DIFFERENTIAL BENEFITS TO FIRMS PARTICIPATING IN MULTIPARTNER COLLABORATIVE INNOVATION

by

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STATEMENT OF DISSERTATION APPROVAL

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ABSTRACT

Great innovations seldom come from a single individual or firm. Rather, entire networks of people, usually sponsored by many firms drive great innovation, innovation that is rarely captured in a single product or service, but an entire platform sponsored by an ecosystem of firms. Many of these innovative platforms are guided by a visible hand, coalitions of firms that coordinate and collaborate. One such “visible hand” is the multipartner alliance, a collection of tens, hundreds, or even thousands of firms assembled to collaboratively define, develop, and promote innovation. While much research in collaborative innovation assumes homogenously available benefits and an exogenously determined appropriation of these benefits, this dissertation assumes heterogeneity and explores the degree to which benefits may be endogenously determined. The benefit of interest is a firm’s own innovation productivity based on technologies defined by the multipartner alliance. In studying firm actions, choices, and characteristics as they relate to participating in multipartner alliances, I examine the relationships between a firm’s innovation productivity and its entry timing, value-chain position, level of membership, contribution, timing of contribution, and size. These are tested primarily using hierarchical negative binomial regression and an original dataset developed in cooperation with the Bluetooth Special Interest Group, a multipartner alliance of over 12,000 firms interested in defining, developing, and promoting short range wireless technology. Empirical findings suggest support of heterogeneity in the availability of benefits and a degree of endogeneity in how they are appropriated.

This dissertation is dedicated to Pam, Karla, Amandee, Nathan, Jaron, Mom and Dad

To Pam for encouraging and accepting

To Karla, Amandee, Nathan, and Jaron for adapting

To Mom and Dad for promoting endless learning

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CHAPTER 1

INTRODUCTION

Collaborative innovation is responsible for invention, development, and exploitation of many of the world's great information technologies from the internet to wireless connectivity to smart energy. These innovations that require substantial "interrelated changes in product design, supplier management, information technology, and so on" (Chesbrough & Teece, 1998:3) frequently go well beyond the boundaries of a single firm and may require the innovation efforts of tens, hundreds, or even thousands of firms. The market's invisible hand often shapes the ongoing efforts of firms creating and capturing economic value from these innovations. However, hybrid forms of organizations often surface to satisfy the complementary needs of technology or to aid in the winnowing efforts of the industry to achieve a dominant design. One hybrid form, multipartner alliances, may be created to more formally coordinate the collaborative innovation activities of an entire value chain or ecosystem. This coordination effort strives to standardize, economize, facilitate, and/or accelerate using collaboration. Frequently, the goals of the collaboration are to build a large economic base from the innovation and create opportunities for member firms to appropriate the benefits of participation, particularly when collaboration turns to competition (Dyer, Singh, & Kale, 2008; Jacobides, Knudsen, & Augier, 2006; Lavie, 2007; Sammarra & Biggiero, 2008).

Research in standards, firm networks, and alliances has shed much light on the benefits, opportunities, and challenges associated with multipartner alliances such as standard-setting organizations (SSOs), R&D consortia, and industry networks. However, these benefits, opportunities, and challenges are often assigned to the collective or assumed to be homogeneously available or distributed across the membership of the collective as observed by Lavie, Lechner, and Singh (2007). This research refutes this assumption and works from the premise that there is significant heterogeneity in the availability of many of these benefits and while some appropriation of benefits is exogenously determined, some appropriation is endogenously determined through firm choice and managing alliance dynamics. As recently highlighted by Chesbrough (2009), Teece (1986) asked the question why do some firms profit from their innovation invesments and others do not? Teece then proceeded to describe a variety of exogenous influences to appropriability including the nature of knowledge, the intellectual property rights related to that knowledge, and the nature of complementary assets required to exploit innovations in the market. Supporting an endogenous view of capturing some value from innovation, Chesbrough (2009) then raised the point that firms that own or have access to these complementary assets may profit from innovation activities, even within weak appropriability regimes. Within the setting of multipartner alliances, I extend the endogeneity argument to include the impact of a firm’s entry timing, value chain position, membership level, contribution to the collective, firm size, and timing of contribution on the innovation productivity of the firm.

In Chapter 2, the relationship between alliance entry timing and firm innovation productivity is examined. While the traditional definition of first-mover status relies on market entry (Lieberman & Montgomery, 1988), this work explores the dynamics of coordinated innovation years before market entry and the entry timing decisions of other firms who enter an industry years after first products were offered. Prior research hypothesized and validated a positive U-shaped relationship between multipartner alliance entry timing and firm innovation productivity suggesting that it was beneficial to the firm to be early or late, but less beneficial to enter in the middle (Lavie, Lechner, & Singh, 2007). In this chapter, I introduce the importance of value chain position in this relationship by hypothesizing that a firm with a primary focus on products defined by the specifications of the alliance (standard products) may experience significant early entrant disadvantages attributed to technological and organizational inertia. Late entrants pursuing standard products may also experience significant disadvantages due to scale economies that benefit firms pursing standard products. For firms focused on complementary products, I hypothesize that these firms will exhibit the same entry timing/innovation productivity relationship found by Lavie et al. (2007) leveraging traditional theory of early- and late-entrant advantages. Empirical testing suggests general support for these hypotheses.

While entrance into a multipartner alliance reflects initial intent by management, research suggests that firms enjoy greater benefits of membership from increased levels of involvement. These increased benefits may be from increased network embeddedness (Granovetter, 1985), superior access to tacit knowledge (Grant, 1996; Uzzi, 1997) control of alliance decision processes and agendas (Dutton, 1995; Saxton, 1997), exerting influence on the alliance by occupying leadership positions (Rosenkopf, Metiu, & George, 2001), or the exploitation of open innovation (Chesbrough, 2003; Chesbrough, Vanhaverbeke, & West, 2006) . Prior research has examined network position and membership level (with specific focus on multipartner alliance board members) (Lavie et al., 2007) as proxies for involvement. In Chapter 3, not only do I analyze the relationship between innovation productivity and membership level (a previously used proxy for network position, access to tacit knowledge, influence and control), but I also extend research on a fundamental question of open innovation – the relationship between purposive outflows or spillovers of knowledge to the collective and firm-specific innovation productivity. While mechanisms related to intellectual property rights and use of complementary assets typically drive appropriation discussions in open innovation, I highlight two additional mechanisms (alignment and absorption) that may be particularly useful in large multipartner alliance settings with particularly weak appropriability regimes. From the perspective of the firm, I empirically examine these mechanisms by breaking down total contribution into dimensions of breadth and depth of contribution and assessing their influence on the innovation productivity of the firm. Results not only confirm the expected advantages to contributing firms, but provide a rare, large-scale empirical analysis of open innovation and mechanisms related to alignment and absorption.

Technology-focused multipartner alliances can be characterized by a dual innovation process (West, Vanhaverbeke, & Chesbrough, 2006). Not only do member firms actively collaborate (particularly in early stage development) to produce requirement documents, specifications, and strategic plans for exploiting core technologies, but individual firms also strive for firm-level, product differentiating innovations. This dual innovation process leads to an interesting competitive/collaborative dynamic that may also influence firm innovation productivity by extending additional benefits to firms that actively contribute during early stage developments of the core technologies.

During the early-stage, intensely collaborative phase of the alliance, firm leaders may rely less on traditional sources of competitive advantage for positioning their firms for dual innovation, and more on sources of collaborative advantage such as flexibility, social capital, and willingness to share unique knowledge with the collective (Dhanaraj & Parkhe, 2006; Laursen & Salter, 2006; Schilling & Phelps, 2007). Resource deficient new ventures that actively leverage these sources of collaborative advantage may thrive in an environment where future competitive positioning may be dependent on this early-stage collaborative positioning (Agarwal, Audretsch, & Sarkar, 2007; Gilbert, McDougall, & Audretsch, 2008).

In Chapter 4, I explore the relationship between active participation and firm innovation productivity moderated by the maturity phase of the alliance (collaborative vs. competitive) and firm size. While theories attributed to liabilities of smallness/newness and absorptive capacity may suggest an initial innovation productivity gap between less and more endowed firms that grows larger with increased participation (Cohen & Levinthal, 1990; Deeds, 2001), I hypothesize that actively participating new firms can leverage early-stage collaborative positioning to narrow the innovation productivity gap between less and more endowed firms. Empirical results suggest little impact of contribution timing to innovation productivity and small firms at a deficit do not close the gap with increased levels of contribution. Surprisingly from at least the initial perspective outlined in Chapter 4, small firms that actively contribute during the collaborative phase of specification development experience significant innovation productivity disadvantages. This leads to a discussion highlighting appropriation patterns of relational rents within the multipartner alliance that may be discouraging to altruistic small firms yet favorable to those firms that subscribe to leveraging accumulated resources and capabilities while protecting against the hazards of transacting within the multipartner alliance.

In Chapter 5, I conclude with a summary of findings from this dissertation, highlights contributions that should increase understanding of the heterogeneity in benefits firms may experience from collaborative innovation, and outline my research agenda.

CHAPTER 2

TIMING OF ENTRY IN MULTIPARTNER ALLIANCES

Competing and complementing firms increasingly form multipartner alliances to define, standardize, develop, and market new technology under a framework of rules striving for cooperation and benefit sharing. Forms of these multipartner alliances include standard-setting organizations (SSO), industry networks, R&D consortia, and supplier networks. Examples from technology-driven industries include the 300+ member Wi-Fi Alliance, the 800+ member USB Forum, the 950+ member GSMWorld, and the 12,000+ member Bluetooth Special Interest Group (SIG). Research in this area often extends from alliance and multiple dyadic alliance networks research (Gulati, 1998; Powell, 1990; Uzzi, 1997), which highlights benefits (e.g., relational rents, enhanced trust, improved innovation) that networks offer to alliance partners (Dyer & Singh, 1998; Gulati, Nohria, & Zaheer, 2000; Powell, Koput, & Smith-Doerr, 1996). However, while much research assumes that benefits are homogenously available to all partners, emerging research has demonstrated that the availability and distribution of benefits are diverse among partners (Lavie et al., 2007).

Lavie et al. (2007) analyzed differential benefits to the partners of the Wi-Fi Alliance (a coalition of firms focused on wireless networking technologies) based on timing of entry and level of involvement. Arguing that differential benefits could be attributed to early-mover and late-entry advantages (Lambkin, 1988; Lieberman &

Montgomery, 1988, 1998) and path dependence (Gulati, 1995), they conjectured and validated a U-shaped curvilinear relationship between a firm's timing of entry into a multipartner alliance and its benefits from affiliation with the alliance, specifically what I refer to as the firm's innovation productivity. This suggests that enhanced innovation productivity may accrue to early-movers and late-entrants in technology alliances such as the Wi-Fi alliance. However, considering the complex technologies like Wi-Fi that require an entire ecosystem of providers to innovate, develop, and bring the technologies to market, I questioned whether both early-mover and late-entry benefits are available to all links in the value chain represented by the membership of the multipartner alliance.

There is both a temporal order to and temporal variance in the development of complex technologies. Development tools, demonstration platforms, hardware and software components, subsystems, and end product are rarely developed simultaneously. Each often represents a building block for links downstream in the value chain. Simultaneous innovation in the value chain is constrained by required antecedents and outcomes that limit the speed of system-wide innovation (Kessler & Chakrabarti, 1996; van Hoek, 1998). More specifically, there may be a distinction between firms that primarily focus on standard technology defined by the alliance and those firms that position themselves as complementary technology providers. Standard technology providers may be more subject to the timing and development processes of the standardization effort, their own ability to revisit their product's system architecture to deal with alliance-defined revisions, and the operating rules defined by alliance governance. Complementary technology providers may be more dependent on their own innovation capabilities and less dependent on the specifics of the standard technology due to modular, “black box” design techniques (Sanchez & Mahoney, 1996). These influences suggest that product focus or value chain position may alter the findings of Lavie et al. (2007).

Extending the work of Lavie et al. (2007), I examine the overall relationship between a firm’s innovation productivity and its timing of entry into the alliance, but demonstrate in this chapter that adherence to an early-mover or late-entry strategy for at least one link in the value chain of a multipartner alliance ecosystem may be an inferior innovation productivity strategy. The reduction in design control and potential need to return to the architecture design to satisfy requirements of new versions of the standard may limit early-mover advantages (Henderson & Clark, 1990) to those firms developing emerging standard technology. Many multipartner alliances aim to carefully specify and subsequently standardize certain parts of the final technical solution to improve interoperability, testability, and manufacturability. The links in the value chain developing standardized product may face rapid commoditization and hence, learning-curve and economies of scale advantages may also limit late entrant options (West, 2005).

I evaluated the relationship between a firm’s innovation productivity and the firms alliance entry timing using a database from the Bluetooth Special Interest Group (SIG), currently a multipartner alliance with more than 12,000 member firms focused on short-range wireless solutions for the communication, computer, consumer, and automotive industries. Formed in 1998, this alliance represents members responsible for shipping nearly one billion Bluetooth-enabled phones, wireless headsets, computer peripherals, and gaming devices in 2009. Comprising three levels of membership, alliance governance is a shared activity between the member firms that constitute the promoter level (currently Ericsson AB, Intel, Lenovo, Microsoft, Motorola, Nokia, and Toshiba) and a privately held, not-for-profit trade association responsible for publishing Bluetooth specifications, administering the qualification program, protecting the Bluetooth trademark and evangelizing Bluetooth technology (www.bluetooth.com). Technical committees in the Bluetooth SIG specify the standard technology that primarily defines the wireless communications hardware and software components of the system solution that ensure both interoperability and application-specific functionality.

This study contributes to alliance research by examining partner productivity differences in multipartner alliances that are attributed to value chain position and timing of entry. While the analysis confirms the overall U-shaped curvilinear relationship between productivity and entry timing identified by Lavie et al. (2007) using a different technology-focused multipartner alliance, it also challenges the generality of that finding in important ways. This study reveals, empirically, differences in the relationship between productivity and timing of entry when considering different parts of the value chain represented by the alliance. This not only suggests implications for firm-specific entry strategies and need for firm-level dynamic capabilities, but also implications for appropriate alliance governance to support member firms that may benefit from different entry strategies.

Theory and Hypotheses

As system design complexity increases in emerging technologies, firms have discovered that the combined system, hardware, software, and marketing requirements are often beyond the capabilities and capacities of the individual firm. Reaching beyond the borders of the firm through joint ventures, contractual relationships, and strategic alliances to solve this issue is common practice and extensively researched (Dyer & Singh, 1998; Kotabe & Swan, 1995; Madhok & Tallman, 1998; Williamson, 1985), but some of the world's major technological innovations that touch the lives of hundreds of millions or even billions of people may require the collaboration and coordination of an entire ecosystem of firms. Large, broad-based, multipartner alliances have emerged to develop and standardize new technologies, drive rapid global acceptance, and in many cases literally create new product markets in industries such as mobile communication, smart energy, computing, and consumer multimedia.

Launching from alliance and multiple dyadic alliance networks research (Gulati, 1998; Powell et al., 1996; Uzzi, 1997), multipartner alliance research has explored motivation for formation and governance mechanisms (Gomes-Casseres, 1994; Mitchell, Dussauge, & Garrette, 2002), and value of cooperative R&D (Sakakibara, 2001). The research also involves standardization of technologies, including both alliance-level issues such as standards development, adoption, organization, overall economic welfare, processes, and impediments (David & Greenstein, 1990; Farrell & Saloner, 1985, 1988; Sakakibara, 2003; Tushman & Anderson, 1986; Wade, 1995), and firm-level issues such as firm choice between standards and network development, information, and marketing advantages of participation (Axelrod, Mitchell, Thomas, Bennett, & Bruderer, 1995; Rosenkopf, Metiu, & George, 2001). With this solid foundation established, one branch of research in multipartner alliances has started to explore a central question of strategy: differences in benefits appropriated by individual participating firms. Potential sources of private benefits may be related to size of alliance network, relative partner size and their network configuration, and informal ties to dominant partners (Dyer et al., 2008; Khanna, Gulati, & Nohria, 1998; Lazzarini, 2007). Lavie et al. (2007) explored whether partners enjoy differential benefits and what factors explain some of the distribution of benefits among partners. They found that there are differential benefits and factors such as timing of entry, level of participation, and external involvement all contribute to these differential benefits.

