs)	Internal R&D projects (SBIRs)
	(2)	(3)	(4)	(5)	(6)
Outcome model independent variables					
formalIPR		.101(0.051)**	.045(0.022)**	.543(0.265)**	-.178(0.134)
projectnovelty		-.282(1.237)	.207(0.342)	-2.321(1.637)	1.588(0.923)*
formalIPR×projectnovelty				-.721(0.426)*	.338(0.205)*
Choice model independent variables					
ownSTTRsuccess	.135(0.034)***				
otherSTTRsuccess	-.087(0.042)**				
ownSBIRsuccess	-.146(0.027)***				
otherSBIRsucess	.007(0.061)				
Controls					
projectnovelty	-.183(0.345)				
forrmalIPR_firm	.045(0.022)**				
other_avgtotal	-.020(0.041)				
own_total	.003(0.005)	.006(0.006)	-.001(0.004)	.006(0.006)	-.001(0.004)
other_total		-.029(0.156)	.027(0.039)	-.042(0.159)	.028(0.039)
pi_research_year		.003(0.011)	-.004(0.007)	-.0005(0.011)	-.004(0.007)
pi_founder		-.008(0.259)	-.018(0.082)	-.048(0.257)	-.017(0.083)
avgdistance_similar		.189(0.277)	-.183(0.080)**	.195(0.279)	-.191(0.081)**
amount		.881(0.810)	.637(0.263)**	.994(0.825)	.637(0.263)**
period		-.608(0.207)***	-.395(0.082)***	-.625(0.206)***	-.403(0.082)***
outcome_d (tangible)	.095(0.105)	.134(0.242)	-.111(0.094)	.141(0.243)	-.108(0.095)
award_year (2010)	.013(0.088)	.014(0.228)	-.013(0.079)	-.040(0.237)	-.012(0.079)
age	.006(0.007)	.023(0.018)	-.001(0.006)	-.019(0.018)	-.001(0.006)
employment	.001(0.002)	-.012(0.011)	.0004(0.002)	-.011(0.011)	.001(0.002)
constant	-.888(0.357)	-.007(1.278)	.245(0.349)	1.270(1.439)	-.657(0.666)
Rho		.126	-.486	.150	-.458
Wald Chi2		17.64	38.03***	22.74*	38.46***
obs. (censored,uncensored)	1374	1193/181	181/1193	1193/181	181/1193

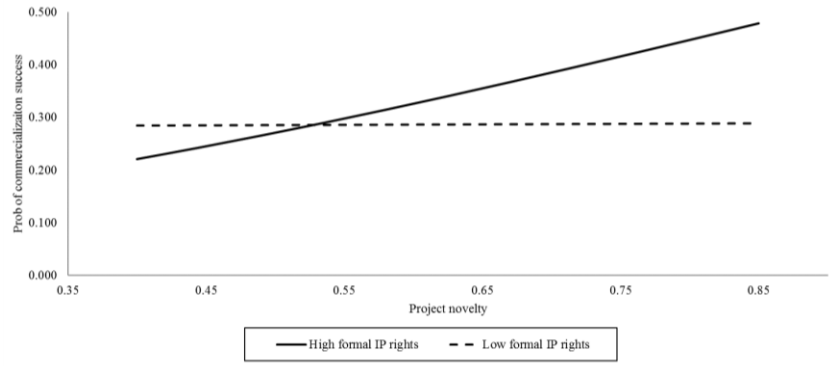
*p<0.10 **p<0.05 ***p<0.01, two-tailed tests, standard errors (adjusted for clustering) in parentheses.

†The choice model is estimated simultaneously for each case but is reported here for the case "chose STTR" program (model 2). Full results available by requests.

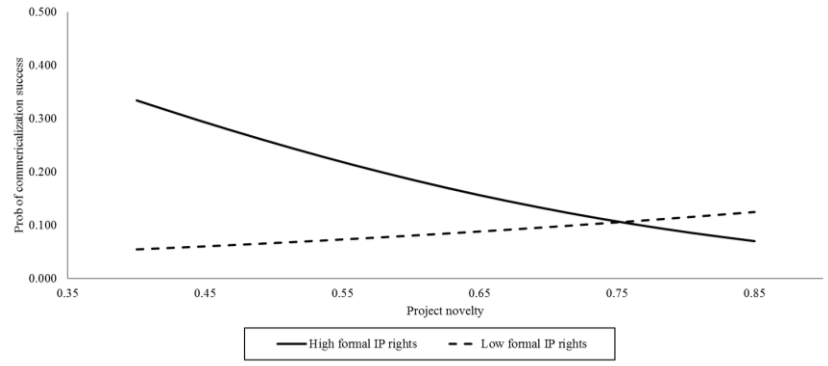
Table 3 Predicting Likelihood of Commercialization Success

H4 suggests formal IP rights strengthen the positive effect of project novelty on commercialization success. We find a positive, significant interaction effect of formal IP rights on project novelty and commercialization for internal R&D projects (model 6), lending support to H4. To better understand this relationship, we used an interaction plot. Due to the probit form of the model, the value of other specified variables can amplify the moderation effect due to assumed fixed residual variation (Allison, 1999). Following (King & Tucci, 2002), we used the median value for all variables in the appropriate sample to estimate the moderation effects. That is, Figure 2A depicts internal R&D projects a five-employee, seven-year-old firm completes in 548 days with $193,511 in grant funding for tangible products (median values). We set high formal IP rights level as when the PI obtained one patent before the award year, with the low level representing no patents, following Huang et al. (2013). As seen from the plot, the upward slope for projects with high formal IP rights is steeper, consistent with H4. Specifically, a larger increase in commercialization success probability with high formal IP rights occurs at higher project novelty (from 28.9% to 47.9% at two standard deviations away from mean *projectnovelty*, ceteris paribus).

H5 suggests that for external R&D projects, higher formal IP rights weaken the negative effect of project novelty. We find for external R&D projects a negative, significant interaction effect of formal IP rights on project novelty and commercialization success (model 5, $p<0.10$), contradicting H5. We also plotted an interaction graph to illustrate this moderation effect, holding other variables at median values. Figure 2B estimates a five-



A



B

Figure 2 Moderation Effects of Formal IP Rights: A Internal R&D Projects, B External R&D Projects

employee, six-year-old firm completed an external R&D project in 701 days with $181,353 in grant funding for tangible products. As seen from the plot, the downward slope for projects with high formal IP rights is steeper compared to projects with low formal IP rights, counter to H5. Specifically, when project novelty is low, small firms with high formal IP rights enjoy a higher probability of commercialization success (this

increases from 5.4% to 33.4% at two standard deviations away from mean *projectnovelty,* ceteris paribus). However, this IP rights-associated advantage diminishes and eventually reverses as project novelty increases: Commercialization success probability for external R&D projects drops from 12.4% to 7.0% at high project novelty (at two standard deviations), ceteris paribus.

One potential explanation for the evidence opposing H5 is that small firms with high-novelty projects may grow reluctant to share information with partners, especially when they possess formal IP rights. Some studies even find formal IP rights may not eliminate all IP leakage concerns (Lemley & Shapiro, 2005) and may provide useful knowledge to other firms (Chun & Mun, 2012). Many patents can be circumvented, while others provide little protection because of stringent legal requirements for proof of validity or infringement (Bessen, Meurer, & Ford 2011). Costs and time required to secure a court judgment often may be too much for a small firm, which may still prefer guarding proprietary knowledge even in possession of formal IP rights. In a case study of university-industry collaboration, Kneller et al. (2014) referred to this as the "IP lockup" problem. Per this research, university collaboration requires companies to consider "*how much information to share …. The company must be careful not to divulge too much to university staff, especially students who may take that information with them anywhere, including when they go to work for competitors. Confidential agreements are signed with the university, not with an individual student, which increases risk of dissemination of proprietary information. The company requires time to review any presentation or*

manuscript in advance to ensure no proprietary information is disclosed and patentable inventions are properly protected. (p. 10)"

This IP lockup problem may grow in severity along with project novelty. At minimum, small firms may spend more time negotiating with partners for more novel projects. In turn, these reservations and the effort they require may hinder communication and openness required for success (Cui et al., 2012). At high project novelty, therefore, high formal IP rights may lead to more coordination troubles and thus reduce the likelihood of commercialization success.

Post-hoc Analyses

Did the R&D Path Decision Matter?

We performed additional analyses to derive more insights on these results. First, to examine how extensively the first-stage R&D path decision influences commercialization success, we compared the models with and without accounting for sample selection and endogeneity (Figure 3). Specifically, we plotted the predicted probability of commercialization success separately for external and internal R&D projects derived from our simultaneous model. We also plotted these predicted probabilities without accounting for the decision by running a simple probit model on all outcome model independent variables.

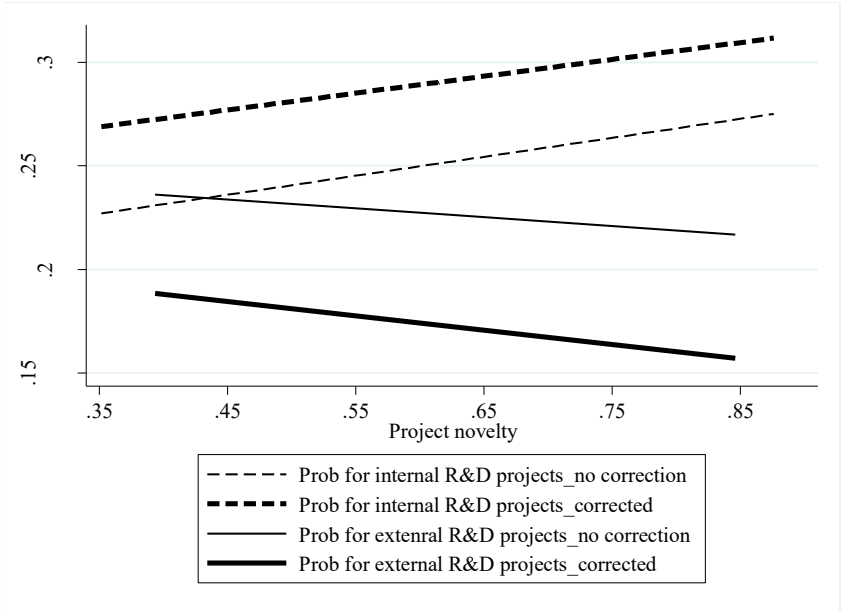


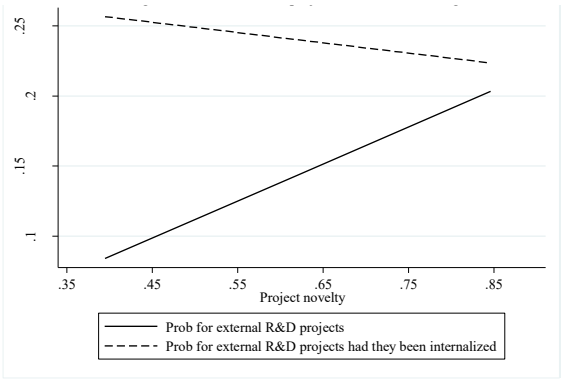
Figure 3 Predicted Probability of Commercialization Success with and Without Correcting for the R&D Path Decision

As seen from Figure 3, the corrected probability of commercialization success differs significantly between external and internal R&D projects (bold lines). After correcting for the initial decision, the average predicted probability of commercialization success for internal R&D projects is higher than external R&D projects (net difference of 12.1% (=29.2%-17.1%), $p<0.01$). In contrast, the raw proportions of internal and external R&D projects' commercialization success are not significantly different (at 22.6% and 25.3% respectively, $p>0.1$) (light lines). This finding suggests the initial R&D path decision indeed influences commercialization success, thus it is important to account for it. After appropriately accounting for it, we find the R&D path itself affects commercialization

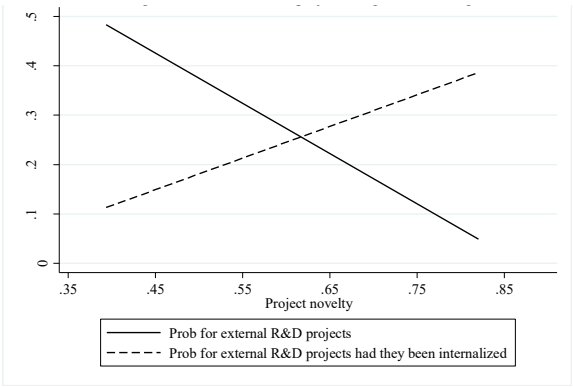
success, crucial as much of the extant research fails to correct for it. As such, we further explored small firms' R&D path decision quality with a counterfactual analysis.

Did Small Firms Make the Right R&D Path Decision?