The theory behind the U-shaped curvilinear relationship between timing of entry and innovation productivity (Lavie et al., 2007) was developed based on early-mover and late entry advantages (Lambkin, 1988; Lieberman & Montgomery, 1988, 1998; Shankar, Carpenter, & Krishnamurthi, 1998) that are traditionally applied to market entry, but applied in this case to multipartner alliance entry, often a precursor to market entry. Lavie et al. (2007) suggested early mover advantages could be attributed to influencing the evolution of multipartner alliances, forming and utilizing governance mechanisms in these alliances, and extending the lead time for innovations and product applications. Late entry advantages, often ascribed to firms pursuing the exploitation phase of a product market life cycle, include avoiding set-up investments, significant R&D and market education costs, selecting the alliance more successful at achieving the dominant design, and facilitating the use of accumulated alliance knowledge while focusing on commercialization (Shankar et al., 1998).

Early-mover and late-entry advantages may hold for many firms participating in multipartner alliances, but there may be strong, countering influences for some firms which could be attributed to their principal product offering and value chain position.

More specifically, firms producing the products focused on the standard technology defined by the alliance may experience different temporal challenges than those firms producing complementary products and services.

The different outcomes for early-mover, standard technology providers may be attributed to issues identified in Henderson and Clark's (1990) seminal article on architectural innovation. The process of achieving a standardized definition of the fundamental technology in the multipartner alliance (Farrell & Saloner, 1985, 1988) may be likened to the process of achieving a dominant design (Suarez & Utterback, 1995). As the alliance releases a ratified version of standard technologies, firms cease to invest or at least reduce investment in learning about alternative configurations (Henderson & Clark, 1990) and advance the product design focused on that version of the standard technology. Unfortunately, for many technology-focused multipartner alliances that attempt to define standard technology products, feedback from product developers, testing houses, and the general market often drive the development of improved versions of the standard before a mass-produced, mass-marketable, and consumer-desired product is offered. At a lower level of abstraction than that discussed in Henderson and Clark (1990), the different versions of the standard technology may force engineering teams to return to the system architecture implementation. While the individual components of the architecture may be similar, the less-obvious linkages in these components may vary causing a need to return to a redesign of the system architecture. Should new architectural knowledge be required, those firms that invested heavily in prior versions may be handicapped in their attempts to switch to a new mode of learning and invest time and resources into a new architecture. This handicap may cause those firms pursuing products centered on the standard technology to enjoy fewer early-mover advantages.

While producers of complementary products may continue to enjoy product and service differentiation opportunities late in the technology life cycle (Lavie et al., 2007), producers of standard technology products face commoditization challenges. A frequent output of the multipartner alliance is a documented standard that firms use to produce similar technology giving consumers vendor choice and often interoperability for those products designed to the standard. The dynamics of this part of the ecosystem frequently drive firms to pursue cost leadership strategies with economies of scale and learning curve advantages determining the long-term success of firms (West, 2005). This commoditization of the standard technology may lead to a deterioration of late-entry advantages for those firms primarily pursuing the standard technology.

Lavie et al. (2007) hypothesized and found a U-shaped curvilinear relationship between timing of entry and productivity for members of the Wi-Fi Alliance. They argued that early-mover and late-entry advantages were instrumental in describing why this relationship was found. Leveraging the same case, I hypothesize a similar relationship between entry timing and innovation productivity in larger multipartner alliances when examining aggregate membership.

> *Hypothesis 1: Timing of entry is curvilinearly related to firm innovation productivity with early and late entrants experiencing greater innovation productivity than intermediate entry.*

This study also analyzes segments of the value chain often represented by the membership of technology-focused multipartner alliances. To successfully define, produce, and subsequently market products designed using the complex technologies developed by these alliances, governing bodies often strive to obtain a membership represented by all related links in the technology's value chain. For example, in mobile telephony, the GSM World multipartner alliance includes "750 of the world's mobile operators, as well as 200 companies in the broader mobile ecosystem, including handset makers, software companies, equipment providers, internet companies, and media and entertainment organizations" (www.gsmworld.com).

Considering the value chain diversity of membership in these technology-focused multipartner alliances, the positive U-shaped curvilinear relationship examined in Hypothesis 1 may not apply to all links in the value chain. A key distinction explored in this paper is between firms principally producing products designed specifically to the alliance technology standards versus firms principally producing complementary products and technology. As highlighted earlier, those firms that principally focus on the standard technology may face challenges when alternating between component and architectural design due to technical changes that are exogenously redefined by the collaborative innovation efforts of the alliance. The inability of some firms producing standard technology to transition between architectural and component level design through the revisions (as predicted by Henderson & Clark's (1990) architectural innovation theory) may reduce early-mover advantages for firms pursuing the standard technology. Firms pursuing complementary products often modularize or "black box" the standard technology. This may enable less dependence on exogenously influenced changes to standard technology and more control over the system architecture of their own products. This reduced dependence and increased control may require fewer revisits to the complementary product system architecture and thus enable greater early-mover advantages as firms can focus on product differentiation. Additionally, commoditization of standard technology may reduce advantages of late entry that are available to complementing firms that have more flexibility to differentiate. These effects lead to hypotheses that examine different timing-of-entry versus productivity relationships in the various links in a value chain represented by a multipartner alliance.

> *Hypothesis 2a: For firms principally focused on complementary products, timing of entry is curvilinearly related to firm innovation productivity with early and late entrants experiencing greater innovation productivity than intermediate entry.*

> *Hypothesis 2b: For firms principally focused on standard products, timing of entry is inversely curvilinearly related to firm innovation productivity with early and late entrants experiencing smaller innovation productivity than intermediate entry.*

Data and Methods

The Bluetooth SIG, Inc. is a nonprofit trade association supporting the activities of over 12,000 member firms representing the full ecosystem supporting Bluetooth technology, a short-range wireless technology used in a variety of applications including cell-phones, wireless headsets, and personal computer peripherals. Organized in 1998, the Bluetooth SIG represents an excellent setting for this research. First, the Bluetooth SIG formed technical committees to specify much of the software and hardware component technology that enables wireless networking and interoperability. Additional technical and marketing committees describe application-specific features to enable a common platform for subsystem and end product differentiation. Second, multipartner alliance governance is a shared activity between the Promoter firms and the professionally managed trade association. This governance structure aims to provide balance between the needs of the Promoters and the Associate and Adopter levels of membership while striving to provide an equitable foundation for members to compete. Third, as one of the largest technically-focused, multipartner alliances in history, the extensiveness of this alliance not only enabled empirical analysis of membership, time of entry, and product qualification, but also a detailed exploration of the different links in the Bluetooth value chain.

By 1996, several firms looking to standardize a low-cost, short-range wireless technology to unite computing and telecommunication devices started discussing collaboration. Intel had a program called Business-RF, Ericsson's program was called MC-Link, and Nokia had a program called Low Power RF. Discussions and technical work continued through 1998 when Ericsson, IBM, Intel, Nokia, and Toshiba put their weight behind a new technology and marketing initiative called Bluetooth, named after the tenth century Scandinavian King Harald Bluetooth who was famous for uniting Scandinavia. By 2000, 3Com, Lucent, Microsoft and Motorola had joined the promoter group and over 1200 firms had joined the Bluetooth SIG in one of three levels of membership: Promoter, Associate, or Adopter. Version 1.0 of the standard had been released and component providers were actively trying to develop and qualify product. In these early days with rapid vendor adoption, Bluetooth's hype may have driven immature technology to market and subsequent customer confusion. The technology suffered from a lack of interoperability, or the process which allows products from various manufacturers to work together, and a lack of customer experience with "connecting" wireless technology (Bluetooth technology requires pairing, or the process of securely connecting two devices). Version 1.0b was released in December 1999 to correct some of the early errata. Version 1.1, released in November 2000 to provide authentication and repair errors found in version 1.0b, arguably became the first successful operating version of Bluetooth technology, facilitating the rapid growth in membership and qualified product. Providing backward compatibility, version 1.2 was released in November 2003 to improve connection speed, transmission rate, and improve voice quality and market adoption expanded rapidly after the release of version 1.2. Version 2.0 was released in November 2004 to boost data rate and improve power consumption. Version 2.1 was released in July 2007 to improve security and pairing. Versions 3.0 and 4.0 representing alternative communication technologies were released in 2009.

This study analyzes firm entry and date of product qualification through June of 2008 for firms entering the alliance by November of 2007. Commencing in 2000, firm entry is determined by the “clickwrap” or member creation date. The clickwrap date is when a member accepted the electronic contract available on the web. While there were approximately 2,000 members prior to the institution of this method of electronic agreement, these prior members were subsequently required to reestablish the electronic agreement with the Bluetooth SIG. By November 2007 (the end of this study), membership had grown to over 9700 firms with rapid growth experienced in 2006 and 2007 (Figure 2.1). In analyzing recent growth, much of the rapid membership growth can be attributed to firms from China, Taiwan, and other countries in southeast Asia, reflecting the maturity of the technology and economic trends in this part of the world. By November 2007, there were 5856 qualified product from 955 registered firms. Entries registered to separate divisions of the same firm were combined. Furthermore,

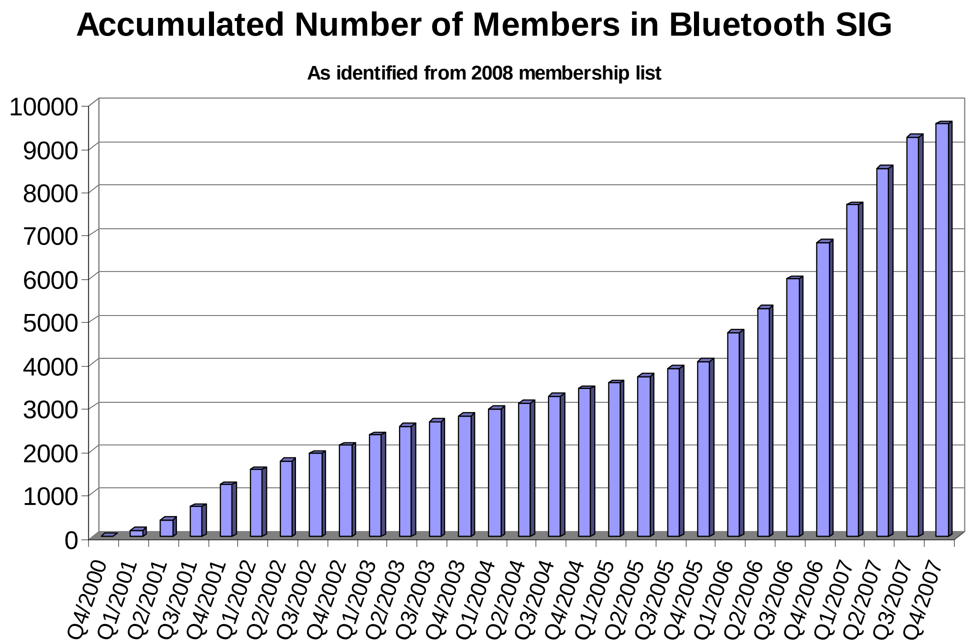

Figure 2.1. Bluetooth membership growth

entry dates were not available in the database for 71 firms responsible for 127 qualified products. These firms and qualified product were not included in the final set consisting of 5729 products and 884 firms (see Figures 2.2 and 2.3).

Membership in the Bluetooth SIG is open to all firms with an interest in Bluetooth products and technology. Three membership levels are available to partner firms. Promoters within the Bluetooth SIG (a group that has fluctuated between five and nine firms over the history of the SIG) each hold one seat and one vote on the board of directors and qualification review board to influence the strategic and technological directions of Bluetooth. These firms make considerable investment in personnel to support the various working groups and committees of the SIG. Promoter membership is

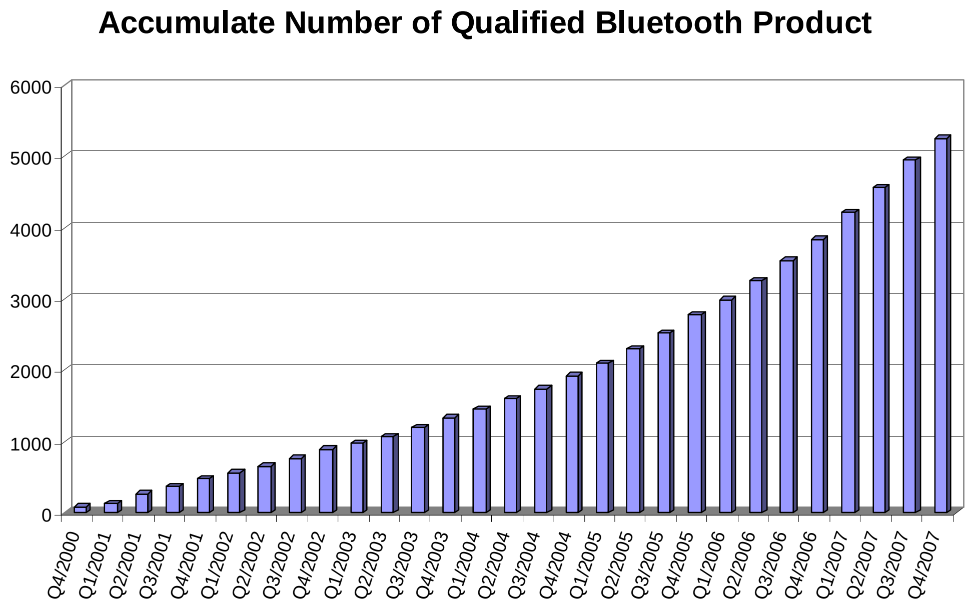

Figure 2.2. Growth in newly qualified products

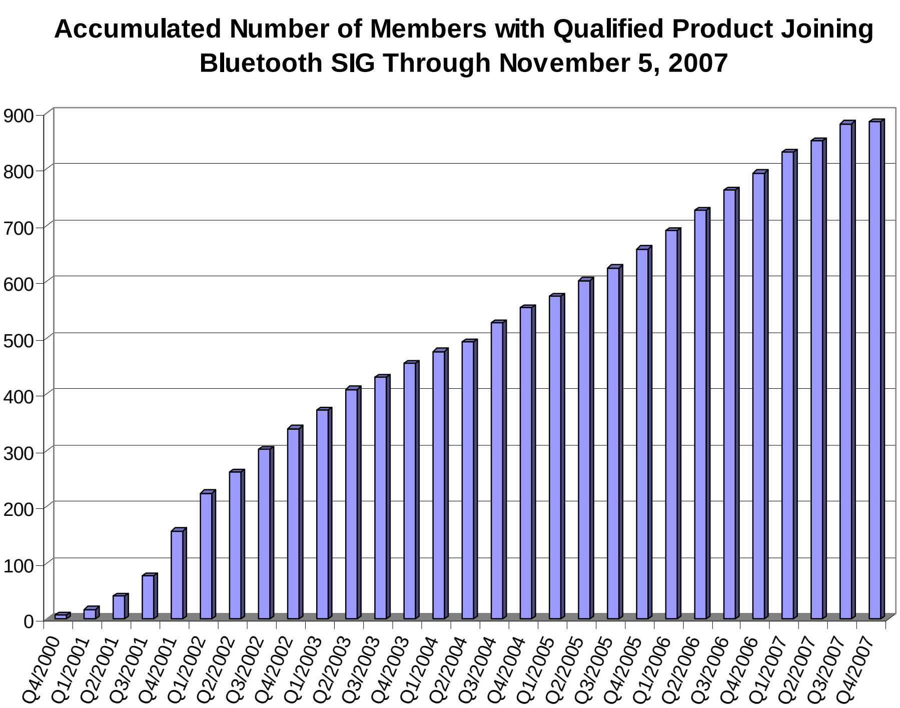

Figure 2.3. Growth in firms with qualified products

subject to approval by the board of directors. Associate membership is open and is subject to an annual membership fee ranging from $7500(USD) to $35,000(USD) which enables early visibility into draft specifications, committee membership, limited voting rights, and discounted listing fees for products. At the end of 2007, there were 273 Associate members. Of the 884 firms with qualified product in this database, 338 have been Associate members at some time during the duration of this analysis. The vast majority of the membership is at the Adopter level. Adopter membership is free and these companies gain access to completed specifications and may use the Bluetooth trademarks. There are 439 firms with qualified product included in the Adopter level of membership.

The Bluetooth value chain consists of development tools and test systems, software and hardware components, subsystems and modules, and end product. The analysis in this paper partitions the value chain into four links: Dev/Demo Kit (Development Tool/Demonstration Kit), HW/SW Components (Hardware and Software Components), Subsystems, and End Product. In tracking and listing qualified product over the 7 years of this analysis, the Bluetooth SIG maintained two different sets of categories depending on the qualification program version. Figure 2.4 highlights the grouping used in this paper to reflect the four links in the Bluetooth value chain.