The counterfactual analysis allows us to estimate the likelihood of commercialization success had small firms made the opposite decision. If the likelihood of commercialization success decreases (increases) had the firm made a different decision, this indicates a correct (incorrect) decision. To evaluate this, we first estimated the predicted probability of commercialization success for each project given the initial decision. We then estimated the predicted probability of commercialization success for each project for the opposite decision to procure counter-factual estimates. Furthermore, we regressed these success probabilities on project novelty and plotted them separately for projects with high and low formal IP rights. Four plots emerge from these analyses: For external R&D projects with low and high formal IP rights (Figures 4A and 4B) and for internal R&D projects with low and high formal IP rights (Figures 4C and 4D). Counterfactual analysis results for external R&D projects suggest that reversing the R&D path decision (i.e., conducting it internally) when formal IP rights are low (Figure 4A) would increase the likelihood of commercialization success from 15.0% to 23.8% ($p<0.01$), regardless of project novelty (the dash line in Figure 4A compared to the solid line in Figure 4A).



A



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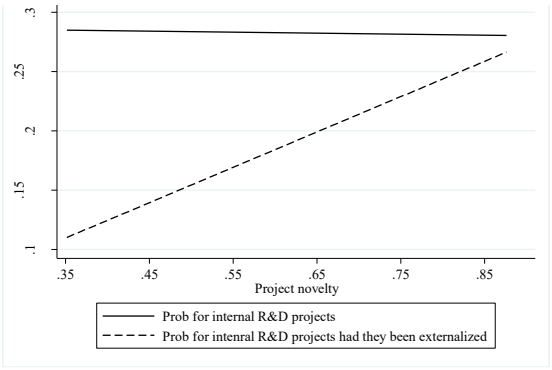
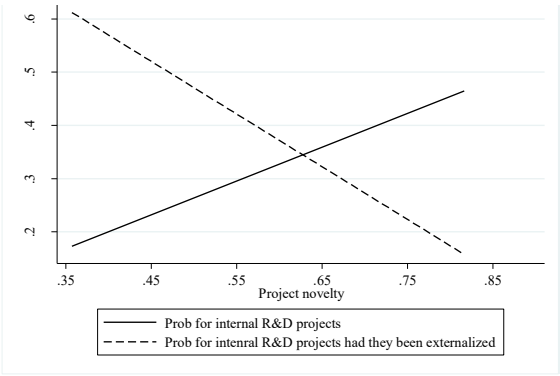


C



D

Figure 4 Post-hoc Analyses: A External R&D Projects with Low Formal IP Rights, B External R&D Projects with High Formal IP Rights, C Internal R&D Projects with Low Formal IP Rights, D Internal R&D Projects with High Formal IP Rights

When formal IP rights are high (Figure 4B), however, reversed decision would be an inferior (superior) choice at low (high) project novelty (see dash line vs. solid line at low and high project novelty levels). In summary, these results suggest that, save for when formal IP rights are high and project novelty is low, R&D projects are more likely to be

successful were firms to have reversed their R&D path decisions (i.e., change from external to internal R&D).

For internal R&D projects (Figure 4C and 4D), a similar inference can be made. That is, except when formal IP rights are high and project novelty is low, R&D projects are more likely to succeed were small firms to maintain their original, internal R&D path decision. We elaborate on this finding when discussing managerial insights.

Robustness Checks

We performed numerous robustness checks to ensure the validity of our findings. First, we assessed the validity of using Phase II awards as a measure of commercialization success probability by collecting data on project commercialization. *Dvproduct* is a dummy variable for whether a commercial product resulted from the R&D project; this, unlike *dvphase2*, is a direct measure of commercialization success. One researcher on our team checked technologies and products listed on small firms' websites to identify if any matching the description in SBIR/STTR award abstracts, recorded the product, then assigned a value of 1 for a match, zero otherwise. If a small firm's website could not be found, the researcher manually verified the firm's existence and gave a value of zero if it did not exist. Two other researchers then cross-referenced the recorded product matched with abstract descriptions. In total, we constructed this alternative measure for a random sub-sample of 300 (39 external and 261 internal) R&D projects.

To check robustness, we ran a simple probit regression of the outcome model using *dvproduct* as the dependent variable regressed on *dvsttr*, its interaction term with

projectnovelty and *formalIPR*, and all control variables[6]. Results indicate the three-way interaction between *projectnovelty*, *formalIPR,* and *dvsttr* was significant with $p<0.05$. This suggests that, using this alternative and direct measure of commercialization success, all three factors still influenced the likelihood of commercialization success. The full result of this robustness analysis is available upon request. For brevity, we show the interaction plots in Figure 5. For internal R&D projects, the interaction plot using *dvproduct* is consistent with the findings reported in the main analyses. The likelihood of commercialization success increases at a faster rate with project novelty for projects with high formal IP rights, compared to those with low rights (bold lines). For external R&D projects, both lines for low and high formal IP rights are nearly flat (light lines), which could be attributed to a small external R&D project sample size for which a *dvproduct* was collected. Overall, our alternative approach to measure success is consistent with the original results reported for internal R&D projects, strengthening our findings.

[6] We did not use the generalized Heckman selection model here. We acknowledge that accounting for the initial decision to conduct R&D projects internally or externally could have made the discrepancy between external and internal R&D projects more pronounced, as indicated by our counter-factual analysis. Nevertheless, the effects (slope) of novelty and formal IP rights found with a simple probit model will be similar to those using a more complex model with sample selection. As the sample size for this robustness check is small, a simple probit model with fewer parameters is more appropriate.

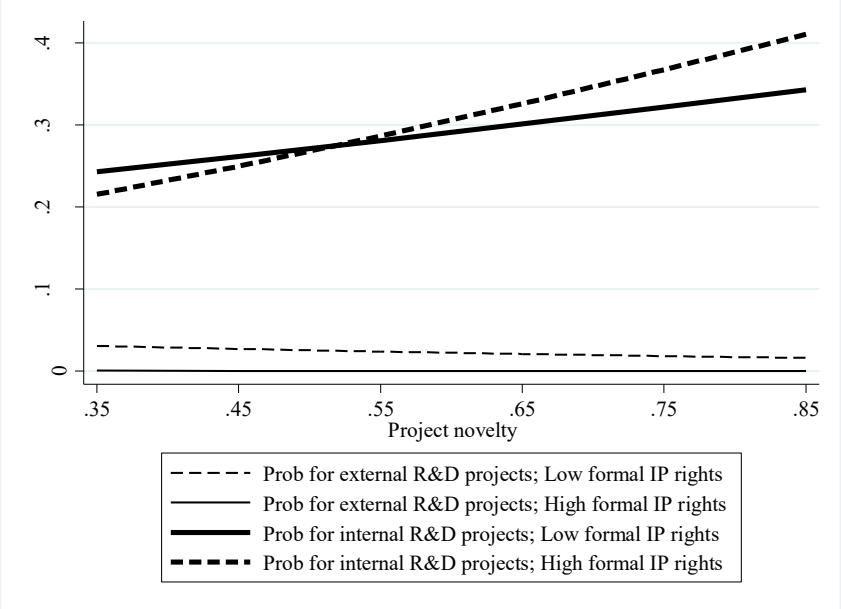


Figure 5 Robustness Check: Alternative Measure of Commercialization Success

Second, our sample contained several missing values for some control variables. We relied mostly on the D&B Million Dollar dataset for firm-level demographic information, supplementing it through alternative search mechanisms (e.g., Google search). In total, 211 were missing information on year established (age), employment, or founder name and were originally dropped. As a robustness check, we also tried to include these awards in our model (dropping these firm-level controls) and arrived at consistent results. Another source of missing values is PI information. We made multiple attempts to cull additional information using LinkedIn's professional service and basic Google search. If unable to determine how long the PIs worked for a research institution, we used mean-replacement by R&D path (SBIR or STTR program) to construct the corresponding

control variable in our analysis. For robustness, we addressed this issue using two additional approaches: 1) We ran our analysis with a reduced sample, dropping records where PI experience could not be found; 2) We ran a similar analysis without controlling for PI academic experience. Both robustness checks provide similar results using mean-replacement, an approach for maximally using available information.

Third, we followed the 20-mile definition of nearby firms the NIH used in its RePORTER database to identify nearby competitors. For sensitivity analysis, we also tried identifying competitors within 40 and 60 miles. Forth, when measuring success, we tried constructing a ratio-based measure by calculating the proportion of new Phase II awards over new Phase I awards. We obtain similar results regarding the effect of firm success and others' success based on the reduced sample. All these results help strengthen the validity of our findings.

Discussion

Theoretical Implication

Several relevant theoretical implications emerge from this study. First, our results contribute to the emerging literature on the role of formal IP rights in small firms (Gans et al., 2000; Huang et al., 2013). Previous studies have argued for formal IP rights as an important predictor of a small firm's external R&D decision. We augment these findings by showing that formal IP rights possession may not always benefit these projects. In fact, having formal IP levels on high-novelty initiatives may deter small firms from sharing important proprietary knowledge vital for collaborative success, largely due to

concerns over infringement or costly legal battles (Bessen et al. 2011). Referred as the IP lock-up problem, this idea was first introduced by Kneller et al. (2014) through a qualitative case study. Our research offers strong empirical support to the presence of this issue among science and technology firms.

Second, our study fully illustrates how R&D path decisions affect R&D performance, accounting for important project- and firm-level characteristics. We argue that the development effort involved (i.e., project novelty) and the firm's capability to protect its technology (i.e., formal IP rights) play an important role in determining commercial success. Existing findings on this topic are mixed, largely because research has looked only at the R&D path-performance relationship without simultaneously accounting for project- or firm-level contingencies. For instance, university collaboration has been positively associated with performance through a model that does not control for project novelty or formal IP rights (Link & Ruhm, 2009), crucial factors in our research that must be considered. A number of studies have looked at two-way interactions among factors such as project novelty and R&D path decision (Rothaermel & Alexandre, 2009), formal IP rights and R&D structure (Cassiman & Veugelers, 2006; Huang et al., 2013), or formal IP rights and project novelty (Colyvas et al., 2002). Unfortunately, none offers a holistic understanding of how these factors jointly determine commercialization success. Had we followed this approach, we would have incorrectly concluded on the role of formal IP rights for these small firms, irrespective of R&D path. Our results

suggest commercialization success is a function of all three factors, all of which must be considered to avoid inaccurate conclusions.

Third, our study supports the role of behavioral factors when making R&D path decisions in small firms. Interestingly, our finding that small firms are less likely to mimic competitors in conducting external R&D runs counter to the vicarious learning argument (Haunschild & Miner, 1997; Haveman, 1993). This result suggests that, for small firms, the value of differentiating themselves from the competition may actually exceed the benefits of replicating their R&D strategy. That is, if a small firm's competitor has successfully collaborated externally, the firm is constrained by resource (partner) availability and the need to differentiate in response to competitors. Some scholars have noticed this replication-differentiation tension (Baum & Oliver, 1992; Porac, Thomas, & Baden‐Fuller, 1989). Deephouse (1999) developed a conceptual argument to integrate both perspectives, suggesting intermediate levels of differentiation can increase performance. Unfortunately, no other empirical study has validated these arguments. Our finding that small firms avoid competitors' successful strategy thus offers nuance to the vicarious learning arguments when applied to a resource-constrained environment. Also, several studies on learning from competitors have measured learning behavior indirectly by performance improvement. This showed evidence of learning by outcome but not the firm's actual actions (Baum & Dahlin, 2007; Kim & Miner, 2007; Madsen & Desai, 2010). For instance, Madsen & Desai (2010) reported that other orbital launchers' prior success reduced the likelihood of the focal firm's failed launch but provided no detail on

how this was achieved during the learning process. Our findings, therefore, contribute to the literature by articulating the specific decisions small firms make to improve performance in response to competitors.

Finally, our post-hoc analysis suggests the R&D path decision is endogenous to commercialization success. We find that a clear majority of research on commercialization success has not corrected for this decision, thus its conclusions may not be consistent. Had we not accounted for these, we would have concluded the average likelihood of commercialization success is equal between external and internal R&D projects (as the raw percentages are the same). After accounting for endogeneity, the discrepancy between the likelihood of internal-external commercialization success becomes more salient. Specifically, we showed that previous experience and competitors' actions influence this decision. Altogether, our study contributes to future research on the effects of R&D paths by highlighting the necessity to account for endogenous drivers behind the initial R&D path decision.

Managerial Insights

Our study sheds light on how small firm owners can make R&D path decisions, suggesting managers can benefit from looking at factors such as project novelty and formal IP rights. Table 4 gives four different scenarios for the small-firm R&D path decision based on the levels of formal IP rights and project novelty. Our results suggest that when the investigator has limited IP experience, the firm is better off conducting R&D projects internally regardless of project novelty level. When the investigator is

experienced with formal IP rights, internal (external) R&D is more effective if project novelty is high (low). For instance, the inventors of a novel technology called the "Pipe Pig" decided to leave the external R&D initiatives with Pontifical Catholic University of Rio, which cultivated the original idea (Brant & Lohse 2013). With a strong patent portfolio, they established an independent company called PipeWay Engenharia for commercialization of the invention. It hired the original research team and protected the team's tacit knowledge by developing and testing everything in-house. The resultant strong IP position became especially important as the firm expanded overseas. In this example, PipeWay made the right strategic decision to abandon the external R&D initiative and conduct its R&D internally given the technology's high novelty level.

		Formal IP rights	
		Low	High
Project novelty	Low	SBIR/Internal R&D projects	STTR/External R&D projects
	High	SBIR/Internal R&D projects	SBIR/Internal R&D projects

Table 4 Managerial Implication: When to Conduct R&D Projects Externally

Our analyses also have important implications for the U.S. SBA and other federal agencies on the effectiveness of the SBIR/STTR program in innovation and technology transfer. This program offers more than $2 billion in funding for crucial R&D efforts small U.S. firms undertake. Our conversations with program administrators suggest that current Phase II selection policies and subsequent success rates were identical across both

programs. Our study, however, shows that the likelihood of commercialization success changes dramatically depending on R&D path. Additionally, the current NIH review process assesses project novelty as a stand-alone criterion (under innovation) and does not differentiate based on R&D path. Our findings suggest that reviewers may recommend applicants to choose SBIR or STTR depending on project novelty and possession of formal IP rights. For instance, a firm with low project novelty and high formal IP rights should be encouraged to find a partner and apply for STTR funding. The NIH can help small firms identify research institution partners with available capacity. Our findings also show that formal IP rights possession can create obstacles for STTR projects, thus they must be evaluated carefully. We hope our results offer guidance that can be incorporated into the NIH review process, ultimately to improve commercialization success.

Limitations and Conclusions

Several limitations in our study may suggest potential avenues for future research. First, our sample is limited to small-firm, government-funded U.S. R&D projects in early stages. While government funding plays an important role in early-stage innovation funding, it is worth testing the findings from our study in situations where funding can come from other sources such angel investors and other private funds. Moreover, our suggestions are limited to early stages of R&D such that the dynamics of external party involvement in later stages of R&D may be quite different. Second, we assume small firms are aware of nearby competitors' past success due to geographic closeness, research

similarity, and public availability of funding information. While this insight is derived from our qualitative interviews with award applicants, we acknowledge this as a limitation with our operationalization as we did not directly observe whether small firms in our sample were aware of this information. Third, our study focused on the effects of formal IP rights developed prior to the project under concern. One interesting extension could examine formal IP rights development during the R&D process and its influence on commercialization success. Formal IP rights, moreover, could be a measure of innovation capability as often seen in the literature. If this is true, however, formal IP rights will be positively associated with the likelihood of commercialization success at all scenarios, which is not the case in our results. Fourth, our study takes the perspective of small firms and examines how they make R&D path decisions. Future research may examine the motivation of research institutions collaborating with small firms and how their attitudes influence commercialization of collaborative efforts. Indeed, a stream of research has examined issues related to research institution-initiated technology transfers (Agrawal & Henderson, 2002; Lockett & Wright, 2005; Sine, Shane, & Gregorio, 2003; Thursby & Thursby, 2002). We encourage more work from the perspective of the research institution collaborator given their differences in managing innovation.

Finally, we acknowledge potential sources of uncontrolled endogeneity in our empirical methods. While we used the control function approach in our model to account for endogeneity of the R&D path decision, we are aware no econometric procedure is

perfect. Nevertheless, we are confident that our results are the most accurate possible given the nature of the empirical data we collected.

Overall, this paper provides important insights for theory and practice. Our unique context of NIH SBIR/STTR program affords examination of small firms' R&D path decision and subsequent commercialization success. Our primary contribution is a theoretical description of how project novelty, contingent on formal IP rights and the R&D path decision, influences commercialization success. Insights we unearthed contribute to the clarifying effects of this decision under different scenarios.

Chapter 3: Connecting Small Minority Suppliers to Large Corporations through Participation in BMO-sponsored Activities

Introduction

Based on U.S. Census Bureau, more than half of all Americans will belong to a minority group by the year 2044. With this demographic shift comes a growing concern about the growth and survival of minority business enterprises. A minority business enterprise (MBE) is defined as being owned, capitalized, operated, and controlled by a member of an identified minority group (http://www.mwbe-enterprises.com/mbe/). Minority groups include US citizens in one of the following groups: African Americans, Hispanic Americans, Native Americans, and Asian Americans. Using this definition, minorities currently represent approximately 37% of the US population. Based on data from the 2012 census there were 8 million minority-owned firms up from 5.8 million in 2007 – 38% increase. Employment at minority-owned firms increased to 7.7 million employees – a 33% increase while combined grossed receipts at minority-owned firms increased to 1.4 trillion in 2012 – a 35% increase. However, despite this growth in employment and combined total gross receipts the average minority-owned firm still trails the average non-minority-owned firm in average gross receipts 1.2 million to 2.3 million.

One of the main obstacles in closing this disparity is connecting minority businesses to entities that can provide needed resources and support for their growth. For example, connections to large buying organizations were shown to bring increased revenues and employment for small minority-owned firms (Foggin, 2011; Mills, 2013). Meanwhile, many large companies are also implementing supplier diversity programs to build their minority supplier base. However, previous literature has discussed the difficulties minority businesses face when accessing large buying organizations (Bates, 2001; Krause, Ragatz, & Hughley, 1999). Barriers such as size, scope, capacity and access to financing hinder minority-owned firm's growth more than non-minority-owned firms (Lowry & Holland, 2005). Fairlie, Robb, and Hinson (2010) showed that minority-owned firms have a more difficult time accessing capital when compared to non-minority owned firms. Indeed, because of size minority-owned firms also have few connections to other minority-owned firms who can share good practices and market information. Studies show that many minority-owned firms rely heavily on the personal network of their CEO/founder and have a hard time building connections beyond it (Lopez, 2014).

To help overcome this disparity President Richard Nixon established the Minority Business Development Agency dedicated exclusively to assist in network building for improved access to contracts, access to best practices, and access to market opportunities. The National Minority Supplier Development Council (NMSDC) is one such organization with a mission to advance business opportunities for minority suppliers in the global corporate supply chain. In this study, we limit our analysis to an examination

of the potential benefits resulting from minority supplier's involvement in corporate membership programs, hereafter referred to as Business Membership organizations (BMO).

Previous studies have examined the impact of BMO membership on small suppliers' performance (Battisti & Perry, 2015; Bennett & Ramsden, 2007; Boehe, 2013). However, direct generalization of their findings to minority suppliers is inappropriate. One key distinction is that for small majority-owned firms, membership in BMOs is mostly voluntary. In contrast, for minority suppliers, membership is required as large buying organizations often rely on BMOs to access certified minority suppliers. For instance, in the U.S., becoming certified by NMSDC is often considered the gold standard and is used virtually by all Fortune 500 corporations to verify firm's minority-owned status. Therefore, the issue for minority suppliers is not whether to become a member, but how to best exploit the BMOs' resources post-membership. The decision system under study in this paper are the actions minority suppliers take after they have joined the BMO to grow their business. Given limited time and energy available for minority suppliers, minority suppliers face the challenge to exploit BMO's resources and network more effectively through smarter participation. Relatively little scholarly attention has been devoted to studying minority suppliers' participation with BMOs.

This study provides an empirical attempt to understand the role of participation in BMO-sponsored activities in helping minority suppliers grow sales. Based on a sample of minority suppliers affiliated with the Ohio branch of the NMSDC, our results indicate

that minority suppliers with membership in this branch can expand their social networks with other minority-owned firms and with large buying corporations through participation in BMO-sponsored activities. Moreover, when considering the type of activities to participate in, our results suggest that participation in connect-oriented activities is more effective in expanding social networks with other minority-owned firms than participation in development-oriented activities. As for expanding social networks with large buying corporations, there is no significant difference in effects of participation in connect- versus development- oriented activities. In turn for growing sales, our results indicate that expanding relationships with other minority-owned firms is positively associated with sales growth. This positive effect is stronger when minority suppliers are younger and when they are smaller. Surprisingly, we find a negative association between expanding relationships with large buying corporations and sales growth. This finding has important implications for practice since BMOs often emphasize connecting minority suppliers to large buying corporations, as opposed to facilitating network building among minority members. Further exploration suggests that expanding social networks with large buying corporations are positively associated with sales growth only when minority suppliers are very small (i.e. fewer than 10 employees). Overall, our study recommends minority-owned firms consider expanding social networks with other minority-owned firms during BMO-sponsored connect-oriented activities, especially when they are young and small. Our findings also provide insights for BMO administrators in activity design.

Background

Literature on Supplier Diversity

Supplier diversity has been a strategic initiative of government and private corporations for over 40 years. Corporations are motivated to do business with minority owned companies for several reasons. First, minority suppliers are major customers to corporate America and have significant buying power (Weeks, 2014). Second, it is socially responsible to support local businesses in the community one serves. Research shows that consumers want to purchase parts, products and services from companies that they believe hold the same core values as they do (Drumwright, 1994; Maignan, Hillebrand, & McAlister, 2002; Worthington, Ram, Boyal, & Shah, 2008). Lastly some companies are motivated to do business with small corporations as they have shown to be more responsive and flexible in meeting their customer needs (Ebben & Johnson, 2005; Fiegenbaum & Karnani, 1991).

For many organizations supplier diversity comes under the umbrella of corporate social responsibility (Worthington et al., 2008) and effectiveness is measured under corporate social performance (Chen & Delmas, 2011). Legislation dating back to the 1960s was enacted to assist minority businesses in gaining contracts with government agencies (Spratlen, 1979). Reviews by Levinson (1980), Rice (1991), and Bates and Bradford (2009) discuss the government's role in assuring minority firms get their fair share of government contracts. Studies by Giunipero (1981), Dollinger, Enz, and Daily (1991), Pearson, Fawcett and Cooper (1993), and Adobor and McMullen (2007) have explored

the challenges private corporations face in building and sustaining supplier diversity programs. One of the main obstacles large buying organizations face is identifying and building relationships with minority suppliers. Pearson et al., (1993) and Adobor and McMullen (2007) suggest connecting with nonprofit organizations as a possibility for growing supplier diversity. However, none of these papers empirically examined the effectiveness of nonprofit organizations in connecting diverse suppliers with large corporations.

Over the past thirty years, nonprofit business membership organizations were formed to make it easier for minority suppliers to become suppliers to large corporations. Such organizations exist with the objective of providing economic opportunities to diverse businesses to spur U.S. job growth. Studies have examined the motivations (Bennett & Ramsden, 2007) and selection criteria (Battisti & Perry, 2015) for membership in BMOs, as well as benefits from such membership (Barnett, 2007; Dalziel, 2006; Waddock, 2008). However, none of these papers discussed post-membership actions minority suppliers should take to connect with large buying organizations and to ultimately grow sales. In this study, we explore how minority suppliers can make full use of non-profit organizations when trying to connect with large buying organizations and other minority-owned suppliers to grow sales. This study uses NMSDC as the empirical context and investigates how minority suppliers exploit their BMO membership most effectively through participation in BMO-sponsored activities.

National Minority Supplier Development Council

NMSDC is one of the country's leading business membership organizations helping minority suppliers grow sales by connecting with large buying corporations. NMSDC strives to match over 12,000 certified minority business enterprises (MBEs) to a vast network of corporate members who aspire to build relationships with minority suppliers under the mission of responsible sourcing. NMSDCs' network includes a national office in New York City, 23 regional offices throughout the US and 1800 corporate members operating worldwide (http://www.nmsdc.org/corporate-membership/corporate-members/). Based on a 2014 study by the NMSDC, their certified minority suppliers alone have a total economic impact of over $400 billion dollars in output that results in the creation of and/or preservation of more than 2.2 million jobs. These minority suppliers also generate close to $49 billion in tax revenue for the benefit of local, state, and federal governments. With the goal of training, developing, and growing minority suppliers NMSDC makes it easier for diverse suppliers to connect with large corporations.

To meet their supplier diversity goals, private companies search for minority suppliers through BMOs that have certification processes. For the 1700 corporate members of NMSDC, minority certification is an order qualifier in selecting minority suppliers. Membership in NMSDC and certification through NMSDC is often specified in corporate supplier diversity programs. In other words, to do business with these companies, minority suppliers must be certified through NMSDC. To connect with large buying

corporations, minority suppliers are expected to participate in various formal and informal activities hosted by NMSDC. These activities are designed to not only connect minority suppliers but also to assist in developing their capabilities. There are other reasons why minority businesses join BMOs. Government agencies and corporations set goals for buying from minority-owned companies, so becoming certified increases a minority suppliers chance of gaining business. Battisti and Perry (2015) reported evidence that small firms select BMOs based on prestige, access to learning from other members, and social opportunities.