To complete the value-chain analysis in this paper, firms with qualified product were identified by their main product offering as determined by selecting the value chain category with the most products qualified from a given firm. To capture the impact of firms qualifying product in more than one category, a control variable was included to

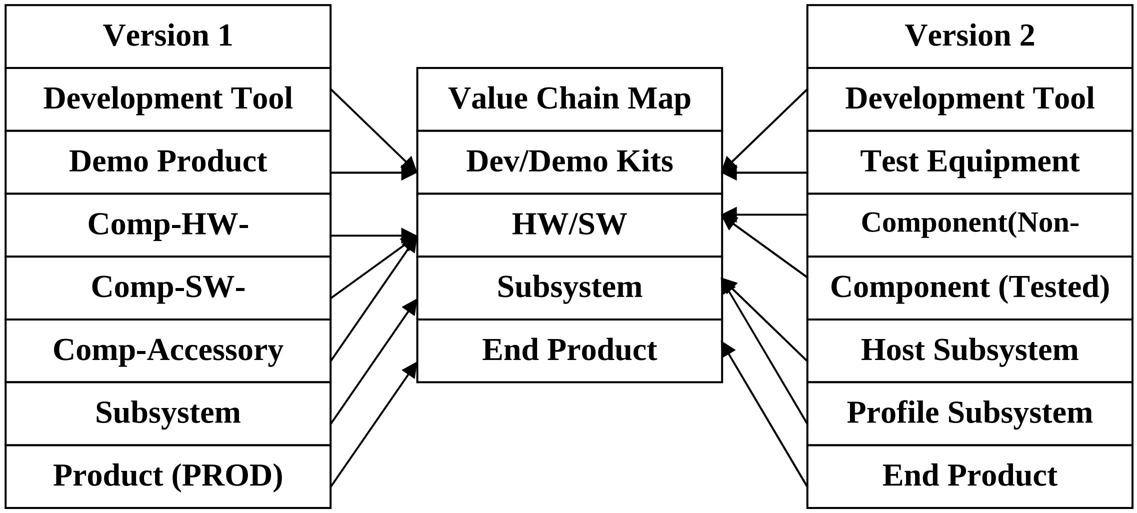

Figure 2.4. Mapping of Bluetooth products by value chain position

capture vertical integration intensity. Figure 2.5 captures the value chain breakdown of the 884 firms represented in this sample. Figure 2.6 represents the total number of products in each of the four links of the value chain.

Some data used in this paper were derived from public sources including www.bluetooth.org, www.bluetooth.com, and individual member firm websites. Additional data were obtained through direct contact (phone and email) with member firms from October 2009 to May 2010. I have entered into a confidential disclosure agreement (CDA) with the Bluetooth SIG that enabled the availability of comprehensive product qualification data, membership information, and private interviews. The CDA allows aggregate reporting of the data while protecting the privacy interests of the Bluetooth SIG and their members.

Firm entry and membership change dates were recorded by members of the Bluetooth SIG administration, these analysts currently headquartered in Bellevue,

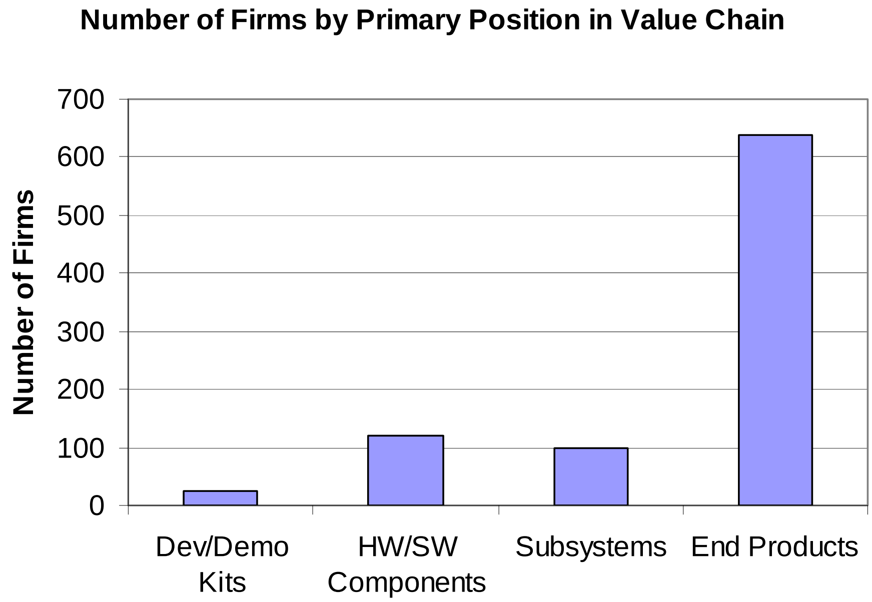

Figure 2.5. Firm count by value chain position

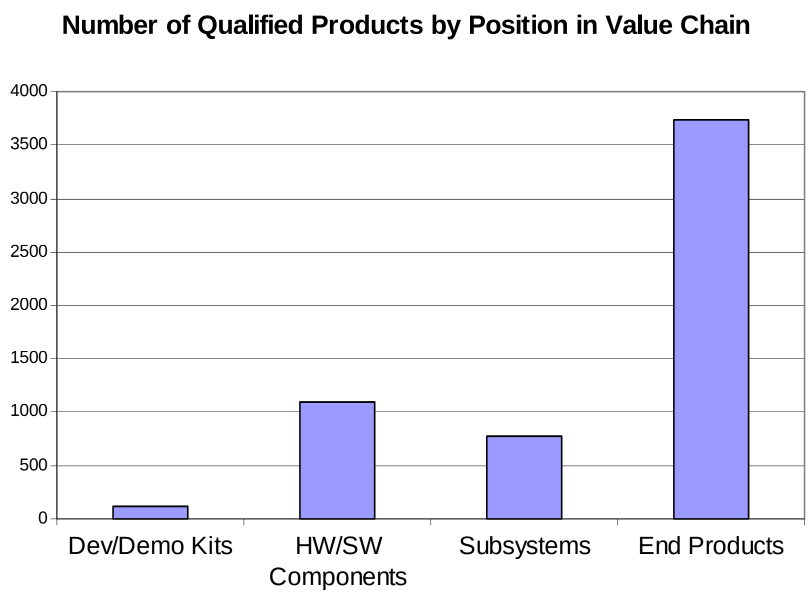

Figure 2.6. Number of qualified products by value chain position

Washington. Since the Adopter level of membership is free of charge, firms no longer participating in the benefits of paid membership are automatically moved to this level. As a result, exit from the multipartner alliance is not a recorded event. Product and qualification data were recorded by a combination of the administration and self-reporting member firms.

Measures

Dependent variable. Technology-focused multipartner alliances strive to provide both technological and marketing benefits to complement a member firm's own product development and subsequent marketing efforts. A key measure of firm-level benefits from multipartner alliance participation is satisfying the testing standards for product certification or qualification. Satisfactory completion of the Bluetooth Qualification Process provides member firms with the ability to qualify their products, obtain the Bluetooth intellectual property license, use the Bluetooth trademarks, and list their qualified products on the Bluetooth website (www.bluetooth.com).

Consistent with the method used by Lavie et al. (2007), I measure firm *innovation productivity* as the number of products a firm has qualified through the Bluetooth Qualification Process by June 30, 2008, standardized by the duration of the firm's membership in the Bluetooth SIG measured in years. While nearly half (407 out of 884) of the firms in the sample qualified only one product during the period analyzed, 214 out of 884 firms qualified five or more products with one firm qualifying over 500 products.

Independent variables. To test the timing of entry hypotheses, I measure a partner's *Order_of_Entry*. A U-shaped relationship in order of entry was analyzed using a squared term *Order_of_Entry_Squared.* Sorting the partner's entry as determined by the date recorded in the Bluetooth SIG database, I calculated order of entry and treated this variable as a continuous variable in the analysis. To analyze differences that may exist between complementary (coded '1') and standard (coded '0') product focused firms, I constructed a dummy coded variable *Std_vs_Comp.* To then test the individual links in the value chain and to compare the relationship between timing of entry and innovation productivity for standard and different forms of complementary product firms, I created dummy variables for *Development*, *Subsystems*, and *End_Product* to allow comparisons to the development kit classification and to provide additional explanatory power to the variance in performance.

Control variables. To capture differences in productivity that may be attributable to level of membership, I created dummy variables for *Promoter* and *Associate* members with *Adopters* being the comparison group and representing the remaining members. Approximately one-fourth of the sample (219 of 884) produced product in more than one of the four value chain categories. To control for innovation productivity effects that may be attributable to firms servicing more links in the value chain, I measure a partner's *integration intensity* as $1 - \sum_j k_{ij}^2 / N_i^2$, where k_{ij} is the number of products qualified by partner i in value chain link category j, and N_i is the partner's total number of qualified products. High values of this measure suggest greater and more balanced levels of integration across the value chain. Finally, to capture model effects that may be linked to firm size, I used a simple binary measure for *Large_Firm* to account for firms with revenues in excess of ~$300M USD or 1,000 employees. This measure was used due to the high percentage of private firms (>65%) and international firms (>76%) included in the database that required extensive secondary and imprecise data gathering methods.

Analysis

Table 2.1 reports descriptive statistics. I used hierarchical negative binomial regressions to examine the effects of the control and independent variables along with interactions on entry timing and value chain position variables. The negative binomial model, a member of a family of distributions characterized as general linear models (GLM), is recommended when evaluating count data with overdispersion, a case when the variance of the estimated count exceeds the mean. Correcting overdispersion by using an ancillary parameter, the negative binomial model is appropriate when using a count dependent variable with an order of entry independent variable (Hilbe, 2007). The expected value of the estimated number of products certified by partner *i* during its alliance membership (t_i) was determined using the equation:

$\log \lambda_i = \log(t_i) + \beta_o + \beta_1 x_{i1} + \beta_2 x_{i2} + ... + \beta m x_{im} + \sigma \varepsilon_i$, where λ_i is the expected value of products qualified. This model was developed using maximum-likelihood estimation in the GLM analysis tools of SPSS with the log of membership duration measured in years as the offset variable to normalize innovation productivity for time spent in the multipartner alliance. Order of entry was mean-centered to reduce impact of collinearity between the linear and squared order of entry terms. Testing of Hypothesis 1 was based on the full model (model 4 in Table 2.2).

To test the concept advanced in this paper that firms focused on complementary products would exhibit different innovation performance characteristics than firms

Table 2.1. Descriptive statistics[a]

	N	**Mean**	**STD**	1	2	3	4	5	6	7	8	9	10	11	12
1. Innovation Productivity	885	6.47	23.83	1.000											
2. Promoter	885	.01	.09	.111	1.000										
3. Associate	885	.38	.49	.441	-.070	1.000									
4. Integration_Intensity	885	.11	.20	.645	.130	.266	1.000								
5. Large_Firm	885	.28	.45	.289	.144	.001	.230	1.000							
6. Development	885	.03	.16	-.074	-.015	-.003	-.045	.099	1.000						
7. Components	885	.16	.37	.130	.031	.108	.219	.034	-.073	1.000					
8. Subsystems	885	.09	.29	.037	.016	-.016	.167	.066	-.053	-.138	1.000				
9. End_Product	885	.72	.45	-.103	-.030	-.077	-.270	-.107	-.269	-.702	-.512	1.000			
10. Std_vs_Comp	885	.84	.37	-.130	-.031	-.108	-.219	-.034	.073	-1.000	.138	.702	1.000		
11. Order_of_Entry	885	1.00	255.62	-.304	-.134	-.052	-.303	-.236	-.138	-.251	.010	.249	.251	1.000	
12. Order_of_Entry_Squared	885	6.53E+04	5.84E+04	-.104	.113	-.090	-.020	.020	.053	.085	.001	-.089	-.085	.007	1.000

[a] Table 1 reports the number of observations, means, and standard deviations of the variables and the Spearman's correlation matrix
Correlation coefficients larger than 0.065 in absolute value were significant at the 5% level. Order_of_Entry centered before squaring.

Table 2.2. Negative binomial regression results

	Model 1	Model 2	Model 3	Model 4
Intercept	-6.982***	-7.017***	-6.955***	-7.084***
	(0.106)	(0.105)	(0.100)	(0.111)
Promoter	1.630***	1.513***	1.970***	1.766***
	(0.331)	(0.324)	(0.317)	(0.327)
Associate	1.059***	1.031***	1.046***	1.081***
	(0.073)	(0.072)	(0.069)	(0.070)
Integration_Intensity	1.658***	1.796***	2.133***	2.129***
	(0.185)	(0.189)	(0.185)	(0.185)
Large_Firm	0.752***	0.782***	0.966***	0.966***
	(0.076)	(0.075)	(0.074)	(0.074)
Std_vs_Comp	0.371***			
	(0.0975)			
Development		-0.974***	-0.836***	-0.853***
		(0.255)	(0.249)	(0.250)
Subsystems		0.069	-0.177	-0.168
		(0.145)	(0.142)	(0.141)
End_Product		0.463***	0.307***	0.325***
		(0.099)	(0.096)	(0.096)
Order_of_Entry[1]			1.6E-3***	1.6E-3***
			(1.56E-4)	(1.57E-4)
Order_of_Entry_Squared				1.71E-6**
				(6.39E-07)
Dispersion Parameter	0.70*	0.67*	0.63*	0.63*
N	885	885	885	885
Log Likelihood	-2183.5	-2164.4	-2113.1	-2109.5
df	878	876	875	874
2x Delta Log Likelihood from Model 1		38.3***	140.8***	148.0***

Standard errors are reported in parentheses.

Significance levels (2-tailed): † p < .1, * p < .05, ** p < .01, *** p <.001

[1] Order of Entry mean-centered prior to squaring to reduce collinearity issues.

focused on standard products, I tested a variable dummy coding each firm primarily focused on standard ('1') or complementary ('0') products in model 1. Observing a significant different, I then analyzed dummy coded measures for each link in the value chain compared to component (standard) products in model 2 and found all to be significantly different than components. Models 3 and 4 included a linear and squared order of entry term to complete analysis of Hypothesis 1.

For model 5 in Table 2.3, I examine the linear and quadratic terms of *Order_of_Entry* independent of value chain position. Exploring the relationship of innovation productivity and timing of entry further, I isolated each link in the value chain by analyzing the interaction of both the linear and squared order of entry terms with each dummy coded measure representing the four links in the value chain in models 6 through 9 to provide greater insight into the phenomenon explored in Hypothesis 2a and 2b. For this Bluetooth dataset, complementary products are best represented by models 6, 8, and 9, while primary products are best represented by model 7.

Results

Hypothesis 1 was tested by examining the significance and sign of the coefficients of the timing of entry variables (model 4). While Lavie et al. (2007) found a negative and significant linear relationship between timing of entry and productivity, I found a positive and significant relationship $(\beta = 1.6E-3, p < .001)$. This can partially be attributed to the centering of the order of entry data. Consistent with the findings of Lavie et al. (2007), the aggregate data illustrated a significant U-shaped curvilinear relationship

Table 2.3. Firm innovation productivity by value chain position and order of entry

	Model 5	Model 6	Model 7	Model 8	Model 9
Intercept	-6.922***	-6.920***	-6.921***	-6.921***	-6.917***
	(0.069)	(0.069)	(0.069)	(0.069)	(0.069)
Promoter	2.069***	1.997***	1.967***	2.046***	1.828***
	(0.330)	(0.328)	(0.331)	(0.329)	(0.328)
Associate	1.094***	1.090***	1.087***	1.086***	1.064***
	(0.070)	(0.070)	(0.070)	(0.070)	(0.070)
Integration_Intensity	1.869***	1.835***	1.915***	1.894***	1.978***
	(0.176)	(0.175)	(0.176)	(0.178)	(0.177)
Large_Firm	0.952***	0.957***	0.946***	0.954***	0.949***
	(0.075)	(0.074)	(0.074)	(0.074)	(0.074)
Order_of_Entry	1.22E-3***	1.15E-3***	1.11E-3***	1.18E-3***	1.69E-3***
	(1.54E-4)	(1.55E-4)	(1.67E-4)	(1.62E-4)	(2.86E-4)
Order_of_Entry_Squared	1.46E-7	3.86E-7	6.17E-7	2.78E-7	-1.96E-6*
	(6.33E-7)	(6.35E-7)	(6.64E-7)	(6.46E-7)	(9.68E-7)
Order_of_Entry x Development		1.43E-3			
		(2.16E-03)			
Order_of_Entry_Squared x Development		5.58E-6			
		(6.41E-5)			
Order_of_Entry x Components			2.57E-4		
			(4.43E-4)		
Order_of_Entry_Squared x Components			-2.46E-6†		
			(1.34E-6)		
Order_of_Entry x Subsystems				6.90E-04	
				(4.83E-04)	
Order_of_Entry_Squared x Subsystems				1.98E-6	
				(1.45E-06)	
Order_of_Entry x End_Products					-7.83E-04*
					(3.28E-04)
Order_of_Entry_Squared x End_Products					3.20E-06**
					(9.96E-07)
Dispersion Parameter	0.65*	0.64*	0.65*	0.65*	1.178*
N	885	885	885	885	885
Log Likelihood	-2122.0	-2115.3	-2118.4	-2120.1	-2109.8
df	877	875	875	875	875
2x Delta Log Likelihood from Model 1	123.1***	136.4***	130.2***	126.9***	147.4***

Standard errors are reported in parentheses.

Significance levels (2-tailed): † p < .1, * p < .05, ** p < .01, *** p <.001

[1] Order of Entry mean-centered prior to squaring to reduce collinearity issues.

between the squared term of entry timing and innovation productivity $(\beta = 1.71E-6, p < .01)$, suggesting support for Hypothesis 1.

Hypothesis 2a was tested by examining the significance and sign of the coefficients for the timing of entry variables first in model 1 and then separately in models 6, 8, and 9. Model 1 demonstrates a significant difference in innovation productivity between firms coded as standard product focused firms (Components) and complementary product focused firms (all others) by examining the Std_vs_Comp variable $(\beta = 0.371, p < .001)$. Extending the analysis to each link in the value chain, the interaction of order of entry and the dummy coded links were independently evaluated. With only 24 firms with a primary product focus in demonstration and development kits (model 6), no significant relationship was found between timing of entry and innovation productivity for this early stage in the value chain. No additional variance is significantly explained by the interaction of model 8 for *Subsystems*. Model 9 highlights the impact *End_Product* has on the overall model showing significant negative linear $(\beta = -7.83E-04, p < .05)$ and positive curvilinear $(\beta = 3.2E-06, p < .01)$ relationships between *Innovation_Productivity* and *Order_of_Entry*. These results suggest support for Hypothesis 2a and explain the importance of end products to the overall relationship.

Hypothesis 2b was tested by examining the results of model 7 which accounted for hardware and software components, the primary output of the standardization efforts of the Bluetooth SIG. A positive significant relationship was found on the mean-centered linear *Order_of_Entry* term $(\beta = -1.11E-3, p < .001)$. As hypothesized, an inverse U-shaped relationship is observed as demonstrated by the negative and significant beta term of the interaction between *Components* and *Order_of_Entry_Squared* $(\beta = -2.46E-6, p < .1)$. While the linear term on *Order_of_Entry* dominates, a moderate negative curvilinear relationship suggests empirical support for Hypothesis 2b. Of particular interest to the arguments of this research, all links in the value chain do not exhibit the U-shaped curvilinear results highlighted in prior research (Lavie et al., 2007).

The results of model 4 suggest significant differences between each of the links in the value chain representing complementing products and the omitted comparison of *Components*. *Development* $(\beta = -0.853, p < .001)$ was negatively associated and end product $(\beta = 0.325, p < .001)$ was positively associated with innovation productivity while *Subsystems* did not exhibit significant differences from the control. Innovation productivity of Promoters $(\beta = 1.766, p < .001)$, and Associates $(\beta = 1.081, p < .001)$, vary significantly from Adopters in all models. Integration intensity is also positively associated with innovation productivity $(\beta = 2.129, p < .001)$, a strong effect that remained significant throughout the models suggesting that firms with balanced offerings across multiple links in the value chain increased innovation productivity.

Discussion and Conclusion

This study extends the work of Lavie et al. (2007) where they explored the heterogeneity of benefits among partners in a multipartner alliance. Beyond confirming their aggregate finding of a positive U-shaped curvilinear relationship between timing of entry into the multipartner alliance and productivity using a different technology-focused alliance, this study extends this work by analyzing the entry timing versus innovation productivity relationship between standard and complementary products and strengthened that analysis by exploring the contribution of each link of the value chain in the timing of entry and innovation productivity relationship. The key finding is that while end product firms primarily focused on complementary products exhibit a U-shaped relationship between innovation productivity and timing of entry, those firms focused on standard products exhibit a weak inverse U-shaped relationship with a strong positive linear element to order of entry, contradicting the relationship advanced by Lavie et al. (2007). Additionally, greater insight was obtained by examining the relationship for all links in the value chain. Results show that firms focused on end products enjoy benefits of early and late entry as demonstrated by the significant positive U-shaped relationship, but no other link in the value chain experienced the relationship discovered by Lavie et al. (2007) potentially bringing into question the early-mover and late-entry advantages advanced in that study. The positive relationship between the linear term of *Order_of_Entry* and the dependent variable potentially suggest additional advantages to later entry.

The theory leveraged and advanced in this paper suggests differences in the entry timing versus innovation productivity relationship based on if a firm's primary offering is focused on the standard technology defined by the multipartner alliance. Some differences may be attributed to architectural innovation issues of transitioning between system architecture and component design due to exogenous signals. Firms desiring early-mover advantages to outweigh the disadvantages may need increased emphasis on developing dynamic capabilities and competence to readily move between system architecture and component design in times of technological change (Teece, Pisano, & Schuen, 1997). More specifically, to improve the likelihood of meeting the architectural challenges required to satisfy multiple versions of a standard, organizations could develop a capability in top-down, hierarchical design. Fundamentally, top-down, hierarchical design provides a level of abstraction, a methodology, and tools for each level of design to enable more seamless interactions between the various levels of design, improve overall design verification, and facilitate rapid correction of design issues at all levels of the design. For a general review and background on top-down, hierarchical design used in hardware and software design and a discussion of the advantages described above, see Chang et al. (1999). As a form of a dynamic capability, leveraging this methodology in product development eases the pain new versions of standards, market feedback, design-for-manufacturing needs, or even internally driven errata introduces to the product innovation process, thus potentially reducing some early-mover disadvantages attributable to the challenges of multiple transitions between component and architectural level design.

The findings of this study contribute to emerging research on differential benefits available to members of multipartner alliances by examining temporal aspects of firm participation decisions. Prior research highlights a general relationship between productivity and timing of entry (Lavie et al., 2007), exploration versus exploitation opportunities based on alliance entry timing (Lavie & Rosenkopf, 2006), and general advantages of early mover and late entry (Lieberman & Montgomery, 1988, 1998; Makadok, 1998; Shankar et al., 1998) into markets. I contribute to this area of research by examining firm-level innovation productivity differences attributed to timing of entry and value chain position in multipartner alliances.

My findings suggest at least two key implications. First, firms developing standard technology products face an interesting strategic dilemma when choosing between traditional early-mover benefits which include learning curve advantages, favorable market positions, and network establishment and the potential architectural change and path dependence pitfalls described in this study. To successfully compete as an early entrant, my findings hint at the importance of creating dynamic capabilities in engineering to overcome architectural changes required by the alliance (Teece, Pisano, & Schuen, 1997).

The second key implication challenges the governance of the multipartner alliance (Reuer, Zollo, & Singh, 2002). Much of the organizational structure, the interorganizational processes, and the rules of interaction and engagement are established by the founding and early-stage partners of the alliance to establish the social, economic, and technical order that enables collaborative innovation. If, as this research suggests, there are early-mover disadvantages for at least one link in the value chain represented by the alliance, this group of firms may be underrepresented or misrepresented in the early-stage governance-formation activities of the alliance since key stakeholders may choose to delay participation. This suggests a need for flexibility or even the development of dynamic capabilities by the governing body of the multipartner alliance. Of equally significant importance is the notion that the group of firms experiencing the inverse U-shaped relationship between timing of entry and productivity is the same group of firms that should be heavily involved in defining the standard technology of the alliance. This further implies that many of the firms striving for early-mover advantages in the standard technology are often instrumental in the definition of the standard, yet may not reap the benefits attributed to standard definition, suggesting a potential disconnect between the inventers of the standard and the innovators of the technology (Chesbrough, 2003). While firms need to develop dynamic capabilities to combat the issues of architectural change for their own products, the governing bodies of these multipartner alliances also need to develop their own dynamic capabilities to adequately manage the complexities of the value chain represented by the alliance.

This Bluetooth database includes details from firms that represent the full spectrum in firm size, organizational structure, headquarters location, and product focus. No single major geographic area has a majority representation within the alliance reflecting a tremendously diverse membership. Approximately 72% of the 885 firms in this sample are privately held. In spite of heroic data collection efforts relying on both primary and secondary sources, emailed interviews, and assistance from the Bluetooth SIG, detailed knowledge about a firm's activities prior to the alliance, ancillary innovation efforts, alliance portfolios, participation in other multipartner alliances, and internal emphasis of Bluetooth are essentially unknown. Each of these factors could contribute to unexplained variance in the existing model.

Little is known about the comparable market success, economic impact, and level of innovativeness of individual products. Details such as where a product was developed, complexity of the innovation, and how long it took to produce are also unknown. Greater knowledge of each of the 5700+ products could enrich the analysis and provide greater insight into both the innovativeness and the performance of the firm related to the technologies of the multipartner alliance. However, the dependent variable of choice throughout this dissertation (*Firm Innovation Productivity*) captures not only a firm's ability to leverage the collaboratively developed innovations of the multipartner alliance for their own benefit, but increasing numbers of new qualified products also reflect to an extent a firm's economic performance from their own innovation productivity.

Considering the ecosystems perspective briefly highlighted in this chapter (more discussion on value networks later in Chapter 3), there is little knowledge of how a firm's products contribute to the overall success of the Bluetooth ecosystem. Some firms may contribute greatly to the success of the overall technology. For example, Cambridge Silicon Radio reported in 2005 and 2006 annual reports that a majority of all Bluetooth qualified end products used their integrated circuits. Others may simply contribute through network effects as each new product released raises the awareness and legitimacy of the technology.

Lastly, as is the case with numerous studies of this nature (including the reference study by Lavie et al. (2007)), these hypotheses were tested using data from a single multipartner alliance drawing concerns of external validity. However, the simple replication study from Hypothesis 1 highlights the effort to increase our understanding of multipartner alliances by crossing alliance boundaries. Additionally, as will be shared in Chapter 5, preliminary work is underway to examine how strategic choices within multiple multipartner alliances may alter the benefits participating firms may enjoy.

While this study extends the study by Lavie et al. (2007), as noted above, more research is needed to generalize the findings for other industries, alliance configurations, and governance structures. The boundary conditions of this study may be defined by each of these areas. First, the Bluetooth SIG was formed to "create a market" for short-range wireless communication between computing, consumer, and communication devices. Members of this multipartner alliance faced significant technological and market uncertainty for at least the first five years of existence. Future research could examine benefits attributed to order of entry and value chain position in settings facing much less uncertainty, perhaps in markets where uncertainty is not determined by the question of "if" the technology would be adopted, but rather, "which one."

Second, the Bluetooth SIG exhibits several characteristics that differentiate it from many of the alliance configurations that receive much attention in the literature. Borrowing language from wireless networking vocabulary, many of the technology-focused multipartner alliances tend to have a "mesh" network configuration as opposed to a "star" network configuration. A star network is defined as a central hub and spoke configuration with a powerful, decision-making central-node with ancillary nodes tied primarily to the hub. The automotive maker/supplier and pharmaceutical distributor/innovator networks are excellent examples of star networks. Alternatively, the mesh network configuration has distributed monitoring and control responsibilities with the potential for some clustering and a significant number of ties between many participants (hence the moniker "mesh"). Multipartner alliances, including the Bluetooth SIG, typically have open membership with diversified control and opportunities to influence by many members. Benefits attributed to timing of entry and value chain position may differ in alternative network configurations and closed membership.

Third, governance structure varies across multipartner alliances. While the Bluetooth SIG uses a semidemocratic combination of a governing board consisting of large sponsoring partners, multiple layers of membership, and professional management, other alliances may be governed by a focal sponsoring firm, government agency, trade association, or a full democracy that may improve or degrade the social order necessary to execute the objectives of the alliance. These alternative governance structures may change the innovation opportunities of member firms.

Lastly, in the expanding exploration of heterogeneity of benefits in multipartner alliances, new venture creation is an instrumental and understudied aspect of these alliances. Understanding the role new ventures play in multipartner alliances could contribute to not only their impact on the alliance, but also an understanding of the entrepreneurial challenges of differentiating in highly competitive ecosystems built on the principle of establishing commonality. Participating new ventures are studied in more detail in Chapter 4.

Beyond the guidance this study provides to firms developing participation strategies in multipartner alliances, this study also advances the research on heterogeneity of benefits to partners. Considering the number of substantial and complex innovations that are being developed and marketed by the collaborative efforts of large multipartner alliances, advancing the understanding of firm strategies designed to maximize appropriation and improve alliance governance represents an important agenda for strategy, organization theory, and entrepreneurship research.

CHAPTER 3

CONTRIBUTION STRATEGIES IN MULTIPARTNER ALLIANCES

In Chapter 2, the early-stage participation decisions of when to join and where to focus in the value chain were examined with respect to the firm's innovation productivity. Once a member, participation decisions expand to include levels of membership and contribution to the multipartner alliance. The direction, resources, and capabilities of a member firm are rarely aligned with the direction and collaboratively created resources and capabilities of the alliance. A firm will often select a membership level and how it contributes to the multipartner alliance to narrow this gap. Two key mechanisms for narrowing the gap are advanced in this chapter. First, a firm may actively attempt to influence the direction and knowledge-pool of the alliance through purposive outflows of knowledge to align with existing capabilities and resources of the firm. On the other side of the gap, a firm may leverage these employee-contributors to learn and absorb collectively generated tacit knowledge and latent information that is not captured in codified specifications developed within the alliance (Cohen & Levinthal, 1990; Schilling & Phelps, 2007; Zahra & George, 2002).

Research has found that increased levels of involvement in networks such as multipartner alliances have been linked to increased benefits from membership. These increased benefits have been attributed to greater embeddedness (Granovetter, 1985; Ibarra, 1993), superior access to tacit knowledge (Grant, 1996), control of alliance decision processes and agendas (Rosenkopf et al., 2001), influence on the alliance through leadership (Uzzi, 1997), or the exploitation of open innovation (Chesbrough, 2003; Chesbrough, Vanhaverbeke, & West, 2006). The work in this chapter is built upon the open innovation paradigm initially labeled and defined by Chesbrough (2003) and advanced by an expanding collection of scholars (Almirall & Casadesus-Masanell, 2010; Dahlander & Gann, 2010; Henkel, 2006; Laursen & Salter, 2006; Vanhaverbeke, 2006; Waguespack & Fleming, 2009; West, 2006). I extend open innovation research in two ways. First, this chapter joins the sparse large-scale empirical work in open innovation by testing a fundamental question of open innovation – the relationship between purposive outflows or spillovers of knowledge and appropriated firm benefits. While appropriation of benefits has frequently been tied to tight appropriability regimes relying on strong intellectual property (IP) protection (Chesbrough et al., 2006; Dahlander & Gann, 2010; Teece, 1986; West, 2007), this research explores this fundamental question inside a weak appropriability regime where members of multipartner alliances work within the framework of a royalty-free IP agreement. Second, while IP and complementary assets have frequently been described as mechanisms enabling appropriation (Chesbrough, 2009; Teece, 1986; West, 2006, 2007), this study advocates that the less-formal, gap-narrowing mechanisms of aligning and absorbing can significantly influence benefit appropriation, particularly in weak appropriability regimes.

Prior research has examined network position and membership level (with specific focus on multipartner alliance board members) (Lavie et al., 2007) as proxies for involvement. These are not direct measures of involvement and contribution but only reflect the opportunity for involvement. While opportunity for involvement is also assessed in this chapter, I explore the impact of direct, purposive contributions to the alliance's standard specifications on a firm's innovation productivity. Empirical results defend the benefits of active involvement and contribution while providing support to appropriation mechanisms of alignment and absorption.