In summary, researchers have emphasized different mechanisms by which minority suppliers gain access to large buying organizations. However, none of them have focused on non-profit business membership organizations as a source of gaining access. Specifically, we ask, "Are there economic gains associated with minority suppliers' participation in BMO-sponsored activities?" Our exploration is proposed as a promising approach to the study of supplier diversity and a natural extension of the existing literature.

Hypotheses Development

The above discussion suggests that connections with BMOs is a plausible path to growing sales for minority suppliers. Further, participation in various types of activities seems to be beneficial. In this section, a series of hypotheses are developed.

Participation and Expanding Social Networks

Participation in BMO-sponsored activities provides minority supplier the opportunities to meet and interact with other BMO members. NMSDC has two types of members; minority owned firms and large corporations. Per president of NMSDC, there are usually four types of BMO-sponsored activities. A summary of these four types is presented in Figure 6. First, BMOs serve as an advocate through lobbying, news media, etc. to promote and strengthen a universal understanding of the value of minority supplier development. Second, BMOs organize a certification process to examine and investigate each minority supplier to verify its viability, practices, and capacity for growth. Third, BMOs organize develop-oriented activities that assist and enable minority suppliers in expanding their capabilities to meet the needs of corporate members. Here, minority suppliers may choose to attend seminars on topics of interests or monthly-long training programs hosted by local universities/colleges or educational institutions. Seminar speakers come from large corporations to help minority suppliers understand corporate expectations, and assists in building key capabilities. They also come from other minority-owned firms, who are often role-models sharing success stories and good practices with fellow minority-owned firms. Mutual learning among minority suppliers is also encouraged for improvements in these occasions. Fourth, BMOs organize connect-oriented activities to introduce and facilitate a mutually beneficial business relationship between minority suppliers and corporate members. These connect-oriented activities can

be large group gatherings like annual meetings and award galas or more focused small social events like breakfast and golf trips.

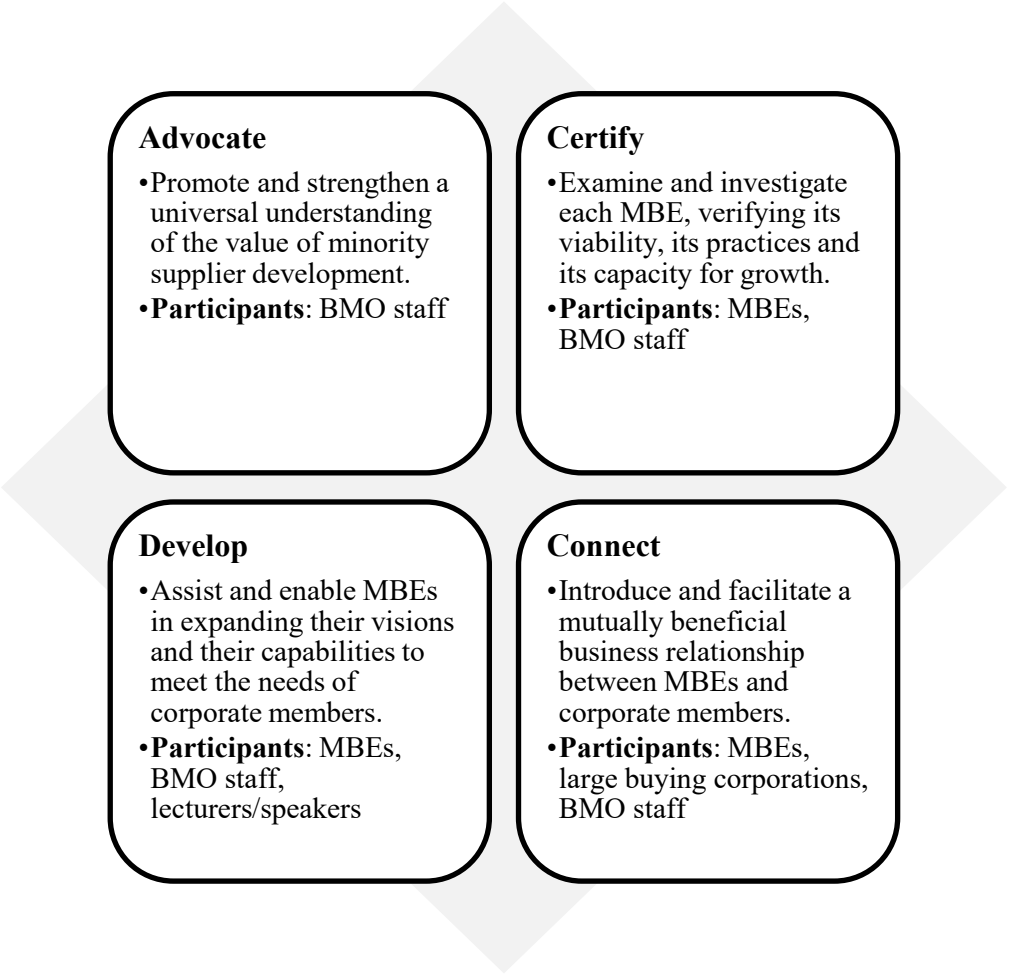


Figure 6 Types of BMO-sponsored Activities

If minority suppliers attend more BMO-sponsored activities over time, they enhance their chance of building personal relationships with other minority suppliers as well as corporate organizations. Cousins, Handfield, Lawson, and Petersen (2006) found informal socialization mechanisms, which refers to activities occurring outside workplaces such as social events, off-site workshops, etc., increase the level of trust between the interacting parties. Homans (1961) discusses how trust is produced through interpersonal interactions that lead to social-psychological bonds of mutual norms, commitment and cooperation. Ring and Van De Ven (1994) proposed that trust in other parties is a cumulative product of repeated past interactions among parties through which they come to build a relationship and evolve a common understanding of mutual commitments.

Thus, we propose:

Hypothesis 1: Participation in BMO-sponsored activities is positively associated with expanding social networks with external entities (both large corporations and other minority-owned firms).

Moreover, we argue that participation in different types of BMO-sponsored activities[7] may influence who the minority supplier can expand social networks with (corporate members or other minority-owned firms). Participation in connect-oriented activities is more effective in building relationships with large corporations since minority suppliers

[7] We do not discuss advocate activities and certification here as the former often represent the collective interests of the minority community, while the latter is a must-do for all minority suppliers to get considered by large corporations' minority purchasing program.

are exposed to a larger number of corporate members during connect-oriented activities than during develop-oriented activities. Also, when designing and organizing these connect-oriented activities, BMOs' objective is in facilitating social network building between minority suppliers and corporate members rather than among minority suppliers. Thus, minority suppliers may also spend more time talking to purchasing managers or investigators for direct business opportunities rather than to other minority-owned firms during such activities. In contrast, during develop-oriented activities, minority suppliers are exposed to a smaller number of corporate members but a larger amount of minority suppliers. Through the training process, it is likely that minority suppliers will develop relationships with other minority suppliers. Therefore, given the same participation level, the mix of connect- vs. develop-oriented activities participated by minority suppliers may have an impact on whom minority suppliers build relationships with. In summary, we propose the following hypotheses:

Hypothesis 2A (H2A): The positive effect of participation in BMO-sponsored activities on expanding social networks with large corporations becomes more positive when the proportion of connect-oriented activities is higher.

Hypothesis 2B (H2B): The positive effect of participation in BMO-sponsored activities on expanding social networks with other minority-owned firms becomes less positive when the proportion of connect-oriented activities is higher.

Expanding Social Networks and Sales Growth

Expanding social networks with external entities can be valuable mechanisms for minority suppliers' sales growth. First, personal relationships to purchasing managers of large corporations can increase the chance of being considered as a potential supplier. It is also more likely that managers will award contracts to a minority supplier that they know through BMO-sponsored activities. This is due to trust and a culture of mutual commitment created through personal relationships (Cousins & Menguc, 2006). Personal connections are important channels for managers to build reputation assessment of potential candidates in face of information asymmetry and uncertainties (Batjargal & Liu, 2004; Petkova, Wadhwa, Yao, & Jain, 2014). Social networks with large corporations can provide in-person opportunities for minority suppliers to convince potential buyers of their value. Consequently, minority suppliers are more competent in obtaining sales opportunities with large buying corporations.

Second, personal relationships with other minority-owned firms may bring in valuable information that leads to sales opportunities. It is found that personal relationships can facilitate information exchange (Lawson, Petersen, Cousins, & Handfield, 2009) and transfer of good practices (Cousins, Lawson, & Squire, 2008). Minority suppliers can learn from each other through such personal relationships as they often face similar challenges (Bengtsson & Johansson, 2014). Recent research in horizontal collaboration among small firms also suggests benefits of leveraging peers' resources on innovation performance (De Jong & Freel, 2010; McAdam et al., 2014). Jim Roberts, CEO of a

minority financial services firm and director of Michigan Minority Supplier Development Council, comments "[w]e need minority business owners to reach out to other minority business owners…It doesn't mean I am paying more. Connections make differences for minority firms." Thus, we expect expanding social networks with other minority-owned firms can be a driver to improve competency, which in turn translates into sales growth. Thus, we propose:

Hypothesis 3A (H3A): Expanding social networks with large corporations affiliated with a BMO is positively associated with sales growth.

Hypothesis 3B (H3B): Expanding social networks with other minority-owned firms affiliated with a BMO is positively associated with sales growth.

Research Method

Data Collection

Our data was collected via an online survey of minority suppliers with membership in the Ohio Minority Supplier Development Council (OMSDC). OMSDC is the Ohio regional branch of NMSDC and dedicates to providing a direct link between minority suppliers and corporations. OMSDC serves approximately 500 certified minority suppliers. We conducted a focus group with representatives of 10 minority suppliers attending a quarterly OMSDC meeting before survey distribution. These minority suppliers have been affiliated with OMSDC for at least five years. During the focus groups, minority supplier representatives were asked to share their views regarding OMSDC membership and benefits. A recurring theme was they wanted more opportunities to build

relationships with purchasing managers from large corporations. For instance, when asked about services offered by OMSDC that they would like to see in the future, representatives mentioned they need “assist in helping approach decision makers”, “more networking opportunities”, “face-to-face meeting with decision makers”, “more connection with big corporations to diversify and include more MBE's”, “more MBE to MBE services”, “forums geared to enhancing practices in different aspects of running a successful business”, etc. One representative also pointed out his own challenges to participate: “It is not that services are not provided; my personal challenge is being in a situation where I am unable to take advantage of what OMSDC offers! It is very difficult to break away from daily workload and stress to actually participate as well as reap the benefits of the services offered by OMSDC.” All these responses confirm the relevancy of our research question of how to participate wisely in BMO-sponsored activities given constraints of time and energy often faced by minority suppliers. We also asked for representatives’ understanding of the drafted survey instrument, which provided insights into the clarity of the questions included in the survey instrument.

When conducting the survey, we first contacted the president of OMSDC to go over the objective of the research study and asked for access to minority suppliers’ contact information. In administering the survey instrument, researchers emailed a letter to all 500 members, notifying them of an upcoming survey seeking insights into their interactions with OMSDC and benefits from such interactions. Three days later, executives of the 500 small suppliers received an email with an invitation to participate

by clicking an embedded hyperlink to the survey instrument. The links were individually tailored to the email recipient such that a CEO or President responded to questions that were different from those that were asked of functional managers (e.g., procurement or operations). A follow-up email was sent two weeks later to executives who had yet to respond to the invitation.

A total of 157 supplier surveys were logged in Qualtrics, with this total including duplicate and incomplete surveys. After removing duplicates and incomplete surveys we retained a total of 113 completed surveys for a response rate of 22.6%. We evaluated non-response bias by comparing minority suppliers that completed the survey against those that did not respond in terms of firm size (Rogelberg & Stanton, 2007; Wagner & Kemmerling, 2010). Two-tailed t-tests found no statistical difference between respondents and non-respondents with respect to employment size ($p=0.47$). In addition, we conducted a wave analysis (Armstrong & Overton, 1977), comparing the 41 small suppliers who completed the survey early (i.e., within 10 days of the initial email invitation) to the 29 who completed the survey late (i.e., within 10 days of the second follow-up email invitation). The early versus late responses did not differ with respect to employment size ($p=0.34$). A summary of sample firm characteristics and descriptions of all variables are included in Table 5 and 6, which is also described in the next section.

Variables	Description
salesup	Your firm’s sales revenue increased through affiliation with OMSDC (strongly disagree to strongly agree).
networkup_corp	Your firm’s social network with potential customers was expanded by your affiliation with OMSDC (strongly disagree to strongly agree).
networkup_MBE	Your firm’s social network with other minority-owned firms was expanded by your affiliation with OMSDC (strongly disagree to strongly agree).
no_activity	Number of activities your firm participated in.
p_connect	Proportion of connect-oriented types of activities (i.e. breakfast, golf, annual meeting, awards gala) your firm participated in out of all activities your firm participated in.
city_d	(categorical) which city is your firm located?
goalalign	Your firm's overall goals and values are shared by OMSDC (strongly disagree to strongly agree).
age	(categorical)How long have your firm been in business?
employment	(categorical)What is your firm’s organizational size (# of employees)?
government	(dummy)Does your firm conduct business with the government?
memberlength	How long have your firm been a member of OMSDC?
industry_d	(categorical) What is your firm’s industry classification?