Theory and Hypotheses

Following the decision to join a multipartner alliance, a firm makes strategic decisions regarding its level of involvement in the alliance. These decisions may include selection of membership level, quantity and method of knowledge contribution to the collective, and how to appropriate benefits from membership (particularly for this study, the benefit of increased firm innovation). A cost-benefit tradeoff exists between costs attributed to active contribution to the collective and the opportunity to appropriate innovation benefits from involvement in the multipartner alliance. Far greater than actual cost of participation which may be attributed to member dues and participation expenses, contributing firms incur direct costs in dedicated personnel, management attention, and operational costs tied to the development and production of technology or products related to the alliance. Indirect costs related to unintentional spillovers, opportunity costs of participation, and delays attributed to consensus seeking add complexity to the tradeoff. On the surface, cost-economizing theory (Williamson, 1985) may suggest that actively contributing firms may destroy firm value without proper isolating and appropriation mechanisms. Additionally, resource-based theory (Barney, 1991; Wernerfelt, 1984) may argue that free movement of firm knowledge and capabilities beyond the borders of the firm hurts competitive advantage through reduced rarity and ease of imitation.

On the other side of the cost-benefit tradeoff, considerable research has examined the benefits of collaboration and found that firms can enhance their own innovation through contributions to the collective. These innovation improvements have been linked to the absorptive capacity of the firm (Cohen & Levinthal, 1990), embeddedness (Granovetter, 1985), opportunities for better dyadic alliances (Rosenkopf et al., 2001), improved ties with other firms (Ahuja, 2000), greater discernment of tacit knowledge (Grant, 1996), or through an exploitation of open innovation (Chesbrough, 2003; West, 2005; West & Gallagher, 2006). As noted in the introduction, this chapter builds upon open innovation in that increased levels of active contribution to the alliance (purposive outflows) can be positively related to the innovation productivity of the firm. However, the key to a favorable outcome for the firm may be in managing how to actively contribute to the alliance in spite of abundant free-riding opportunities, a weak appropriability regime, and need for complementary assets (Chesbrough, 2003; Teece, 1986; West, 2006).

Open Innovation has been defined as "the use of purposive inflows and outflows of knowledge to accelerate internal innovation, and expand the markets for external use of innovation, respectively" (Chesbrough et al., 2006). While accessing and using external innovation and knowledge have been highlighted in various research for decades (Cohen & Levinthal, 1990; Nelson & Winter, 1982; Zahra & George, 2002), Chesbrough (2006) outlines key differences including the balance between internal and external innovation, use of external innovation as central to the business model, enabling others to exploit internal innovation, and the assumption that useful knowledge is widely distributed and generally of high quality.

Firms using external innovation as central to the business model may rely on external knowledge sourcing from suppliers, customers, alliance partners, and even competitors to increase a company's innovativeness (Laursen & Salter, 2006). This has recently been labeled the "outside-in process" as compared to the "inside-out process" where externalizing firm knowledge and innovation is instrumental to firm success (Enkel, Gassmann, & Chesbrough, 2009). More germane to this study is the "coupled process" (Enkel et al., 2009) that combines both processes to jointly develop and commercialize innovation, and specifically complex innovations that require an ecosystem or value network to successfully define, develop, and market the innovation.

While the concept of position within a linear value chain was used in Chapter 2 to illustrate moderating effects on the relationship between entry timing and innovation productivity, the value network adds dimensions of complexity. Within a value network, not only are complementors and competitors added to the traditional value chain of suppliers and customers, but a nested architectural hierarchy suggests parallel value networks pursuing different levels of the overall system architecture (Christensen & Rosenbloom, 1995). For example mobile handset, network, and service providers form a value chain to bring mobile telephony to the consumer. Within standards bodies such as those focusing on GSM technology, competing and complementing firms collaborate to develop standards for interoperability. Dropping down a level in the nested hierarchy, semiconductor and software firms ensure components are available to the value chain to meet the standards. Moving up a level, governments and standards organizations such as

ANSI (American National Standards Institute) and ETSI (European Telecommunications Standards Institute) help regulate and ensure compatible standards. This is an example of a value network with nested hierarchy. It also highlights the complexity associated with coordinating innovation within and appropriating value from value networks structured as multipartner alliances.

Within some multipartner alliances that rely on member contributions to formally define technology, intellectual property pools (Rysman & Simcoe, 2008; Simcoe, 2006) may be used to determine innovation value and appropriation patterns for contributors. In weak appropriability regimes, complementary assets and selective release of firm know-how often dominate appropriation patterns (Chesbrough, 2009; West, 2007). In this work, I make a case for two additional mechanisms, alignment and absorption, that may be used in collaborative value network settings such as multipartner alliances to influence appropriation from open innovation. Alignment is the intentional effort of a firm to shift the direction of the alliance to more closely align with the firm. Absorption is the assimilation and use of collaboratively generated knowledge to shift the direction of the firm to more closely align with the alliance. This is a reflection of the coupled process described earlier (Enkel et al., 2009). Considering a probable misalignment or gap between the direction, resources and capabilities of the alliance compared to those of the firm at the time of entry, the mechanisms of alignment and absorption may be used by a firm to narrow this gap. The mechanisms represent endogenous attempts at influencing the direction of or extracting knowledge from the multipartner alliance for the benefit of the firm.

In identifying mechanisms of appropriation, Teece (1986) was particularly interested in how profits or rents accrue to the innovator. In this study, I take an intermediate step towards appropriation of economic rents by exploring the mechanisms that influence how a firm uses collaboratively developed innovation to enhance the firm's own innovation productivity or the rate at which a firm develops new products that rely on the collaborative innovation. While the link to economic profits is not direct, it is also not distant as high levels of sustained innovation productivity suggest that a firm has likely captured sufficient value from the technology to maintain and increase the product portfolio. The link becomes more ambiguous for low levels of innovation productivity suggesting that a firm may have successfully made the intermediate step towards appropriation of economic rents, but for a variety of reasons (many of which may have been associated with the firm's failure to appropriate profit), innovation productivity was not sustained.

In large scale multipartner alliances where no single firm provides the technological and strategic leadership for the alliance, direction is often determined through consensus and formal voting processes among influential members of the alliance. Less formal means of providing direction and establishing the resources and capabilities of the alliance may be found in the working committees of the alliance as participating members advance alternative approaches and use conflict resolution processes to hone in on preferred directions and technologies (Rosenkopf et al., 2001). The direction, resources, and capabilities of a contributing firm are rarely aligned with those of the alliance creating the aforementioned gap. An objective for some contributing firms may then be to influence the direction, resources, and capabilities of the alliance to more closely align with those of the firm. Alignment may be attempted by occupying leadership positions within the alliance, creation of dyadic alliances within the multipartner alliance to consolidate influence, accelerated external market leadership in the technology of interest, or active contribution to internal technical and market specifications (Ahuja, 2000; Rosenkopf & Almeida, 2003; Rosenkopf et al., 2001; Schilling, 2002; Schilling & Phelps, 2007). I focus on contribution in the form of purposive outflows as an alignment mechanism arguing that an individual firm can influence collaborative efforts through active contribution.

With diffused leadership and participation, the mechanism of alignment will rarely fully close the gap between alliance and firm direction. Adapting a firm's direction to the collaboratively developed direction, resources, and capabilities will likely be required. Adaptation relies heavily on the concept of absorptive capacity initially set forth by Cohen and Levinthal (1990) and reconceptualized by Zahra and George (2002) requiring firms to use knowledge learned from external sources. The mechanism of absorption enables firms to understand not only the codified information that is found in the specifications developed by the alliance, but also gain valuable insight into tacit knowledge and latent information concerning the technology that is shared exclusively by those individuals actively contributing to specification development (Agarwal et al., 2007; Schilling & Phelps, 2007). This insight that can only be gained by actively contributing alliance members may provide a significant innovation productivity advantage to a firm striving to narrow the direction, resource, and capability gap between the alliance and itself.

Prior research examined level of involvement in multipartner alliances as determined by board membership status (Lavie et al., 2007). While board members enjoyed positive effects on market success and exposure, board membership was negatively related to innovation productivity. Level of membership in multipartner alliances is not a direct measure of involvement, but rather a measure of opportunity for involvement and contribution. While greater opportunity (and usually greater expectations) comes from higher levels of membership, considerable variance in involvement and contribution may persist due to the different agendas pursued by members at these levels. In spite of this variance and the finding of Lavie et al. (2007), I assert that greater opportunity for involvement and contribution will lead to enhanced firm innovation through sustained commitment and the mechanism of alignment, a benefit of “higher” levels of membership. In many multipartner alliances, higher levels of membership provide greater opportunities to influence the technical and market direction of the technology through committee participation, voting rights, and internal/external promotion of the technology. This opportunity to align the direction, resources, and capabilities of the alliance with those of the firm may positively influence a firm’s own innovation productivity. Creating a virtuous cycle, greater levels of innovation productivity invite a sustained commitment to the technology and the alliance. Paying membership dues, fulfilling participation expectations, and assigning a firm’s technical- and management-focused employees to the activities of the alliance reflect commitment expected of higher levels of membership. This commitment to the alliance and opportunity for alignment should result in a positive impact on a firm’s innovation productivity.

H1 – Increased opportunity for involvement in a multipartner alliance is positively related to firm innovation productivity.

While membership level may describe opportunities for involvement, it does not examine the direct involvement of participating members. Actively involved members contribute to the development of specifications, provide leadership in the various committees and working groups, and assist in creating the evolving culture of the alliance through attendance and involvement (Rosenkopf et al., 2001). Of particular interest in this study is a detailed examination of contribution to technical specifications that are used by the alliance to create standardized technology and the relationship this contribution may have with a firm's own innovation efforts.

Firms that choose to actively contribute with other firms to the development of specifications may enjoy at least two benefits that enhance a firm's own innovative efforts compared to those firms that do not contribute. First, while a primary purpose of the specification development effort is to codify collective knowledge and reduce it to information, studies have shown and interviews with participants in this effort have suggested that some knowledge required to successfully implement a specified technology remains tacit or uncodified and thereby, exclusively shared and potentially absorbed by those firms involved (Agarwal et al., 2007; Ahuja, 2000; Schilling & Phelps, 2007). Second, a firm contributing to specification development may bring unique resources or knowledge to the collaboration that aligns specifications with firm-specific capabilities, resources, and knowledge. This alignment may contribute to reduced innovation risk for the contributing firm and accelerate innovation productivity. Based on these benefits of active contribution, I hypothesize that contributing firms will enjoy greater innovation productivity than noncontributing firms.

> *H2 – Contributing firms have greater firm innovation productivity than non-contributing firms.*

Once a firm chooses to contribute to specification development, other strategic collaboration choices remain. These include how to contribute, how much knowledge to share, when, and what to contribute to the collective. Here, I examine how a firm contributes and the relationship between different proxies for contribution and innovation productivity. In Chapter 4, I explore the innovation productivity differences that are related to the timing of a firm's contribution.

Chesbrough (2003) suggests an innovation paradigm shift is occurring in some industries where firms appropriate benefits from innovations that may originate inside of the firm but are exploited by others (purposive outflows) or originate elsewhere and are exploited by the focal firm (purposive inflows). The multipartner alliance setting presents a small twist to the open innovation paradigm in that purposive outflows by multiple firms partially contribute to innovation but also requires the collaborative efforts of the contributors to complete usable specifications. Purposive inflows reflect a firm's ability to absorb and use (Zahra & George, 2002) the collaboratively developed innovations. This highlights once again the mechanisms of alignment and absorption used to close the gap between the direction, resources, and capabilities of the firm and those of the alliance.

Two dimensions of contribution are proposed and tested in this chapter. While both mechanisms of alignment and absorption may be at work simultaneously, I argue that each dimension represents a more dominant mechanism. Along the first dimension, labeled breadth, a firm chooses the number of participants it involves in the alliance processes. For this study, I focus on the process of specification development. When a firm's employee has made a sufficient contribution to be recognized by committee leadership, she is acknowledged as a co-author of the specification. Contribution comes in various forms from architectural, component, application or implementation knowledge-sharing to coordination to errata resolution to prototyping. This active involvement by an author provides ample opportunity to not only contribute, but also to absorb the tacit and/or uncodified latent knowledge created within the collaboration. Absorptive capacity is frequently operationalized by R&D intensity (Cohen & Levinthal, 1990) or other measures reflective of the quantity of people invested in creating and absorbing knowledge. When multiple people are involved, a key element of absorptive capacity is the creation, maintenance, and broadening of a common knowledge base from which to absorb tacit knowledge (Reagans & McEvily, 2003) and the ability to broaden that common knowledge base through diversity of expertise (Cohen & Levinthal, 1990). Therefore, I hypothesize that the more employees a firm has that contributes to the specification development in a multipartner alliance, the greater breadth of knowledge a firm will have to not only establish a common knowledge base, but also more diversity of expertise to leverage in firm innovations related to the technology of the alliance.

> *H3a – Increased breadth of knowledge contribution to a multipartner alliance is positively related to firm innovation productivity.*

The second dimension captures the depth of involvement a firm can have in technology developed by the multipartner alliance. Considering the hierarchical and dependent nature of specifications development to innovate the complex technologies developed by technology-focused multipartner alliances, a firm may choose to contribute to more specifications to more closely align the direction of the alliance with that of the firm. While this is done through purposive outflows of knowledge from the firm to the alliance in striving to align technical specifications with technical capabilities of the firm, other devices are also at work. For example, a firm contributing to many specificaitons will likely have employees that create a deeper network within the multipartner alliance (due to the extended influential reach) and assume brokerage positions (Burt, 1992; Burt, 2004) from the connections made while working with various contributors across multiple specifications. These ties may also result in greater network centrality to both align firm and alliance objectives and enhance innovativeness (Bell, 2005). Additionally, contributing to a greater number of specifications deepens not only the component knowledge described by individual specifications, but increases the influence a firm can have on the technology's system architecture defined across the hierarchy of specifications. Considering the alignment opportunities through outflowing knowledge contribution, network positioning, and influencing higher-level architectural issues, I hypothesize that increased depth of knowledge contribution through increasing number of specifications is positively related to firm innovation.

H3b – Increased depth of knowledge contribution to a multipartner alliance is positively related to firm innovation productivity.

While depth and breadth of knowledge are subsets of total knowledge contribution (and are likely highly correlated with total knowledge contribution), the effects of total knowledge contribution on firm innovation productivity may extend beyond the technological alignment, knowledge absorption, system architectural, and network positioning arguments detailed above. Depth and breadth examine contribution on single dimensions and while total contribution reflects a multidimensional view of contribution, it is not simply multiplicative of breadth and depth dimensions. Not only does total contribution reflect the most comprehensive measure of a firm's purposive outflows, but it also highlights the balance (or intentional imbalance) a firm may strive to achieve between breadth and depth. Thus, I argue that a firm's total contribution portrays both tactical and strategic measures of alliance contribution. I hypothesize that total knowledge contribution is also positively related to firm innovation productivity.

H3c – Increased total knowledge contribution to a multipartner alliance is positively related to firm innovation productivity.

Data and Methods

The empirical analysis in this chapter also uses the Bluetooth SIG, a large, international multipartner alliance focused on the ongoing development of short-range wireless technology. As noted in Chapter 2, members of the SIG have joined at one of three different levels of membership (Promoter, Associate, or Adopter) with some flexibility to change membership level throughout their membership (e.g., new Promoters must be invited by the other Promoter firms, Adopters must pay annual member fees to move to Associate membership, etc.). Each level provides varying degrees of involvement opportunity through observation, specification development, leadership, and voting. While membership level has been used as a proxy for involvement in prior research (Lavie et al., 2007), this measure only reflects the opportunity for involvement and is not necessarily a direct measure of involvement.

Throughout the history of the Bluetooth SIG (to the end of 2009), there have been over 100 specifications or subspecifications adopted by the governing board of the SIG. There were 553 unique authors from 106 different firms who participated in the development of these specifications. Authorship is achieved through various means including original contribution, significant editing, errata contributions, or concept validation. Unlike other consortia such as the Internet Engineering Task Force (IETF) (Waguespack & Fleming, 2009) or IEEE where specifications are typically developed and sponsored by a firm or individuals to then be scrutinized, enhanced, and voted upon by fellow committee members, any individual from a Bluetooth member firm may gain authorship through active contribution to the specification development as determined by committee leadership. By examining actual authorship of each specification, it is possible to explore the breadth, depth, and total contribution of knowledge by the 106 actively participating firms.

I examine a firm's qualification of new products as the measure of innovation productivity. To normalize for time involved in the SIG, I also normalize the innovation productivity measure for total duration of membership. As of November 2007, 5856 products have been qualified by 884 different firms. From the 106 firms that actively contributed to specification development, 1814 products were qualified by 74 product producing firms.

Measures

Dependent variable. The dependent variable (*Firm Innovation Productivity*) is measured as the number of new products a firm has qualified to the Bluetooth standard. Only firms that have qualified at least one product in the firm's history are included in the dataset. To account for varying lengths of membership by contributing firms, a variable offset was included in the model to capture the number of years the firm was a member of the alliance.

Independent variables. To capture membership level and considering some firms have occupied multiple levels of membership throughout the history of the Bluetooth SIG, I dummy code each firm based on the highest level of membership achieved: *Promoters* (board members), *Associates* (active members with paid membership), and *Adopters* (passive members with free membership). To differentiate between active and passive participants (*Contributor)*, each firm from the set of firms that qualified at least one product is coded a "1" if the firm had an employee as a contributing author to any specification, and a "0" if the firm did not employ any contributing authors to any specifications.

Considering the breadth and depth of knowledge that may be possessed by employees from contributing firms, I measure a firm's knowledge contribution along two dimensions. Breadth of knowledge is measured as the number of *Total_Unique_Authors* employed by a firm who contributed to any specification, suggesting greater opportunities for absorption with greater numbers of people involved. Depth of knowledge is captured as the number of unique *Total_Specifications* authored by employees of the firm, suggesting deeper involvement in hierarchical specification development and network positioning. A third measure of contribution, *Total_Contribution,* is coded for each firm as the cumulative number of times all authors from a firm received authorship acknowledgement in all specifications.

Control variables. Considering the limitations of working with a large database consisting of firms extensively international and private, a simplified coding scheme was used to capture effects related to firm size. For Hypotheses 1 and 2, *Large_Firm* was coded a "1" for those firms determined to have greater than $300M USD in 2009 revenues and/or greater than 1,000 employees as determined through public records, email interviews, and information available through company websites and press releases. The variable was coded a "0" otherwise. Additionally, *Order_of_Entry* remains in the model to capture variance attributed to timing of entry which is the order of entry as determined by the date a firm joined the Bluetooth SIG. The first entering firm was coded "1," the next firm a "2" and so forth.

For Hypotheses 3a, 3b, and 3c, improved access to data (primarily through the Bluetooth SIG) for firms that actively contributed to specification development enabled the use of additional control variables that may explain variance in the innovation productivity measure for firms actively contributing to the multipartner alliance. To account for failed (*Failed Firm)* or acquired firms (*Acquired firms)* that may reflect an earlier-than-expected end to innovation productivity, two dichotomous measures are included to capture effects related to these exits (coded "1" if failed or acquired, a "0" otherwise). Considering that only alliance members with either Promoter membership or Associate membership are entitled to contribute to the specification development process, I draw distinction between these two levels of membership with the dichotomous measure *Promoter* to capture effects related to membership level (*Promoters* are coded a "1", *Associates* a "0"). Membership duration measured in days is captured as an offset variable in the dependent variable. Firm size is captured in the measure *Small_Firm* which was coded a "1" for those firms determined to have revenues less than $300M USD in 2009 and/or less than 1,000 employees.

Analysis

Descriptive statistics are reported in Table 3.1 for the analysis of Hypotheses 1 and 2 and in Table 3.3 for the analysis of Hypotheses 3a, 3b, and 3c. Hierarchical negative binomial regressions using the SPSS 17.0 GLM module were used to account for the skewed distribution and overdispersion caused by the dependent variable's count data. As in Chapter 2, the dependent variable *Innovation_Productivity* is normalized for time using a log of the number of days each firm has been a member of the Bluetooth SIG. Hypothesis 1 was evaluated using Model 1 from Table 3.2 to understand the innovative productivity gains *Promoter* and *Associate* members have compared to the

Table 3.1. Descriptive statistics – all qualifying members

	N	Mean	STD	1	2	3	4	5	6
1. Innovation_Productivity	885	6.47	23.83	1.000					
2. Large_Firm	885	.28	.45	0.289	1.000				
3. Order_of_Entry	885	1.00	255.62	-0.304	-0.236	1.000			
4. Promoter	885	.01	.09	0.111	0.144	-0.134	1.000		
5. Associate	885	.38	.49	0.441	0.001	-0.052	-0.070	1.000	
6. Contributor	885	.08	.27	0.299	0.253	-0.178	0.259	0.230	1.000

Table 3.1 reports the number of observations, means and standard deviations of the study's variables and the Spearman's correlations. Correlation coefficients larger than 0.065 in absolute value are significant at the 5% level.

Table 3.2. Regressions for level of membership and contribution

	Model 1	Model 2
Intercept	-6.712***	-6.712***
	(0.053)	(0.053)
Large_Firm	1.017***	0.944***
	(0.077)	(0.078)
Order_of_Entry	0.001***	0.001***
	(0.0002)	(0.0002)
Promoter	2.421***	1.994***
	(0.339)	(0.351)
Associate	1.208***	1.139***
	(0.071)	(0.072)
Contributor		0.528***
		(0.125)
Dispersion Parameter	0.74*	0.72*
N	885	885
Log Likelihood	-2181.0	-2171.4
df	879	878
2x Delta Log Likelihood from Model 1		19.2***

Standard errors are reported in parentheses.
Significance levels (2-tailed): * p < .05, ** p < .01, *** p <.001

contrast group of *Adopters*. A positive and significant beta coefficient on these dummy coded measures would suggest support for Hypothesis 1. Hypothesis 2 was examined using Model 2 in Table 3.2 to determine the innovation productivity benefits when comparing product-producing firms that contribute to specification development and those that do not.

Descriptive statistics related to the contribution hypotheses are captured in Table 3.3. Hypotheses 3a, 3b, and 3c were evaluated using models 4, 5, and 6 in Table 3.4. Due to the highly correlated measures of depth, breadth, and total contribution, each

Table 3.3. Descriptive statistics - contributing firms

	N	Mean	STD	1	2	3	4	5	6	7	8
1. Innovation_Productivity	106	22.27	43.03	1.000							
2. Promoter	106	.08	.27	0.244	1.000						
3. Acquired	106	.15	.36	-0.250	-0.120	1.000					
4. Failed	106	.03	.17	-0.157	-0.049	0.087	1.000				
5. Small_Firm	106	.44	.50	-0.472	-0.255	0.207	0.191	1.000			
6. Total_Unique_Authors	106	5.22	9.83	0.431	0.468	-0.038	-0.016	-0.420	1.000		
7. Total_Unique_Specifications	106	9.35	14.80	0.490	0.425	0.066	-0.042	-0.379	0.706	1.000	
8. Total_Contribution	106	19.00	41.28	0.471	0.426	0.026	-0.007	-0.408	0.858	0.936	1.000

Table reports the number of observations, means and standard deviations of the study's variables and Spearman's correlation matrix

Correlation coefficients larger than 0.19 in absolute value were significant at the 5% level.

Table 3.4. Regression results for measures of contribution

Negative Binomial Results - Breadth, Depth, and Total Contribution
DV - Firm Innovation Productivity (offset ln(DaysMember))
Only Contributing Firms Included

	Model 3	Model 4	Model 5	Model 6
Intercept	-4.512***	-4.990***	-5.134***	-4.869***
	(0.240)	(0.261)	(0.259)	(0.254)
Promoter	0.792	-1.927†	-1.240	-0.434
	(0.621)	(1.075)	(0.847)	(0.740)
Acquired	-0.722	-1.175*	-1.454**	-1.237*
	(0.496)	(0.472)	(0.496)	(0.491)
Failed	-2.307†	-2.325*	-2.351*	-2.338*
	(1.206)	(1.179)	(1.187)	(1.193)
Small_Firm	-1.577***	-1.196***	-1.026**	-1.194***
	(0.343)	(0.346)	(0.353)	(0.358)
Total_Unique_Authors (Breadth)		0.090**		
		(0.033)		
Total_Specifications (Depth)			0.052**	
			(0.017)	
Total_Contribution				0.014*
				(0.006)
Dispersion Parameter	2.61*	2.36*	2.26*	2.41*
N	106	106	106	106
Log Likelihood	-364.6	-360.1	-358.4	-361.0
df	100	99	99	99
2x Delta Log Likelihood from Model 1		9.0**	12.4***	7.2**

Standard errors are reported in parentheses.
Significance levels (2-tailed): † $p < .1$, * $p < .05$, ** $p < .01$, *** $p < .001$

model independently examines the impact each type of contribution may have on a firm's innovation productivity. While this method enables the independent examination of different types of contribution, a comparative analysis is not meaningful.

Results

To test Hypothesis 1, I examined the significance of the coefficients for the dummy variables *Promoter* and *Associate* that are contrasted with the lowest level of membership, *Adopter* in Model 1 of Table 3.2. Both variables exhibited positive and significant relationships with the dependent variable, *Innovation_Productivity* $(\beta = 2.421, p < .001; \beta = 1.208, p < .001)$. The magnitude of the *Promoter* predictor coefficient was greater than that of *Associate* suggesting a possible significant difference between these two levels of membership. In an alternative test contrasting *Promoter* and *Adopter* against *Associate* to verify a significant difference between *Promoter* and *Associate*, a positive and significant result was also obtained, suggesting increasing levels of innovation productivity with increasing levels of membership. Hypothesis 1 is supported. Hypothesis 2 was evaluated by examining the positive and significant *Contributor* coefficient in Model 2 $(\beta = 0.528, p < .001)$, suggesting that product-producing firms that actively contribute to the creation of technical specifications enjoy greater innovation productivity than those that do not. Hypothesis 2 received empirical support.

Transitioning to the dataset that includes only those firms that actively contributed to specification development (descriptive statistics are in Table 3.3), I examine the coefficients of contribution measures for each of the different forms of contribution as expressed in Hypothesis 3a, 3b, and 3c. In Model 4, the coefficient for *Total_Unique_Authors* is positive and significant $(\beta = 0.090, p < .01)$ indicating support for the hypothesis that broader participation through an increased number of unique authors is positively related to innovation productivity. From Model 5, the predictor coefficient for *Total_Specifications* is positive and significant $(\beta = 0.052, p < .01)$ providing support for the hypothesis that contributing to the development of an increased number of specifications is positively related to innovation productivity. Finally for Hypothesis 3c, the coefficient for the comprehensive measure of contribution, *Total_Contribution* $(\beta = 0.014, p < .05)$ is also positive and significant. Independently, each measure of contribution is positively and significantly related to innovation productivity providing multi-faceted empirical support to the open innovation argument that firms making intentional outflows of knowledge (even in weak appopriability regimes such as the Bluetooth SIG), may appropriate greater internal benefit from their shared knowledge and highlights multiple contribution methods that may enhance these benefits.

Discussion and Conclusion

While early work in open innovation relied heavily on case studies, small-sample qualitative studies, and examination of a limited number of industries such as open source software and high technology (Chesbrough, 2003; Gruber & Henkel, 2006; West & Gallagher, 2006), academic research is expanding to include recent articles and dedicated issues in journals such as Academy of Management Review, Academy of Management Journal, Research Policy, and R&D Management. While few in number, larger-scale empirical studies have emerged and are reaching beyond traditional industries including manufacturing (Laursen & Salter, 2006), automotive (Ili, Albers, & Miller, 2010), information technology (Waguespack & Fleming, 2009), and user communities (von Hippel, 2005). Reviewing scholarly work from the last several quarters (including the June 2010 edition of R&D Management, a special edition on open innovation co-edited by Chesbrough), I identify at least four general themes for future research. First, empirical work beyond small-scale, industry-specific studies will enhance credibility of open innovation as a meaningful paradigm shift. Second (and as captured in recent work by dissertation committee member, Joel West), making sense of a growing innovation segmentation that includes open, user, cumulative, mass, and distributed innovation could unify the research community examining the opportunities associated with external innovation. Third, while some research has examined how open innovation affects new ventures in open source software, extending the empirical work in different settings and tying open innovation to sources of new ideas and opportunities may provide insight into the value of open innovation in entrepreneurship. Fourth, understanding mechanisms that provide a more holistic model and limitations of open innovation is needed. The research of this dissertation contributes to the first (Chapter 3), third (Chapter 4), and fourth (Chapter 3) themes of future research.

A key goal of this dissertation is to examine endogenously influenced decisions that may provide insight into the relationship between a firm's multipartner alliance participation strategies and its innovation productivity. While Chapter 2 explored decisions of when to become a member, this study picks up after this decision has been made to join and empirically examines the impact of membership level and of contribution. I also explored how certain forms of contribution may impact firm innovation productivity. Multiple theories predict the positive relationship between a firm's participation in network configurations such as multipartner alliances and the benefits the firm may gain. However, considering the weak appropriability regime with Bluetooth's royalty-free intellectual property licensing policy and significant opportunities for free-riding, one could argue that traditional open innovation mechanisms for appropriating value from purposive outflows of knowledge should have been limited in their effectiveness. Beyond providing one of the few large-scale, empirical validations of open innovation concepts, this work explores two additional mechanisms affecting appropriation under conditions of weak appropriability in settings such as multipartner alliances. First, alignment is the intentional effort to influence the activities of the multipartner alliance to align with those of the firm. Second, absorption is the process of learning collaboratively generated knowledge and using it within the firm to move a firm's direction, resources, and capabilities closer to those of the alliance. These alternative mechanisms, which may be particularly effective in weak appropriability regimes, may be used in network settings such as multipartner alliances to affect a firm's appropriation of benefits from participation.

Not only does this contribute to emerging open innovation empirical work, but may also provide theoretical and empirical complements for Lavie's (2006) extension of the RBV that identifies appropriation conditions of relational rent (Dyer & Singh, 1998). These conditions include a firm's relative absorptive capacity (Cohen & Levinthal, 1990), relative scale and scope of resources (Dyer & Singh, 1998), contractual agreement and opportunistic behaviors (Williamson, 1985), and relative bargaining power (Hamel, 1991). Accounting for some of these appropriation conditions, this paper goes beyond the relative scale and scope of resources owned by a participant and examines the scale (and partially the scope) of purposive outflows of knowledge resources contributed to the collective and how this might affect firm innovation productivity.

In conclusion, the goal of this chapter was to explore the impact of a firm's level of membership and contribution to multipartner alliances on its innovation productivity and the potential mechanisms driving that relationship. I found that higher levels of membership and increased levels of contribution are positively related to a firm's innovation productivity. Multiple measures of contribution including the number of unique contributing employees (breadth), the number of unique specifications contributed to (depth), and the total number of author-specification independently demonstrated the positive relationship. Due to the nature of knowledge and weak appropriability regime within the Bluetooth SIG, mechanisms of alignment and absorption were introduced to complement traditional open innovation mechanisms of IP rights and complementary assets to influence appropriation of benefits. Both alignment and absorption are primarily endogenous mechanisms and were found to be influential.

There are several limitations of this study. First, with empirical results from a single multipartner alliance, greater understanding of innovation patterns will come from studying other alliances. In particular, alignment and absorption have been highlighted as mechanisms of value within multipartner alliances with weak appropriability rights, primarily from royalty-free licensing. Considering much standard-setting and some open innovation research use settings with a tighter appropriability regime (including GSM mobile phone technology, some IETF internet technologies, and many of the standards from IEEE, ISO, and ANSI) with meaningful IP protection for contributors, this opens a new door for additional research in standard-setting multipartner alliances and coalitions operating primarily under royalty-free licensing policies. A second limitation of this study is in disentangling and isolating the mechanisms advanced in this chapter. Depth, breadth, and total contributions are highly correlated (depth and breadth are subsets of total contribution) with each other and while breadth and depth have been argued to represent distinct mechanisms of absorption and alignment respectively, are not separable within the Bluetooth context. A third limitation (and strength) is in using the Bluetooth SIG as a context of interest. With a significant majority of the product-qualifying firms headquartered internationally and privately held, greater precision in and breadth of control variables are simply limited by the availability of data. This is in spite of extensive database and internet searches, more than a hundred emailed inquiries, and tremendous assistance from the Bluetooth SIG. This is also considered a strength due to the size and truly international nature of the Bluetooth SIG membership. Fourth, with the measure of contribution related to authoring, neither the value nor the extent of a contribution is captured. Increased insight into the actual contribution could lead to greater understanding of the mechanisms of alignment and absorption.

Considering the still-early stage development of open innovation within collaborative settings such as multipartner alliance, as noted earlier, future research in this area will benefit from understanding how and when certain mechanisms of appropriation may be used to affect the appropriation patterns for firms. Firms participating in standard setting organizations with a relatively strong appropriability regime may delay the disclosure of intellectual property to minimize spillover impact to the firm while still gaining economic benefits (through royalty pools) from the purposive outflows of knowledge. As will be explored in Chapter 4, early use of purposive outflows may generate collaborative advantage for firms within weak appropriability regimes.