Table 5 Variable Descriptions

Variables	Mean	Std. Dev.	city_d	Percent	government	Percent
salesup	3.256	1.127	1=Cincinnati	42.2%	1=Yes	44.5%
networkup_corp	3.473	0.953	2=Columbus	25.0%	2=No	55.5%
networkup_MBE	3.589	0.88	3=Dayton	11.7%		
no_activity	2.473	1.714	4=Other	21.1%	**age**	**Percent**
p_connect	0.578	0.339			1=1-3 years	11.6%
goalalign	2.125	0.813	**employment**	**Percent**	2=3-7 years	24.8%
memberlength	6.328	5.823	1=1-10 employees	53.9%	3=7+ years	63.6%
			2=11-20 employees	16.4%		
			3=21-50 employees	14.1%	**industry_d**	**Percent**
			4=51-100 employees	7.0%	1=Professional services	54.3%
			5=100+ employees	8.6%	2=Construction	15.5%
					3=Manufacturing	16.3%
					4=Retail & Wholesale	14.0%

Table 6 Sample Descriptions

Variables

Participation level

No_activitiy is a measure of participation level by minority suppliers in BMO-sponsored activities. Based on OMSDC's archival events calendar and our conversation with the focus group, a list of eight activities are identified including annual meetings, award gala, breakfast with board, center of excellence (COE), golf, MBE partner summits, MBEseminars, and industry-specific summits. In the questionnaire, we asked respondent's the average number of activities they participated in each year. Furthermore, we asked respondents for each of the eight activities, on average how many times did they participate.

Note that, since minority suppliers make the decision of how many activities they participate in per year, participation level is endogenous to relationships built and sales opportunities obtained. To correct for possible biases due to endogeneity, we used two instrumental variables *city_d* and *goalalign.* Details of these two instrumental variables are given in the method section.

P_connect is the proportion of average number of connect-oriented activities participated per year over the average total number of activities participated per year (*no_activity*). Two researchers from our team and four graduate students categorized the eight activities into connect-oriented activity type or develop-oriented activity type independently based on the primary function of these two activity types defined by NMSDC's 2013 annual report. Connect-oriented activities are to introduce and facilitate relationships between

MBEs and corporate members, while develop-oriented activities are to assist and enable MBEs in expanding their visions and their capabilities to meet the needs of corporate members. Admittedly, some activities may arguably serve dual purposes like annual meetings that are mainly social meetings but sometimes contain keynote sessions where speakers talk about trending practices. In such case, the researchers tried to categorize based on the primary function served by each activity. We also asked representatives in the focus group interviews whether the categorization is appropriate. The final categorization is as following. Connect-oriented activities consist of annual meetings, award gala, breakfast with board, and golf, while develop-oriented activities consist of center of excellence (COE), MBE partner summits, MBE seminars, and industry-specific summits. A summary of the categorization and sample descriptions of each activity type from OMSDC is provided in Table 7.

Expanding Social Networks and Sales Growth

Networkup_corp is a measure of the degree to which minority suppliers can build relationships with large corporations through their affiliation with OMSDC. Using a 5 point likert scale from strongly disagree to strongly agree we asked minority suppliers the following statement: “Your firm’s social network with potential customers was expanded by your affiliation with OMSDC”.

Networkup_MBE is a measure of the degree to which minority suppliers can build relationships to other minority-owned firms through their affiliation with OMSDC. Using a 5 point likert scale from strongly disagree to strongly agree we asked minority suppliers

the following the statement: “Your firm’s social network with other MBEs was expanded by your affiliation with OMSDC”.

Salesup is a measure of the degree to which minority suppliers can obtain sales growth through their affiliation with OMSDC. Using a 5 point likert scale from strongly disagree to strongly agree we asked minority suppliers the following statement: “Your firm’s sales revenue increased through affiliation with OMSDC”.

Control Variables

We included multiple control variables in our model to account for potential firm-level and industry-level factors. *Age* is a measure of the number of years that minority suppliers have been in business, while *employment* measures minority suppliers’ organizational size by number of employees. We also asked minority suppliers whether they conducted business with government, recorded as *government*, as minority suppliers may gain additional recognition and credibility from their experience with government contracts. *Memberlength* is a measure of how long minority suppliers have been a member of OMSDC. Long term members may learn the most effective way of participation. Finally, we recorded industry classification of minority suppliers in our sample as a four-category variable, *industry_d*, to account for industry-level differences.

Activity name	Example description
Connect-oriented activity	
Annual meeting	"Join [BMO's] Supplier Diversity Community as the SDC shares the strategic goals for the upcoming year at the Annual Meeting & Leadership Luncheon. The Annual Meeting is the best place to network with peers, learn from industry leaders and help advance supplier diversity initiatives."
Awards gala	"The Gala is the [BMO's] signature event, recognizing and celebrating the achievements of the Ohio's most notable MBEs and Corporate Members. The [BMO's] Awards Gala highlights the growth and success of minority business enterprise and the commitment to supplier diversity by the corporate members in the region."
Breakfast with board	"Join us for a networking breakfast and meet the [BMO's] leadership. This is an excellent opportunity to connect with supplier diversity professionals and minority entrepreneurs."
Golf	"Register for corporate/MBE golf classic package including green fees, golf cart, breakfast, lunch & awards dinner."
Develop-oriented activities	
Center of excellence (COE)	"This program lasts 18-24 months with all-day working meetings every other month covering areas such as Marketing/Branding, Strategic Selling, Organizational Structure, Quality, or Pricing Model. The objective of the program is to enhance corporate minority business development through knowledge sharing and excellence in implementing [BMO's] best practices."
MBE partner summits	"Join the [BMO] as they engage supplier diversity subject matter experts. Participants will learn next and best practice in supplier diversity and MBE capacity building."
MBE seminars	"How to get the most out of your MBE certification seminar." "Procurement 101: The participants can expect to learn: Some of the questions you should ask before responding to a corporate RFP; Best response methods; and the selection criteria used by supplier diversity executives."
industry summits	"U.S. Bank is partnering with the [BMO] to host the Economic Growth and Opportunity Summit. U.S. Bank Bankers and Small Business experts will kick off the summit by conducting a workshop on Access to Capital."

Table 7 Example Descriptions of Connect- and Develop-Oriented Activities

Method

Account for Endogeneity

Endogeneity issues seem plausible with the primary predictor of our model, i.e. how many BMO-sponsored activities minority suppliers decided to participate in each year. As we hypothesized, active choice by small suppliers to participate in BMO-sponsored activities is one main driver for them to grow sales. However, it will be problematic if we model this using conventional linear regression with assumption that the error term is not contemporaneously correlated with the participation level. This is because it is possible that some unobserved firm-level variables are positively related with both the decision to participate and outcome measures (i.e. relationship building, sales growth) in our model. For example, a minority supplier in a good financial condition may have the money to participate more, while good financing is also a predictor for sales growth. One approach to account for endogeneity, is to include multiple firm-level and industry-level co-variates in the model to reduce unobserved factors. Moreover, we used instrumental variables (*city_d* and *goalalign*) to mitigate the issue of endogeneity.

The basic logic in choosing appropriate instrumental variables is that these instruments should predict the endogenous variable, but are not expected to influence the outcome measures. The first instrument used for *no_activity* is *city_d*, a four-category variable recording which city minority suppliers are in (Cincinnati, Columbus, Dayton, and other). Upon our examination of past activities sponsored by OMSDC, it is found that most activities are hosted in Columbus which is the location of OMSDC's headquarter,

followed by Cincinnati, Dayton, and other cities. Given the burden to travel when activities are hosted in locations other than minority suppliers' base city, it is expected that geographic location can be a factor influencing minority suppliers' participation level. At the same time, geographic location does not translate *directly* to relationships or sales growth without participation in OMSDC-sponsored activities. This is because even if one can argue that certain locations may have the presence of larger population of buying corporations/other minority-owned firms, if the minority supplier does not participate in OMSDC-sponsored activities at all, they are not able to build relationships or gain sales through OMSDC. Notice, we measure sales growth by explicitly asking for the estimation of sales growth from OMSDC rather than general sales growth. Therefore, we argue *city_d* is a theoretically appropriate instrumental variable that influences participation level but not influences outcome measures *directly*.

The second instrument for *no_activity* is *goalalign*, which is a 5 point likert variable measuring the degree to which minority suppliers agreed with the statement "Your firm's overall goals and values are shared by OMSDC (from strongly disagree to strongly agree)". Minority suppliers are likely to participate more in BMO-sponsored activities when their goal and values are aligned more closely with BMO's. Meanwhile, we expect that goal alignment does not translate *directly* to any changes in expanding social networks or sales growth without some form of participation in BMO-sponsored activities. Therefore, we argue *goalalign* is also a theoretically appropriate instrumental

variable that influences participation level but does not influence outcome measures directly.

Methodologically, we also test for endogeneity and the strength and validity of our instrumental variables. We first conducted the Durbin–Wu–Hausman (DWH) test to look for the presence of endogeneity bias with participation level (*no_activity*). As expected, the null hypothesis that *no_activity* is exogenous is rejected for both *networkup_corp* and *networkup_MBE* (Dubin χ^2 is 4.302 ($p \leq 0.05$) and 5.387 ($p \leq 0.05$), respectively; Wu-Hausman F value is 3.879 ($p \leq 0.05$) and 4.905 ($p \leq 0.05$), respectively). Second, we check how strong our instrumental variables are. A good instrumental variable should be reasonably correlated with the endogenous variable instrumented, while uncorrelated with the error term of the dependent variable (Wooldridge, 2012). We regressed *no_activity* on instrumental variables *city_d* and *goalalign*, which produces model fit statistics showing significant correlation between our instrumental variables and the endogenous variable instrumented (partial R^2 for instruments=0.151, F=4.282 ($p \leq 0.01$)). Third, we checked if our theoretical arguments hold that these instrumental variables can only influence *networkup_corp* and *networkup_MBE* indirectly through the instrumented participation level, *no_activity*. That is, we test whether the instruments are uncorrelated with the structural error term (null hypothesis). The null hypothesis is not rejected for both *networkup_corp* and *networkup_MBE* (as Sargan χ^2 is 1.788 (p=0.618) and .637 (p=0.731), repectively; while Basmann χ^2 is 1.543 (p=0.672) and .541(p=0.763),

respectively). Overall, we concluded *city_d* and *goalalign* as sound instrumental variables for the endogenous variable *no_activity*.

Econometric Models for Hypothesis Testing

For Hypothesis 1, we used two-stage least squares (2SLS) estimation method for the following equations. In first stage, we regressed no_activity on instrumental variables (*city_d* and *goalalign*) along with all control variables (equation 1). In second stage, we regressed *networkup_corp* and *networkup_MBE* separately on the predicted value of *no_activity* estimated from the first stage along with all control variables (equation 2 and 3). $\boldsymbol{z}_i$ is the list of control variables mentioned above for observation i.

$$no\_activity_i = \alpha_1 city\_d_i + \alpha_2 goalalign_i + \alpha_3 p\_activity\_connect_i + \boldsymbol{z}_i\boldsymbol{\alpha} + v_i \quad (1)$$

$$networkup\_corp_i = \beta_1 \widehat{no\_activity_i} + \beta_2 p\_activity\_connect_i + \boldsymbol{z}_i\boldsymbol{\beta} + \mu_{c,i} \quad (2)$$

$$networkup\_MBE_i = \gamma_1 \widehat{no\_activity_i} + \gamma_2 p\_activity\_connect_i + \boldsymbol{z}_i\boldsymbol{\gamma} + \mu_{m,i} \quad (3)$$

For Hypothesis 2A (2B), we also used 2SLS estimation method. Due to incorporation of an interaction term between the endogenous variable *no_activity* and exogenous variable *p_connect*, the second stage model now has two endogenous variables. Following the approach by Hoisl and Mariani (2016), interaction term of corresponding instrumental variables and the exogenous variable p_connect is used as the instrumental variable for the new endogenous variable induced by the interaction of the original endogenous variable with the exogenous variable (Baltagi, Demetriades, & Law, 2009; Bun & Harrison, 2014). Therefore, when estimating the interaction effects, in first stage, we regressed no_activity on four instrumental variables (*no_city* and *goalalign*; and two

interaction terms: *city_d* times *p_connect*, and *goalalign* times *p_connect*) along with all control variables (equation 4). We also regressed the interaction term of no_activity and p_connect on these four instrumental variables along with all control variables (equation 5). In second stage, we estimated equation 2' and 3' using the predicted value of *no_activity* from equation 4 and the predicted value of the interaction term of *no_activity* and *p_connect* from equation 5 along with all control variables.