CHAPTER 4

CONTRIBUTION TIMING AND FIRM SIZE

Considering the entry timing, value chain positioning, and contribution strategies explored in Chapters 2 and 3, this chapter adds two new variables of interest to the overarching topic of firm strategies within multipartner alliances that may influence firm innovation productivity. The first examines the assertion of a collaborative phase and a competitive phase within the ongoing life cycle of multipartner alliances and how active contribution within each period may influence a firm's innovation performance. I assert that firms enjoy certain advantages through early-stage or collaborative-stage participation that may lead to enhanced firm innovation productivity. Traditional early-mover advantages highlighted in Chapter 2 that are likely more meaningful for active contributors include the opportunity to influence technological specifications (see mechanism of alignment discussed in Chapter 3) and to initiate market direction. Firms may find the social capital and network positioning gained through making early contributions to the alliance particularly valuable when tangible market performance is not yet available and market leaders are determined through less tangible means such as awareness and perceived influence (Ahuja, 2000; Dhanaraj & Parkhe, 2006). The second variable of interest explores the impact of firm size by contributing firms. Small firms that may be deficient in traditional sources of competitive advantage may use the fertile ground of a multipartner alliance to develop "collaborative advantage" that may lead to enhanced innovation performance as compared to larger firms (Almeida, Dokko, & Rosenkopf, 2002).

This work continues to use the Bluetooth SIG setting for empirical testing. Considering the more collaborative nature[1] and the weak appropriability regime of the Bluetooth SIG, this part of the study may provide valuable insight into timing of contribution. Additionally, this complements research by Waguespack and Fleming (2009) who explored how different forms of contribution by new ventures to the Internet Engineering Task Force (IETF) may improve a startup's chances of a liquidity event by evaluating the effects of contribution on an alternative dependent variable, innovation productivity. Unlike the research of Waguespack and Fleming, I analyzed the small firm's innovation productivity compared to large firms, and I expected that large firms would have greater innovation productivity, but increased levels of contribution by small firms would enable them to close the gap with similarly contributing large firms.

Empirical results do not show significant differences in innovation productivity related to timing of contribution. As expected, small firms are disadvantaged by their size but unexpectedly do not make up ground lost to larger competitors through increased levels of contribution. Exploring further, I then discovered that small firms contributing primarily during the collaborative phase experienced an innovation productivity disadvantage. This leads to a discussion of relational rent appropriation and the

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[1] From interviews of lifetime participants in the Bluetooth SIG, many of the people interviewed have also worked in standard setting organizations such as the IEEE, IETF, ISO, and GSM. Universally, participants involved in multiple standard-setting organizations describe the Bluetooth SIG as the most collaborative and constructive multifirm standardization body in which they have worked.

disadvantages small firms experience while managing the hazards of alliances and trying to leverage the mechanisms of appropriation discussed in Chapter 3.

Theory and Hypotheses

Technology-focused multipartner alliances can be characterized by a dual innovation process. Consistent with the open innovation research agenda advanced by West, Vanhaverbeke, and Chesbrough (2006), members are focused on a dual investment in both the collaborative efforts of the alliance such as specification development, brand marketing, and technology validation, and the internal firm development of technology and complementary assets. As noted in the introduction of this dissertation, this dual innovation process leads to an interesting competitive/collaborative dynamic that may influence the previously analyzed relationships between alliance entry timing, level of involvement, and firm innovation productivity by extending additional benefits to firms that actively contribute during collaborative stage developments of the core technologies.

In Teece's (1986) discussion on appropriability regimes, he highlights two stages in the evolutionary development of technology. The first is a preparadigmatic stage when product designs are fluid and when there is no "generally accepted conceptual treatment of the phenomenon" (Teece, 1986:287). Competition tends to be less focused on profits and more on achieving a dominant design, an activity primarily driven by market forces in Teece's preparadigmatic stage. The second stage reflects the competitive phase when a dominant design emerges. In this phase, firms manage costs, leverage complementary assets, and enhance operational capabilities to compete.

The early-stage activity of a multipartner alliance is similar to a coordinated pre-paradigmatic phase of seeking a dominant design. Relying less on traditional sources of competitive advantage for positioning and more on sources of what could be called “collaborative advantage” such as flexibility, network positioning, and willingness to support knowledge mobility (Dhanaraj & Parkhe, 2006; Laursen & Salter, 2006; Schilling & Phelps, 2007), firms may invest heavily in the collaborative innovation efforts of the alliance while positioning for firm-level innovation activity. During this early phase, high-impact decisions regarding architecture, interfaces, applications, and interoperability are being made, which may lead to opportunities for a firm to align the direction of the alliance with firm-level innovation. Even as a multipartner alliance transitions to a more paradigmatic or competitive phase, evolutionary activities of the alliance may provide numerous opportunities to contribute and influence the alliance; however, these contributions will likely have less impact than early-phase contributions.

Liabilities of smallness or newness (Freeman, Carroll, & Hannan, 1983) suggest that large firms simply have superior resources, more reliable organizational structures, greater absorptive capacity, and more mature processes to compete than small firms (Cohen & Levinthal, 1990; Deeds, 2001). However, considering the collaborative processes and structure of multipartner alliances that may favor collaborative advantage, opportunities may exist for small firms to thrive through active contribution. Recent research by Waguespack and Fleming (2009) explored the relationship between new venture participation strategies in multipartner alliances that focus on standard-setting and the likelihood of a subsequent liquidity event. While I use innovation productivity as a dependent variable, Waguespack and Fleming provide a solid departure point in that they empirically examined multiple measures of new venture participation including authorship, attempt to author, attendance, and leadership and found that attendance was the only measure of participation that enhanced the likelihood of a liquidity event. Adopting the participation measure of authorship, I am particularly interested in innovation productivity differences between small and large firms and how the differences may be affected by increases in authored contributions to the alliance.

Firms actively engaged in the collaborative phase are likely to experience many of the early-entry advantages described in Chapter 2 of this dissertation. These include the opportunity to define technology, set the starting point of the market, and initiate the learning curve (Lieberman & Montgomery, 1988, 1998). Beyond these early-mover benefits, actively contributing firms may improve network position within the social structure of the multipartner alliance to the alliance (Hallen, 2008), and through previously discussed mechanisms of alignment and absorption, may have learning benefits (Almeida et al., 2002) and increased opportunity to absorb and exploit tacit knowledge (Zahra & George, 2002) to enhance innovation. Combining early-mover benefits with benefits from active contribution, firms that actively contribute in the collaborative phase of multipartner alliances will likely generate collaborative advantage that enhances firm innovation productivity.

This is not to suggest that contribution during the competitive phase is without value to a firm's innovation productivity. With much market and technological risk removed, the alliance-adopted and market-accepted transition to the competitive phase provides opportunities to build from the core technologies defined and developed in the collaborative phase. New applications and market expansion create evolutionary opportunities for contribution and further innovation. Reduced technological uncertainty may accelerate the development of new specifications for similar technologies. Fundamentally, multipartner alliances that successfully transition to the competitive phase may have a greater number of opportunities for contributing firms to influence the alliance. However, many of these opportunities are incremental, explore niches, and have less impact than collaborative phase contributions that define the architecture, interfaces, and interoperability of the technology. The higher-impact contributions of the collaborative phase should have greater influence on aligning the core technologies of the alliance with the capabilities of the contributing firm, and thus a firm's innovation productivity. I therefore hypothesize that firms contributing more during the collaborative phase will experience greater innovation productivity than firms that contribute primarily in the competitive phase of the alliance.

> *H1 – Firms focused more on collaborative phase contribution than competitive phase contribution experience greater firm innovation productivity.*

From Stinchcombe's (1965) notion of liability of newness, which has also been extended to smallness (Freeman et al., 1983), deficits related to organizational immaturity, smaller resource pool, reduced absorptive capacity, and lack of legitimacy (Stuart, Hoang, & Hybels, 1999) plague young, small ventures. As was briefly highlighted in Chapter 3, firms choosing to engage in purposive outflows of knowledge may rely on complementary assets under the control of the firm (Chesbrough, 2009) to appropriate benefits from the contributions to the alliance. Larger firms generally have greater access to these complementary assets than small firms, and thus, may use these complementary assets to increase innovation productivity. Therefore, based on longstanding theories related to liabilities of smallness and appropriation mechanisms in open innovation, I hypothesize that actively contributing large firms will have greater firm innovation productivity than actively contributing small firms.

> *H2 – Contributing large firms demonstrate greater firm innovation productivity than contributing small firms*.

Zahra and George (2002) reconceptualized absorptive capacity as a dynamic capability of knowledge acquisition, assimilation, transformation, and exploitation to gain and sustain competitive advantage. They also highlighted various measures traditionally used to capture a firm's absorptive capacity, which include: investment in technical training, R&D personnel, R&D intensity, and process effectiveness. Following absorptive capacity theory (Cohen & Levinthal, 1990; Zahra & George, 2002), firms with smaller R&D functions and fewer personnel are likely to possess smaller absorptive capacity than firms with large R&D functions. This increased absorptive capacity would suggest that as large firms, compared to equally contributing small firms, increase their level of participation and contribution in multipartner alliances, the difference in innovation productivity between large and small firms will likely increase. However, there are certain assets of newness or smallness that may counteract this widening gap. These assets include the ability to overcome major management challenges of adaptation that may exist due to the lack of core rigidities and path dependence that large firms may experience (Leonard-Barton, 1992), possible learning advantages in new areas, and organizational flexibility (Choi & Shepherd, 2005). These assets of newness align with sources of collaborative advantage described earlier suggesting that firms contributing to multipartner alliances may leverage assets of newness to enhance success within the activities of the multipartner alliance which lead to increased innovation productivity. The question of interest is if this increased innovation attributed to assets of newness and smallness by small firms is greater than the increases experienced by larger firms. Considering the need for flexibility, adaptation, and rapid learning in multipartner alliances focused on collaborative innovation and possible conditions of inertia and path dependence experienced by larger, more established firms, I hypothesize that while innovation productivity will likely increase for both firms as contribution increases, the innovation productivity gap between large and small firms will shrink with increased contribution.

> *H3 – Small firms demonstrate greater increases in firm innovation productivity from increased contribution than large firms.*

Data and Methods

The setting for this analysis is once again the Bluetooth SIG, a multipartner alliance that has enjoyed contributions from a broad and diverse set of members since its inception in the late 1990s. I learned through interviews with members of some of the founding Promoter firms that the original vision was to keep all development work the responsibility of the Promoter firms. Founding Promoters presumed they would have the bandwidth and knowledge to complete the specifications of the short-range wireless technology. Additionally, by retaining manufacturing responsibilities of the technology, it was assumed these firms would then have exclusive claim on the rents generated from this technology. This was particularly interesting considering the royalty-free intellectual property agreement these promoter firms had signed, indicating that unlike many communication technologies developed by multipartner alliances at the time (e.g., GSM), there would be no royalty pool and patents attributed to this technology would be freely available to members.

Not long after alliance inception, the board members (represented by Promoters) elected to open the membership to other firms and provided opportunity for committee membership as long as firms were willing to sign the intellectual property rights agreement. Membership grew very quickly and a set of specifications that once was controlled by just a few firms now had hundreds of people from more than one hundred firms actively contributing to their creation. Some commercial acceptance of Bluetooth version 1.1 began with 52 million integrated circuits shipped in 2003,[2] but with the updates to version 1.2 of the core specification released in November of 2003, volumes of product based on the Bluetooth standard grew rapidly (see Figure 4.1)

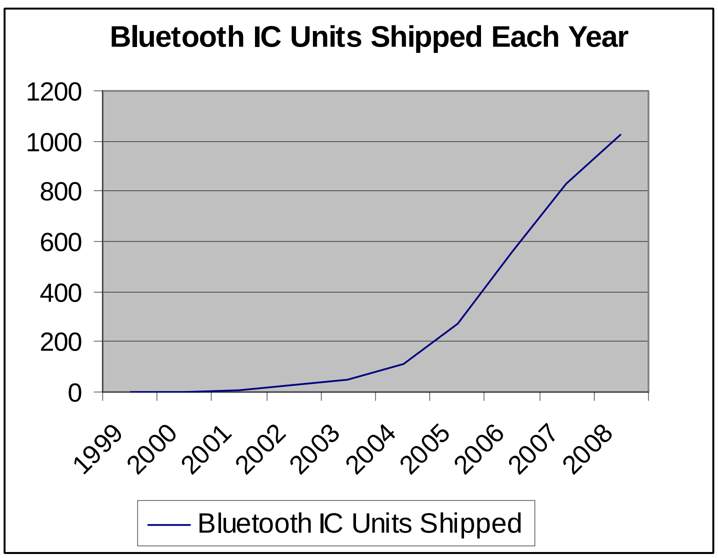

Figure 4.1. Bluetooth growth in number of units shipped by year[2]

[2] Source: IMS Research, 2008

As highlighted by the 2004 knee in Bluetooth adoption growth, I posit that the release of Version 1.2 of the core Bluetooth specification indicates a transition from more focus on collaboration to one of competition as meaningful network externalities and customer adoption were achieved. Evidence from multiple interviews with individual participants involved since the beginning support this assertion. One individual participating from an Associate member firm said, “My impression is that it was much more open in the beginning and tightened when there was meaningful competition happening.” Therefore, to assess potential differences in innovation productivity for firms actively contributing to the alliance, I separated the contributions made up to and including Version 1.2 of the core specification (the collaborative phase) with those contributions made after this (competitive phase).

In total, 553 people from 106 firms actively contributed to over 100 specifications developed by committees within the SIG. There were 285 unique authors from 54 firms who contributed in the collaborative phase, 369 unique authors from 82 firms who contributed to specifications developed during the competitive phase, and 101 authors from 30 firms who contributed to specifications in both phases. Of the total author contributions, 634 were coded for specifications in the collaborative phase and 1380 were coded in the competitive phase.

This study also analyzes the innovation performance of small firms. Of the 106 firms that contributed to the specifications of the Bluetooth SIG, 47 were coded as small firms as determined by an assessment of available data including a combination of quantitative (revenue and employee count) and qualitative data. Considering the diverse nature of the contributing members of the Bluetooth SIG and the decade of continuous standards development, this is an excellent setting for analyzing how the phase of a multipartner alliance and the size of the contributing firm may influence the relationship between active contribution to the alliance and subsequent firm innovation performance.

Measures

Dependent variable. Again, the dependent variable (*Innovation Productivity*) is measured as the number of new products qualified to a Bluetooth standard by a firm. All 106 firms are coded (including 32 firms that qualified no products) with the total number of products qualified to the Bluetooth SIG requirements through May 2010. To account for varying lengths of membership by contributing firms, I measured the number of qualified products per year of membership by including a variable offset in the mode.

Independent variables. From Chapter 3, I continue to use *Total_Contribution* to capture a firm's contribution to the alliance technology. This measure is the cumulative total of all author-specifications contributed by a firm. An author-specification references each time a firm's employee is listed as an author of one specification. Authorship is granted when a working committee leadership determines a contribution was significant. No specific standard for granting authorship was established by the governing board of the Bluetooth SIG leaving much discretion to committee leadership. A firm can contribute multiple authors to the same specification and a single author can contribute to multiple specifications. Author-specifications ranged from one to 293 with a mean of 19 author-specification contributions per firm. To improve interpretability of interactions, *Total_Contributions* was mean-centered.

To explore the impact of firm size and phase of contribution, two dichotomous variables were created. Firm size was a difficult variable to determine due to the majority of firms in the sample being privately held and internationally headquartered. Using public records, email interviews, company websites, and press releases, best efforts were made to determine traditional measures of firm size such as revenue and employee count. With incomplete data, a qualitative, dichotomous variable of *Small_Firm* was coded a "1" for those firms determined to have less than approximately $300M USD in 2009 revenues and/or less than 1,000 employees. The variable was coded a "0" otherwise. *Collaborator* identifies those firms that made a greater contribution during the collaborative phase as compared to the competitive phase. This was determined by comparing the ratio of a firm's author-specification collaborative-phase contributions to all the contributions during the collaborative phase (634) and separately the ratio of a firm's author-specification competitive-phase contributions to all the contributions during the competitive phase (1380). If the ratio was greater during the collaborative phase, the firm was coded a "1", otherwise "0".

Control variables. To account for potential survival issues, failed (*Failed Firm)* or acquired firms (*Acquired firms)* that may reflect an earlier-than-expected end to innovation productivity, two dichotomous measures are included to capture effects related to these exits (coded "1" if failed or acquired, a "0" otherwise). Considering that only alliance members with either Promoter membership or Associate membership are entitled to contribute to the specification development process, I draw distinction between these two levels of membership with dichotomous measure *Promoter* to capture effects related to membership level. Membership duration is captured as an offset variable in the dependent variable.