$$no\_activity_i = \alpha_1 city\_d_i + \alpha_2 goalalign_i + \alpha_3 city\_d_i * p\_activity\_connect_i + \alpha_4 goalalign_i * p\_activity\_connect_i + \alpha_5 p\_activity\_connect_i + \boldsymbol{z}_i\boldsymbol{\alpha} + v'_i \quad (4)$$

$$no\_activity_i * p\_activity\_connect_i = \delta_1 city\_d_i + \delta_2 goalalign_i + \delta_3 city\_d_i * p\_activity\_connect_i + \delta_4 goalalign_i * p\_activity\_connect_i + \delta_5 p\_activity\_connect_i + \boldsymbol{z}_i\boldsymbol{\delta} + v''_i \quad (5)$$

$$networkup\_corp_i = \beta_1 \widehat{no\_activity_i} + \beta_2 no\_activity_i * \widehat{p\_activity\_connect_i} + \beta_3 p\_activity\_connect_i + \boldsymbol{z}_i\boldsymbol{\beta} + \mu_{c,i} \quad (2')$$

$$networkup\_MBE_i = \gamma_1 \widehat{no\_activity_i} + \gamma_2 no\_activity_i * \widehat{p\_activity\_connect_i} + \gamma_3 p\_activity\_connect_i + \boldsymbol{z}_i\boldsymbol{\gamma} + \mu_{m,i} \quad (3')$$

For Hypothesis 3A (3B), as we argue that *networkup_corp* and *networkup_MBE* will in turn influence *salesup* together, we estimate equation 1, 2, 3, and equation 6 simultaneously through three-stage least-square (3SLS) regression.

$$salesup_i = \eta_1 no\_activity_i + \eta_2 networkup\_corp_i + \eta_3 networkup\_MBE_i + \eta_4 p\_activity\_connect_i + \boldsymbol{z}_i\boldsymbol{\eta} + \epsilon_i \quad (6)$$

Results

Model results for testing H1 and H2A(B) are displayed in Table 8, while results for testing H3A(B) are displayed in Table 9.

H1 is supported as *no_activity* is significantly, positively associated with *networkup_corp* and *networkup_MBE* after instrumenting (see Table 8). That is, as minority suppliers participate in more BMO-sponsored activities, they are more likely to expand social networks with large buying corporations and with other minority-owned firms ceteris paribus. In terms of control variables, firms with more than 50 employees are found to be more likely to expand social network with both large buying corporations and other minority-owned firms than firms with fewer than 10 employees. Also, a significant, negative association is found between *memberlength* and *networkup_corp*, suggesting minority suppliers that have joined OMSDC for a longer time are less likely to expand their social networks with large buying corporations, as well as with other minority-owned firms. This may be due to the upper bond of expanding social networks determined by the size of the BMO.

H2A is not supported as the interaction term between *no_activity* and *p_connect* is not significantly associated with *networkup_corp* (see Table 8). That is, whether minority suppliers participate in more connect-oriented activities does not influence the relationship between participation level and expanding social networks with large buying corporations. In other words, participation in connect-oriented and develop-oriented

	Instrumental variables (2SLS) regressions						
	Base Model			Interaction Model			
	First-stage regression	Second-stage regressions		First-stage regressions		Second-stage regressions	
	no_activity	networkup _corp	networkup _MBE	no_activity	Interaction term (no_activity X p_connect)	networkup _corp	networkup _MBE
no_activity†		.543(.157)*** (H1)	.534(.146)*** (H1)			.120(.346)	-.026(.340)
no_activity X p_connect†						1.027(.346) (H2A)	1.292(.717)* (H2B)
p_connect	.570(.425)	-.161(.285)	.013(.265)	4.981(2.652)*	2.694(1.611)*	-1.980(1.329)	-2.258(1.307)*
city_d							
2	.492(.372)			.657(.783)	-.019(.476)		
3	-.443(.475)			.043(.865)	.030(.502)		
4	-.555(.385)			-.756(.833)	.024(.506)		
goalalign	.607(.180)***			1.296(.436)***	.352(.264)		
city_d X p_connect							
2				-.250(1.277)	.256(.776)		
3				-.841(1.376)	-.903(.836)		
4				.263(1.126)	-.432(.684)		
goalalign X p_connect				-.134(.651)*	-.137(.395)		

Continued

Table 8 Participation and Relationships

Table 8 continued

age								
	2	-.564(.509)	.122(.341)	.483(.317)	-.700(.529)	-.520(.321)	.482(.467)	.917(.459)**
	3	-.697(.504)	-.159(.356)	.450(.331)	-.797(.519)	-.533(.315)*	.463(.457)	.801(.449)*
employment								
	2	1.035(.398)**	-.427(.316)	-.575(.294)	1.017(.405)**	.611(.246)**	-.641(.384)*	-.807(.377)**
	3	.207(.415)	-.068(.271)	-.245(.252)	.118(.423)	.095(.257)	-.159(.319)	-.348(.313)
	4	.382(.583)	.635(.384)*	.835(.357)*	.249(.592)	.094(.359)	.690(.445)	.920(.438)**
	5	-.205(.541)	.058(.348)	.549(.323)*	-.327(.553)	-.311(.336)	.201(.415)	.725(.408)*
government (=2)		-.043(.301)	-.104(.192)	-.121(.178)	-.034(.311)	-.128(.189)	.031(.241)	.046(.237)
memberlength		.055(.028)*	-.043(.022)**	-.049(.020)**	.063(.029)**	.042(.017)**	-.059(.027)**	-.068(.027)**
industry_d								
	2	.350(.403)	-.175(.264)	.113(.246)	.318(.410)	.107(.249)	-.142(.305)	.171(.200)
	3	-.654(.412)	.353(.280)	.380(.261)	-.561(.428)	-.258(.260)	.367(.321)	.377(.315)
	4	-.223(.427)	.019(.272)	.217(.253)	-.370(.438)	-.194(.266)	.044(.315)	.244(.310)
constant		.210(.881)	2.347(.525)***	2.058(.488)***	-2.389(1.806)	-.716(1.097)	2.670(.626)***	2.544(.616)***
Number of obs		113	113	113	113	113	113	113
F		2.70***			2.32***	4.84***		
R-squared		0.311			0.336	0.512		
Wald-chi2			20.3*	29.99***			19.22	24.21**
Root MSE			.927	.862	1.432	0.87	1.073	1.054

*p≤0.1, **p≤0.05, ***p≤0.01

† Predicted values from first-stage regressions are used for the corresponding endogenous variables in the second-stage regressions.

		Three-stage least-squares (3SLS) regressions†			
		no_activity	**networkup_corp**	**networkup_MBE**	**salesup**
no_activity			.542(.157)***	.535(.146)***	2.225(1.579)
networkup_corp					-8.904(4.922)* (H3A)
networkup_MBE					5.988(2.261)*** (H3B)
p_connect		.524(.390)	-.161(.285)	.013(.265)	-1.823(1.317)
city_d					
	2	.293(.298)			
	3	-.283(.376)			
	4	-.331(.309)			
re_goalalign		.735(.158)***			
age					
	2	-.577(.468)	.122(.341)	.483(.317)	-1.504(1.332)
	3	-.742(.463)	.159(.356)	.450(.331)	-.937(1.312)
employment					
	2	1.085(.366)***	-.427(.316)	-.575(.294)*	-.625(1.412)
	3	.174(.382)	-.068(.271)	-.245(.252)	1.046(1.005)
	4	.343(.537)	.635(.384)*	.835(.357)**	1.330(1.882)
	5	-.165(.497)	.058(.348)	.549(.323)*	-2.310(1.583)
government (=2)		-.094(.276)	-.104(.192)	-.121(.178)	-.405(.734)
memberlength		.058(.026)**	-.043(.022)**	-.049(.020)**	-.140(.128)
industry_d					
	2	.277(.369)	-.175(.264)	.113(.246)	-2.104(1.471)
	3	-.753(.377)**	.353(.280)	.380(.261)	1.589(1.350)
	4	-.289(.391)	.019(.272)	.217(.253)	-.340(1.060)
constant		-.211(.785)	2.347(.525)***	2.058(.488)***	10.203(7.208)
number of obs		113	113	113	113
chi-square		54.78***	20.3**	29.99***	53.56***

*p≤0.1, **p≤0.05, ***p≤0.01

†All equations shown were estimated simultaneously via 3SLS.

Table 9 Relationships and Sales Opportunities

activities are equally effective in terms of expanding social networks with large buying corporations.

H2B is not supported as the interaction term between *no_activity* and *p_connect* is significantly, positively associated with *networkup_MBE* while we hypothesized a negative relationship (see Table 9). To better interpret the moderation effects, we drew an interaction plot as illustrated in Figure 7. We choose one standard deviation below and above the average as the low and high level for proportion of connect-oriented activities participated by the minority supplier (*p_connect*), respectively. Only at extreme when minority suppliers participate in only one activity, our expectation is confirmed such that participate in develop-oriented activity is more likely to lead to expanding social networks with other minority-owned firms. However, at higher participation level (participation in more than one activity), minority suppliers that participate in more connect-oriented activities are more likely to expand social networks with more minority-owned firms than those that participate in the same number of activities but fewer connect-oriented activities.

H3A is not supported as *networkup_corp* is found to be significantly, negatively associated with *salesup* (see Table 9). This is opposite of what we hypothesized, as expanding social networks with large buying corporations does not have a positive influence on increasing sales for minority suppliers. This result is surprising and seems to be at odds with the practices in most BMOs which dedicate resources to facilitate social

network building between minority suppliers and large corporations. In next session, we explore this finding further by investigating several contingencies.

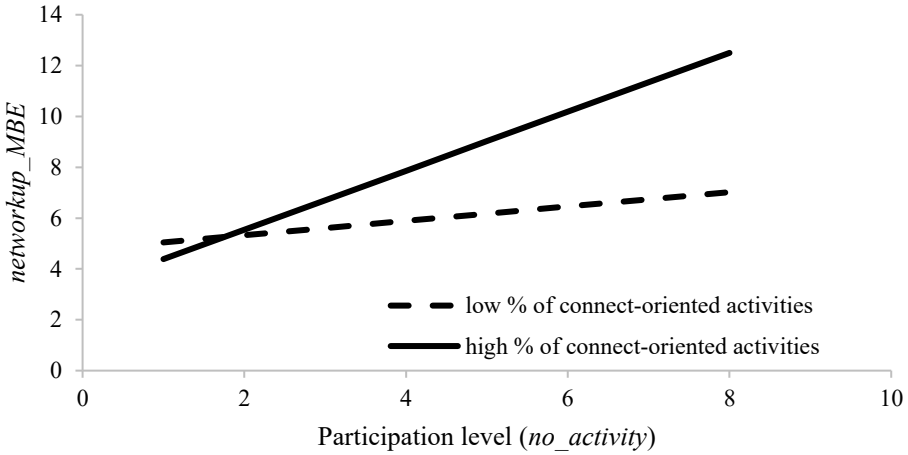


Figure 7 Interaction plot for types of activities participated and relationship building

H3B is supported as *networkup_MBE* is found to be significantly, positively associated with *salesup* (see Table 9). As hypothesized, expanding social networks with other minority-owned firms has a positive impact on increasing sales for minority suppliers, ceteris paribus.

Post-hoc Analyses

To further understand our findings, we ran post-hoc analyses on potential moderation effects of age and firm size on sales opportunities. Previous research has suggested that age and size moderate the effect of inter-organizational social networks on firm

performance (Blount, Smith, & Hill, 2013). Hence, we added interaction terms between *networkup_corp* and *age* and between *networkup_corp* and *employment* and then estimated the 3SLS model again. Similarly, we ran another 3SLS model by adding interaction terms between *networkup_MBE* and *age* and between *networkup_MBE* and *employment*. Model results estimated through 3SLS are reported in Table 10 (for brevity, we only reported model estimates on the final equation on sales opportunities).

Regarding expanding social networks with large corporation, the relationship between *networkup_corp* and sales opportunities is moderated by firm size but not by age. Specifically, this relationship becomes more positive as firm size becomes smaller. We graphed the interaction plot to illustrate the moderation effects of firm size on *networup_corp* in Figure 8A. As shown from the graph, only for minority suppliers with fewer than 10 employees (solid line), expanding social networks with large buying corporations is associated with increased sales opportunities (positive slope).

Regarding expanding social networks with other minority-owned firms, the relationship between *networkup_MBE* and sales opportunities is moderated by both age and firm size. Specifically, this relationship becomes more positive as minority suppliers are younger and smaller. We graphed the interaction plot to illustrate the moderation effects of firm size on *networup_MBE* in Figure 8B and the moderation effects of age in Figure 8C. This finding suggests that smaller minority firms (fewer than 10 employees, figure 8B) and younger minority firms (1 to 3 years old, figure 8C) benefit more from expanding social networks with other minority-owned firms.

	Moderation models (DV: salesup)			
	Moderators			
	age		employment	
	networup_corp	networup_MBE	networup_corp	networup_MBE
no_activity	-.035(.250)	.030(.477)	-.173(.271)	-1.265(.301)***
networkup_corp	-5.474(6.163)	1.477(1.460)	1.708(.701)**	2.175(.269)***
networkup_MBE	2.192(.438)***	1.595(.780)**	1.272(.242)***	.772(.306)**
networkup_corp X age				
2	4.691(5.329)			
3	4.745(5.241)			
networkup_corp X employment				
2			**-1.533(.722)****	
3			**-1.808(.677)*****	
4			**-1.642(.986)***	
5			**-1.855(.756)****	
networkup_MBE X age				
2		**-1.995(.951)****		
3		**-1.865(.874)****		
networkup_MBE X employment				
2				-.138(.488)
3				-.423(.390)
4				-.538(.634)
5				**-1.388(.569)****
p_connect	.324(1.097)	-.333(.403)	-.852(.363)**	.112(.330)
age				
2	-18.216(20.051)	7.725(3.663)**	-.070(.413)	-.526(.389)
3	-18.253(19.826)	7.276(3.329)**	.451(.476)	-.611(.403)
employment				
2	.686(.444)	.070(.441)	5.728(2.425)**	1.929(1.630)
3	.676(.367)*	.138(.329)	6.647(2.311)***	2.078(1.364)
4	-.624(.588)	-.155(.514)	5.202(3.947)	1.167(2.748)
5	-.856(.515)*	.587(.548)	5.975(2.594)**	5.270(2.183)**
government (=2)	.142(.302)	-.127(.224)	.219(.238)	.141(.222)
memberlength_1	.016(.028)	-.015(.039)	-.006(.028)	.102(.030)***
industry_d				
2	.235(.344)	.294(.469)	-.051(.271)	.591(.315)*
3	.313(.294)	.331(.431)	.005(.287)	-.535(.332)
4	.149(.540)	1.108(.397)***	.673(.232)***	.566(.298)*
constant	15.647(19.349)	-8.271(4.293)*	-6.823(2.217)***	-4.399(1.112)***
number of obs	113	113	113	113
chi-square	107.59***	83.95***	145.83***	121.52***

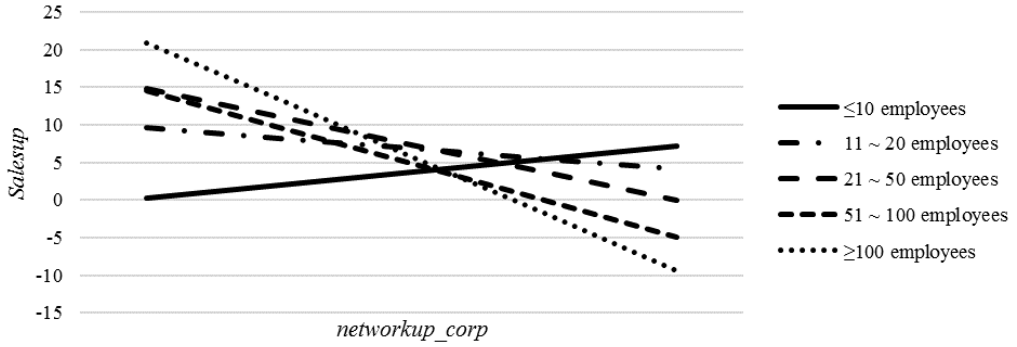
*p≤0.1, **p≤0.05, ***p≤0.01

†All equations shown were estimated simultaneously via three-stage least-squares (3SLS).

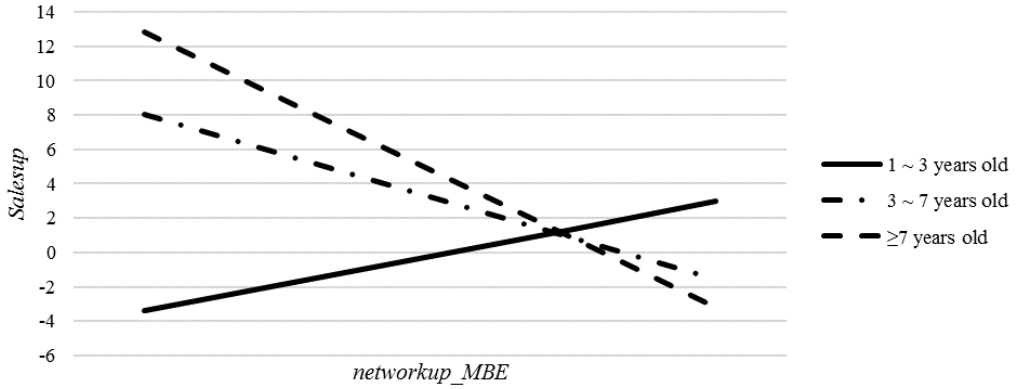
Table 10 Moderation Effects of Age and Employment

Discussion and Conclusions

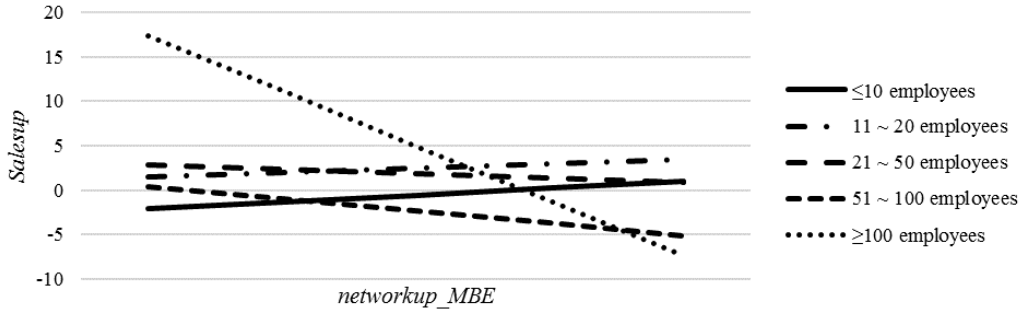
The most surprising result of our study is that expanding social networks with large buying corporations is not as beneficial as social network theory suggests for growing sales. Theories on the benefits of social networks emphasize their facilitating effects on business exchanges from trust and friendship arisen from personal connections (Shane & Cable, 2002). While such facilitating effects have been empirically found in various contexts, an underlying prerequisite has not been explicitly discussed. That is, the parties involved should be able to demonstrate capabilities necessary for the business exchange to build trusts and credibility. Many previous studies investigated impacts of social relationships on samples of large majority-owned businesses who are assumed to be capable. However, in our case, many minority suppliers may not have the resources and experience to meet that prerequisite. Based on the Institute of Supply Management (ISM)'s 2011 Supplier Diversity Survey, "finding quality suppliers" is the most cited challenge with supplier diversity program (with over seventy percent of the respondents citing, more than forty percent higher than other challenges cited). If minority suppliers are not able to convince potential customers that they are qualified, large buying corporations may hesitate providing contracts.



A



B



C

Figure 8 Interaction plots for employment and age on sales opportunities

Racial and gender biases may also play a significant role in shaping relationship between minority suppliers and large buying corporations. Based on a 2010 study by CB Insights, venture capitalists are more likely to back white males over minorities and women. Research also shows white men are more likely to vouch for other white male job seeker than a different race/gender job seeker, where greater trust in the competency of the person being referred and confidence that the person will do a good job are needed (McDonald, 2011). This gender/race difference is not found when white men are simply providing information for job openings. Overall, social networks with large buying corporations may not be able to generate the trust and friendship anticipated in social networks theories for minority suppliers. Consequently, expanding social networks with large buying corporations is not strongly correlated with sales growth.

Our contingency analysis further reveals that the benefits from expanding social networks with large buying corporations are largest for extremely small minority suppliers. One explanation is that for small minority suppliers, such benefits may lie with mere exposure to a bigger pool of potential buyers versus the facilitating effects from trustworthy relationships. Taken together, our study contributes to the literature by showing that expanding social networks with large corporations is not sufficient for minority suppliers to grow sales. For disadvantaged firms, like minority suppliers in our case, it is not as straightforward as it seems to translate social networks with large buying corporations into sales growth.

Further, our study suggests social networks with other minority suppliers can be effective in growing sales, especially for smaller, younger minority suppliers. The "Homophily principle" suggests that contact between similar people occurs at higher rate than among dissimilar people (McPherson, Smith-Lovin, & Cook, 2001). Also, resources and information become more accessible when a firm interact with network partners with similar race/gender (McDonald, 2011). Our findings provide empirical supports that social networks with other minority suppliers can be beneficial. Other minority suppliers can provide good practices and trending information, which in turn helps grow sales. The contingency analysis further suggests that minority suppliers with fewer resources and less experience (smaller and younger) may depend more on their homologous networks to obtain the necessary knowledge and resources. Thus, expanding social networks with other minority suppliers are more positively related to sales growth for them.

Finally, this study makes recommendations on the type of activities to participate in for minority suppliers, as well as recommendations for BMO administrators. We find participation in connect-oriented activities is more effective in building social networks with other minority suppliers compared to develop-oriented activities. Previous study also suggests that minorities tend to form racial homophilous networks from very beginning and persist despite efforts to promote interracial interaction (Mollica, Gray, & Trevino, 2003). Given the benefits of expanding social networks with other minority-owned firms, minority suppliers are recommended to participate in more connect-oriented activities. Currently, many BMOs often advocate that their mission is to connect

minority suppliers to large buying corporations. This study recommends BMO administrators also consider expanding social networks among minority suppliers as part of the mission. This is particularly relevant to younger and smaller minority suppliers with BMO membership. At the same time, we are not suggesting that BMOs abandon facilitating social networks between minority suppliers and large buying corporations, but to understand more investments and careful designs are needed to overcome the racial barriers and to improve the relationship quality for the networks built.

Several limitations in our study may suggest potential avenues for future research. First, our sample is limited to members of a local BMO. While constraining all respondents affiliated under the same BMO reduced additional variance otherwise introduced, future investigation may test generalization of our findings in a national sample. Second, a further extension can investigate whether minority suppliers participate differently for different BMOs. And if so, how they allocate resources and time to participate between multiple BMOs. Whether our findings regarding BMO for diversity suppliers can generalize to other types of BMOs also needs future investigation. Third, we do not have information on the relationship quality of the social networks expanded through participation in BMO-sponsored activities, which as we discussed can help explain our findings. We hope future research can consider this perspective for more insights. Finally, we acknowledge potential sources of uncontrolled endogeneity in our empirical methods. While we used the instrument variable approach in our model to account for endogeneity of participation decisions, we are aware that no econometric procedure is

perfect. Nevertheless, we are confident that our results are as accurate as possible given the nature of the empirical data we collected.

Chapter 4: Conclusions

This dissertation aims to provide empirical understanding of and solutions to operational challenges faced by small firms with non-vertical collaborations. This purpose is fulfilled by two empirical studies that examined two types of non-vertical collaborations.

The first study focuses on the management of the tension between access to resources and IP protection when small firms collaborate with research institutions for R&D. I analyzed secondary data assembled through multiple public databases for a sample of 1374 R&D projects conducted by small firms under federal grant programs. Heckman selection model is used to address issue of sample selection and endogeneity when estimating the models. Differences in performance as influenced by project novelty and formal IP rights are examined between projects conducted by small firms internally and those through external collaborations with research institutions. The key finding is that small firms with a higher level of formal IP rights may suffer from "IP lock-up" when they collaborate with research institutions in high novelty R&D projects. That is, the likelihood of commercialization success for external R&D projects becomes lower at high project novelty level when small firms possess more formal IP rights. This finding suggests that small firms face the challenge of maintaining their own competency in the form of

intellectual property during non-vertical R&D collaborations, especially when novelty is high (which implies high uncertainties).

The second study focuses on understanding how small minority suppliers can participate in BMO-sponsored activities most effectively for sales growth. I analyzed primary data collected through a survey of 113 small minority suppliers affiliated with the Ohio Minority Supplier Development Council. The challenge faced by these minority suppliers is how to best exploit their membership with the consideration of limited time and resources. I hypothesize that sales growth can be achieved by expanding social networks with other minority-owned firms and large buying corporations through participation in various BMO-sponsored activities. As participation is an endogenous decision made by minority-owned firms, 2SLS model is used for model estimation. The key finding from this study is that minority suppliers should participate in more connect-oriented activities to expand social networks with other minority-owned firms, which in turn leads to increased sales growth. In contrast, expanding social networks with large buying corporations is not positively associated with sales growth. These findings raise doubts on the popular approach in many BMOs that advocate building vertical relationships to large corporations. Our study shows that minority suppliers can benefit more from non-vertical relationships to other minority-owned firms through their collaborations with BMO.

In summary, these two empirical studies discover operational challenges faced by small firms during non-vertical collaborations; moreover, solutions to overcome these

challenges are explored. Insights from these studies suggest future research directions regarding non-vertical collaborations for small firms. Next, I will discuss future directions by types of non-vertical collaborations.

Future Directions for Non-Vertical Collaborations with Research Institutions

My first study suggests small firms should be aware of resources required to coordinate research activities and to protect their own intellectual property when collaborating with research institutions. When resource commitment is too high, they may prefer keeping R&D internally rather than collaborating non-vertically with external parties. Future research can investigate how to mitigate coordination costs and IP leakage risks given project novelty and complexity level. Currently, a formal IP agreement is often signed for collaborations between small firms and research institutions. However, the conflict between a firm's interests to keep the secrecy and researchers' interests to publish and share is not easily resolved. Consequently, small firms often have a higher expectation on lead time and lower interests in generalizability, while research institutions are more patient for discoveries that can be generalized. Thus, future research can also investigate dynamics in time and scope management for R&D projects conducted under collaborations with research institutions.

Future Directions for Non-Vertical Collaborations with Membership-Based Organizations

My second study suggests minority suppliers should choose wisely the types of activities to participate in as they are constrained by time and resources. Previous studies also

indicated that firms may choose to be members of multiple organizations for a bundle of services and activities as a single BMO may specialize in certain services (Bennett & Ramsden, 2007). Specialist membership-based organizations obtain advantages of scale and scope and combines individual and collective benefits to mitigate the effects of "free-riding". Future research can build upon my findings to explore how optimal bundling can be achieved through collaborations with multiple membership-based organizations given limited time and resources.

In my study lobbying is not examined. Lobbying is another primary activity carried out in membership-based organizations. National Minority Supplier Development Council invests heavily in lobbying to promote and strengthen universal understanding of the value of minority supplier development. While participation in lobbying will not increase sales directly, it provides a channel for minority suppliers to express their interests to government and public organizations. In the long term, it can be beneficial for their survival and growth. This is important for the prosperity of the minority community, as well as for other disadvantaged groups such as small businesses in general and women-owned firms. In fact, because of advocacy, large corporations are now required to have a diverse supply chain including minority suppliers and other disadvantaged businesses. Future research can take on the perspectives of disadvantaged businesses, or large corporations, or membership-based organizations to investigate how they can collaborate for better public policy.

Future Directions for Non-Vertical Collaborations with Competitors

My second study suggests building relationship to other minority-owned firms, who are competitors when competing for sales to large corporations. Since minority suppliers belong to a smaller and disadvantaged community, they have an even harder time than small majority-owned suppliers to find connections to large corporations and financing. Therefore, it is more important for minority suppliers to establish collaborations within the minority business community. While minority suppliers still compete, collaborations with each other can increase their joint power when dealing with large buying corporations (Ghaderi & Leman, 2013). Future research can investigate the situations in which connections to other minority-owned firms are more positively associated with performance improvements. Alternatively, are there certain barriers that prevent minority suppliers from benefiting from their relationships with other minority-owned firms? More generally, a key challenge for collaborating with competitors is how to maintain one's own competency while leveraging competitors' resources and capabilities. Fukugawa (2006) suggested that dense communication and a high level of commitment are important to establish trusts when collaborating with competitors. Meanwhile, Forrest (1990) noted that small firms' technological prowess and technology leadership are the key to maintain an advantage in collaborations with other small firms. While the former study suggests a way to improve relationship quality for better cooperative outcomes, the latter points out the importance for small firms to protect their key prowess

during collaboration. Future research opportunities on collaboration with competitors is to combine these two perspectives and explore how small firms can obtain the best outcomes from a collaborative relationship without dampening their own competency. Finally, how can other organizations like government, BMOs, and large buying corporations assist in building mutually beneficial relationships among small firms?

Future Directions for Non-Vertical Collaborations with Government

Government can play a critical role in facilitating relationship building and providing trainings and information for small firms. My first study is in the context of a federal granting program that provides funds for formal collaborations between small firms and research institutions. Moreover, federal agencies post solicitations of research topics that guide small firms' research directions and open future federal purchasing opportunities. In other words, federal agencies are providing a complete process where small firms initiate their innovation with government funding, find research partners with government supports, and ultimately sell to federal agencies with the developed products. Findings from my study provides recommendations for federal granting programs on applicant evaluations and IP regulations. Future research can generate additional policy insights on the management of this whole innovation-partner-market process. Potential research questions include: Should small firms collaborate with government in each development stage? If so, how much do they collaborate with government? To what degree, do they customize their innovation to government interests? In other words, should small firms conduct R&D specific to government solicitations or generic to the

interests of the market? Is there a balance between these two approaches and under what conditions?

Another topic related to collaborations with government is regulation. Many small firms complain that excessive filings and regulations are the biggest barrier in working with government. Mechanisms assisting small firms to cope with regulations can be investigated in future research. Some BMOs provide workshops and trainings that provide hands-on assistance for small firms to deal with government paperwork. Except for BMOs, are there other organizations who can help small firms? Alternatively, how can the government itself improve their policies to ease the work?

In conclusion, my dissertation contributes to the small business community by providing suggestions to cope with challenges during collaborations with research institutions and membership-based organizations. Insights from my studies suggest an abundance of future research opportunities to assist small firms in conducting non-vertical collaborations.

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Appendix A: Chapter 2 Subset of Interview Questions

Questions for award applicants

1. How did you decide to apply for SBIR/STTR grants? Where do you learn about it?
2. Did you search for alternative funding opportunities?
3. Why did you choose SBIR or STTR? What are the considerations? What are the pros and cons?
4. If STTR, how did you find your R&D partner?
5. How did you distribute the work with your partner?
6. How did you split the grant? Were there any conflicts? Can you describe it?
7. What's your usual arrangement with respect to patent, invention, etc. in the IP agreement? Who owns the technology?
    a. State specifically the degree of responsibility, and ownership of any product, process, or other invention or innovation resulting from the cooperative research. The degree of responsibility shall include responsibility for expenses and liability, and the degree of ownership shall also include the specific rights to revenues and profits.
    b. State which party may obtain United States or foreign patents or otherwise protect any inventions resulting from the cooperative research.

c. State which party has the right to any continuation of research, including non-STTR follow-on awards.

d. If previous IP exists, state the arrangement in regard to usage of previous IP which will allow the practice and commercialization of the inventions resulting from the cooperative research.

8. Were there conflicts in negotiation of IP agreement? Can you describe it?
9. What's the main revenue source from your collaboration? What is the success rate from your previous experience?
    a. Revenue from patent licensing agreement?
    b. Sales from commercializing product/technology/services developed from the collaboration?
    c. Attracting third-party capital investment?
    d. Other?
10. What are the factors determining success of commercialization?
    a. Third-party capital investment
    b. University involvement/commitment
    c. Cooperative process
    d. Innovation outcome type
    e. Other?
11. Besides STTR grants, did you search for additional investment from third-party during phase I and phase II? Does having partner help in such search?

12. What did you do to improve the chance of getting phase II awards?
13. (University researcher only) Is there any policy or expectations in your university about achievements from such collaboration? How are achievements measured?
    a. Patent
    b. Publication
    c. Grant amount
    d. Revenue from commercialization (sales, license royalty, etc.)
    e. Other?
14. (University researcher only) Are there additional supports/benefits from the university provided for researcher in collaborating with small business in addition to the STTR grants?
    a. Scholarship
    b. Stipend
    c. Special weights in tenure consideration
    d. other

Questions for NIH administrators

1. What are the main types of innovation outcomes?
2. What is the review process?
3. What are the factors the SBIR/STTR reviewers consider in evaluating proposals?
4. How do you assess them? Are there differences when evaluation SBIR and STTR applicants?

5. What is the main criterion used for phase II applications? How is it assessed?
6. From your experience, what are the factors determining success of phase II?
7. How do you decide whether phase II collaboration is successful?
8. How would you measure commercialization success?

Appendix B: Chapter 2 NIH SBIR/STTR Review Criteria

Significance

Does the project address an important problem or a critical barrier to progress in the field? If the aims of the project are achieved, how will scientific knowledge, technical capability, and/or clinical practice be improved? How will successful completion of the aims change the concepts, methods, technologies, treatments, services, or preventative interventions that drive this field? Does the proposed project have commercial potential to lead to a marketable product, process or service?

Investigator(s)

Are the PD/PIs, collaborators, and other researchers well suited to the project? If Early Stage Investigators or New Investigators, do they have appropriate experience and training? If established, have they demonstrated an ongoing record of accomplishments that have advanced their field(s)? If the project is collaborative or multi-PD/PI, do the investigators have complementary and integrated expertise; are their leadership approach, governance and organizational structure appropriate for the project?

Innovation

Does the application challenge and seek to shift current research or clinical practice paradigms by utilizing novel theoretical concepts, approaches or methodologies,

instrumentation, or interventions? Are the concepts, approaches or methodologies, instrumentation, or interventions novel to one field of research or novel in a broad sense? Is a refinement, improvement, or new application of theoretical concepts, approaches or methodologies, instrumentation, or interventions proposed?

Approach

Is the overall strategy, methodology, and analyses well-reasoned and appropriate to accomplish the specific aims of the project? Are potential problems, alternative strategies, and benchmarks for success presented? If the project is in the early stages of development, will the strategy establish feasibility and will particularly risky aspects be managed?

Environment

Will the scientific environment in which the work will be done contribute to the probability of success? Is the institutional support, equipment and other physical resources available to the investigators adequate for the project proposed? Will the project benefit from unique features of the scientific environment, subject populations, or collaborative arrangements?

Appendix C: Chapter 2 Literature Review

Reference	Unit of analysis	Small firms	RI	RQ1: Decision	RQ2: Commercialization success	Independent variables		
						Project novelty	Formal IP rights	other
Arora & Gambardella 1990	Firm		X	X				complementarity
Pisano 1990	Project			X				small number bargaining hazard, R&D dependence
Sinha & Cusumano 1991	Firm			X				resource complementarity, proprietary value of technology
Zahra & Das 1993	Firm				X			product/process, desire to be a leader/follower, R&D intensity
Arora & Gambardella 1994	Firm		X	X			X	scientific capability (publications), R&D intensity
Shan, Walker, & Kogut 1994	firm	X	X		X			network embeddedness, product diversity, access to public funding

Continued

Table 11 Chapter 2 Literature Review

Table 11 Continued

Zahra & Bogner 2000	firm		X		X	X	X	intensity of product upgrades, R&D intensity, environment characteristics (dynamism, hostility, & heterogeneity)
Gans et al. 2000	firm	X		X			X	complementary resources, association with venture capitalist
Romijn & Albaladejo 2002	firm	X	X		X			founder background, workforce skill, R&D intensity, network intensity, proximity
Zahra & Nielsen 2002	firm				X			formality
Zucker, Darby, & Armstrong 2002	firm		X		X			technological capability (publication), venture capital funding
Laursen & Salter 2004	firm			X				openness
Rothaermel & Deeds 2004	project				X		X	exploration vs. exploitation alliances
Karim & Mitchell 2004	firm				X			business unit reconfiguration

Continued

Table 11 Continued

Hsu 2006	firm	X		X	X		X	venture capital funding
Arora & Ceccagnoli 2006	firm			X			X	complementary resources
Lavie & Rosenkopf 2006	project			X				organizational inertia, absorptive capacity
Zhao 2006	firm			X			X	
Cassiman & Veugelers 2006	firm		X		X		X	reliance on university
Ziedonis 2007	project		X	X				uncertainty
Okamuro 2007	project	X	X		X			share mechanisms
Gans et al. 2008	project			X			X	patent timing, patent characteristics
Dechenaux et al. 2008	project		X		X		X	lead time, secrecy, learning effectiveness
Rothaermel & Alexandre 2009	firm				X	X		absorptive capacity
Link & Ruhm 2009	project	X	X		X			non-government funding
De Jong & Freel 2010	firm	X		X				distance
Nieto & Santamaría 2010	firm	X	X		X			product/process, partner type
Cui et al. 2012	firm		X		X		X	trust, stability, defined goal

Continued

Table 11 Continued

Alcácer & Zhao 2012	project			X			X	internal linkages, local competitor expropriation
Chun & Mun 2012	firm	X	X	X			X	incoming knowledge spillover
Burg & Oorschot 2013	project	X	X	X				fairness, R&D experience, learning
Arora et al. 2014	firm			X	X			centralization
Belderbos et al. 2014	project		X		X		X	technological diversity
Gesing et al. 2015	firm		X		X			collaboration governance
Grigoriou & Rothaermel 2016	firm		X		X			internal knowledge re-combinative potential, internal coordination burden