Method

Consistent with the models developed in Chapters 2 and 3, I continue to use hierarchical negative binomial regression with a log link to account for overdispersion in the count-based dependent variable. Interactions between the independent variables enable evaluation and interpretation of changes in slopes to test the effects in Hypotheses 1 and 3. Results were supplemented by an independent samples T-test for Hypothesis 1 to compare innovation productivity means between firms that contributed more in the collaborative phase and firms that contributed more in the competitive phase. Descriptive statistics are available in Table 4.1. Scatterplots of moderated contribution versus innovation productivity relationships are included in Figures 4.2 and 4.3.

Table 4.1. Descriptive statistics

	N	Mean	STD	1	2	3	4	5	6	7
1. Innovation Productivity	106	22.27	43.03	1.000						
2. Promoter	106	0.076	0.265	0.244	1.000					
3. Acquired	106	0.150	0.36	-0.250	-0.120	1.000				
4. Failed	106	0.030	0.167	-0.157	-0.049	0.087	1.000			
5. Collaborator	106	0.406	0.493	-0.056	0.200	0.081	0.207	1.000		
6. Total_Contribution[a]	106	0.000	41.3	0.471	0.426	0.026	-0.007	0.019	1.000	
7. Small_Firm	106	0.44	0.50	-0.472	-0.255	0.207	0.191	0.036	-0.408	1.000

Table 1 reports the number of observations, means and standard deviations of the study's variables as well as the Spearman's correlation matrix.

Correlation coefficients larger than 0.190 in absolute value were significant at the 5% level.

[a] Total_Contribution is mean-centered

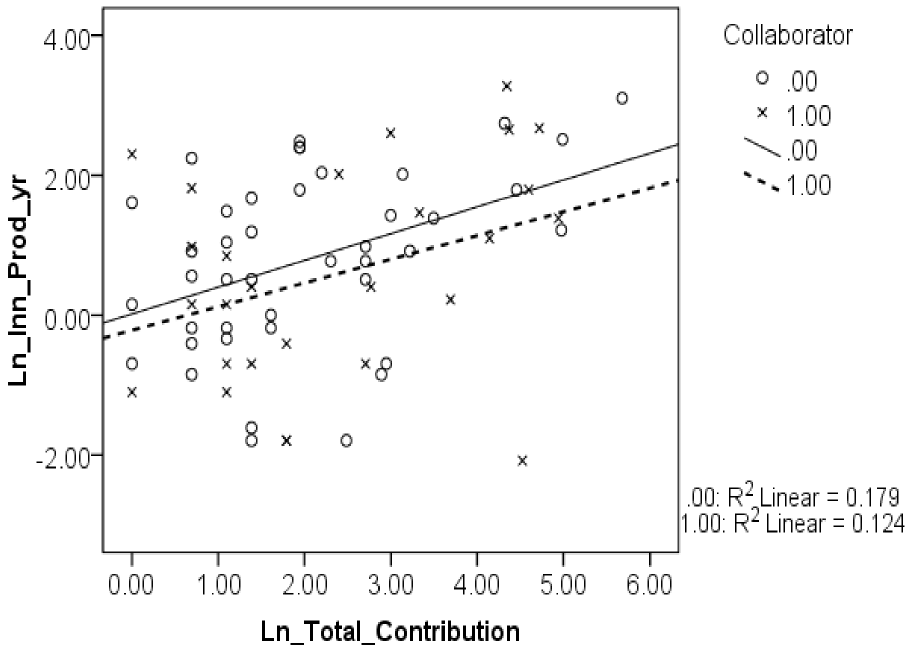

Figure 4.2. Timing of contribution scatterplot

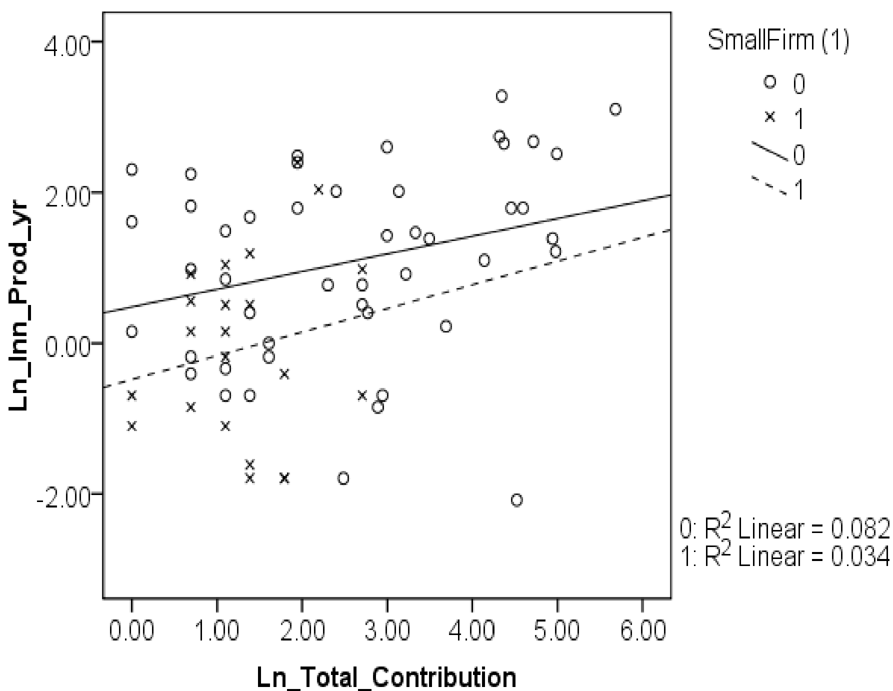

Figure 4.3. Firm size scatterplot

Results

Hypothesis 1 explored the differences in innovation productivity that a firm may realize by focusing more on collaborative phase contributions than competitive phase contributions. As noted above, Hypothesis 1 was evaluated using multiple methods. Results of an independent samples T-test comparing innovation productivity means between firm's focused on collaborative phase contribution and competitive phase contribution were not significant. From Table 4.2, the variable *Collaborator* is not significant to the 5% level in any of the models developed for this study (coefficients for the *Collaborator* variable are significant to the 10% level in Models 3 and 4). Additionally, examining potential slope differences as levels of contribution change, the interaction between *Total_Contribution* and *Collaborator* is not significant in any of the models while *Total_Contribution* remains significant and positive (suggesting as was analyzed in Chapter 3 that there is a significant relationship between increased levels of contribution and greater firm innovation productivity). Hypothesis 1 is not supported.

For Hypothesis 2, I analyzed the impact of firm size on innovation productivity with the expectation that smaller firms experience reduced innovation productivity as compared to larger firms. Model 3 highlights the significant and negative impact small size has on a firm's innovation productivity as demonstrated in the variable *Small_Firm* $(\beta = -1.353, p < .001)$ suggesting support for Hypothesis 2.

For Hypothesis 3, I evaluated if increased levels of contribution by small firms may close the gap identified in Hypothesis 2. Analyzing the sign and significance of the interaction between *Total_Contribution* and *Small_Firm* in model 4, not only is the

Table 4.2. Regression results – timing of contribution and firm size

	Model 1	Model 2	Model 3	Model 4	Model 5
Intercept	-4.762***	-4.779***	-4.359***	-4.355***	-4,573***
	(0.233)	(0.230)	(0.266)	(0.266)	(0.258)
Promoter	-0.249	-0.973	-0.752	-0.671	-0.737
	(0.798)	(1.089)	(0.999)	(0.982)	(0.995)
Acquired	-1.766***	-1.697***	-1.158*	-1.139*	-1.065*
	(0.496)	(0.502)	(0.483)	(0.482)	(0.479)
Failed	-2.778*	-2.700*	-1.652	-1.723	-1.138
	(1.262)	(1.254)	(1.204)	(1.203)	(1.202)
Collaborator	-0.454	-0.364	-0.611†	-0.627†	-0.081
	(0.363)	(0.376)	(0.356)	(0.353)	(0.447)
Total_Contribution[a]	0.020**	0.017**	0.010†	0.010†	0.012*
	(0.007)	(0.006)	(0.006)	(0.005)	(0.006)
Total_Contribution x Collaborator		0.015	0.016	0.015	0.009
		(0.014)	(0.012)	(0.012)	(0.012)
Small_Firm			-1.353***	-0.247	0.275
			(0.358)	(1.130)	(1.157)
Total_Contribution x Small_Firm				0.077	0.080
				(0.072)	(0.072)
Small_Firm x Collaborator					-1.449*
					(0.706)
Dispersion Parameter	2.66*	2.63*	2.29*	2.26*	2.16*
N	106	106	106	106	106
Log Likelihood	-365.3	-364.7	-358.4	-357.8	-355.7
df	99	98	97	96	95
2x Delta Log Likelihood from Model 1		1.2	13.8***	15.0***	19.2***
2x Delta Log Likelihood from prior model			12.6***	1.2	4.2*

Standard errors are reported in parentheses.
Significance levels (2-tailed): † p < .1, * p < .05, ** p < .01, *** p <.001
[a] Total_Contribution is mean-centered throughout the analysis

interaction not significant, but the independent variable *Small_Firm* is no longer significant. Hypothesis 3 is not supported.

To explore the relationship between contribution timing and firm size one step further, I examined the interaction of the dichotomous independent variables *Small_Firm* and *Collaborator* in Model 5 to determine if small firms may improve their innovation productivity by focusing their contribution during the collaborative phase. In the absence of many sources of competitive advantage and with more dependence on sources of collaborative advantage, resource deficient small firms that actively contribute to the alliance may thrive in an environment where future competitive positioning may be dependent on this early-stage collaborative positioning (Agarwal et al., 2007; Gilbert et al., 2008). Unfortunately for small firms, this interaction is significant and negative $(\beta = -1.521, p < .05)$. This unexpected result suggests that participation during the collaborative period by small firms is negatively related to innovation productivity and will be discussed in greater detail below.

Discussion and Conclusion

Lieberman and Montgomery (1988) outlined potential early mover advantages including the opportunity to create technological leadership. Within multipartner alliances, firms often choose to actively contribute to the development of technology (Dhanaraj & Parkhe, 2006) with the intent of creating this leadership suggested by Lieberman and Montgomery. Early, collaborative stage development of new technologies is a time when high-impact decisions regarding architecture, component interactions, and applications are being made. Firms that contribute more intensely during this phase should be more likely to achieve a level of technological leadership and alignment with the activities of the firm that translates to enhanced firm innovation productivity. However, the results of empirical testing in the Bluetooth SIG suggest there is no significant difference in a firm's innovation productivity related to its timing of contribution. This result questions contribution as a possible driver of early mover advantages through technological leadership.

The supported results for Hypothesis 2 indicate that small firms are at an innovation productivity disadvantage when compared to large firms. This is consistent with a wide range of management theories. Hypothesis 3 suggested that while both small and large firms should enjoy increased innovation productivity from increased contribution, the difference should shrink with increased contribution (although absorptive capacity theory would suggest a widening gap). This was hypothesized due to the flexibility, adaptability, and ease of learning advantages often attributed to small firms (Choi & Shepherd, 2005). The insignificant outcome failed to highlight advantages or disadvantages to increasing contributions by small firms when compared to large firms. These results highlight an appropriation concern of the originally conceived concept of relational rents (Dyer & Singh, 1998) in that rents tend to accrue to the larger firm. Recent conceptual work on the appropriation of relational rents (Dyer et al., 2008; Lavie, 2006) favors those with traditional sources of competitive advantage including unique resources and (dynamic) capabilities, large absorptive capacity, careful spillover management, and the ability to carefully manage alliance hazards – typical attributes of larger firms. This study empirically contributes validation of this conceptual work.

The exploratory analysis beyond Hypothesis 3 adds interesting insight into how firm size and timing of contribution together influence a firm's innovation productivity. Small firms engaged in collaborative-phase contribution experience a negative impact to their own innovation productivity. This may be attributed to the small firm's inability to leverage the mechanisms of alignment and absorption to exploit its own purposive outflows of knowledge. In the absence of intellectual property rights, complementary assets, alignment, and absorption, these outflows of knowledge lose purpose and simply become spillovers available to other alliance members where larger firms are better equipped to absorb and use these spillovers.

Beyond limitations related to working with data from a single multipartner alliance, several limitations exist with this study. First, availability of fine-grained data related to firm size among many of the privately held and internationally headquartered firms limit a more refined understanding of how firm size may be related to innovation productivity. In particular, new ventures with few employees and limited resources may view alliance participation as an opportunity to increase legitimacy and enhance partnering opportunities (Rosenkopf et al., 2001) while much larger, well-established firms that push the upper limits of what has been defined in this paper as a small firm may have very different objectives and innovation productivity from participation.

Second, while an argument has been suggested that collaborative phase contributions may be more systemic with higher impact to the core technology, little evidence has been presented. While data are currently unavailable, a qualitative impact assessment of the specifications by subject-matter experts may increase understanding of when impactful contributions are made and how firms may use these contributions to align the interests of the alliance with those of the firm.

A third limitation, particularly in the evaluation of small firm performance, is related to possible reduction in the time from contribution to value capture as technology and alliance processes mature. In the Bluetooth example, early contributions to the standard may require several years to mature and receive committee, alliance, and market acceptance, while evolutionary changes to proven technology may require only months from contribution to acceptance. As highlighted in multiple interviews, small firms may not have the financial resources or the managerial staying power to endure. This shrinking window is not empirically validated and may contribute to the reduced innovation productivity for contributing small firms.

While the results of this study did not bode well for small firms compared to large firms participating in multipartner alliances, this does not stop many firms (literally thousands within the Bluetooth SIG) from initiating significant strategic action in support of the technologies of these alliances. Future research should explore other dimensions of the small venture question including the benefits that accrue to small firms that contribute compared to small firms that do not. Additionally, the opportunities provided to small firms by the multipartner alliance may be superior when compared to small firms innovating on their own. While early contributions had a negative impact on innovation productivity, incremental contributions during the competitive phase may represent a solid strategy for new firms to appropriate value from membership.

Small ventures continue to flock to technology-focused multipartner alliances each day. Understanding how these immature, ambitious, poorly-endowed firms can endogenously influence the alliance for their own benefit is a door that is only opened by this research.

CHAPTER 5

CONCLUSION

This dissertation explored the question of appropriation of benefits from collaborative innovation within multipartner alliances. Assumptions of homogeneity in the availability of benefits and exogeneity in the mechanisms that determine distribution of those benefits have been replaced with assumptions of heterogeneity and endogeneity – at least to a degree. Thus, to Teece's 1986 question of who profits from innovation and who does not, I have simply expanded to collaborative innovation, measured a firm's innovation productivity as one benefit from collaborative innovation, and entered this study assuming endogeneity and homogeneity. Through empirical testing of the relationship between a firm's innovation productivity and its various strategic choices as it relates to participation in the Bluetooth SIG, I have uncovered both heterogeneity in available benefits and endogeneity in appropriation influences.

In Chapter 2, I explored the relationship between innovation productivity and timing of entry moderated by value chain position. While I confirmed prior findings by Lavie et al. (2007) of a U-shaped relationship in the aggregate, I also demonstrated the impact of value chain position on the model. End product suppliers represented the only link in the value chain that exhibited the U-shaped relationship and those firms focused on standard products had an inverse U-shaped relationship between innovation productivity and timing of entry, suggesting that it may be better to be an intermediate entrant if a firm chooses to focus on standard products. Beyond the contribution of value chain position to the previously published relationship between entry timing and innovation productivity, this chapter highlighted a key outcome difference between firms focused on standard and complementary products as firms focused on complementary products enjoyed both early and late entry innovation productivity advantages while standard product firms did not.

In Chapter 3, I examined the impact of a firm's level of membership and contribution to multipartner alliances on its innovation productivity and describe potential mechanisms driving that relationship. I found that higher levels of membership and increased levels of contribution are positively related to a firm's innovation productivity. Multiple measures of contribution including the number of unique contributing employees (breadth), the number of unique specifications contributed to (depth), and the total number of author-specification showed a positive relationship between contribution and a firm's innovation productivity. Due to the nature of knowledge and weak appropriability regime within the Bluetooth SIG, I introduced mechanisms of alignment and absorption to complement traditional open innovation mechanisms of IP rights and complementary assets that influence appropriation of benefits. Both alignment and absorption are primarily endogenous mechanisms and were found to be influential.

In Chapter 4, I researched how the timing of contribution and size of firm moderated the relationship between a firm's contribution and its innovation productivity. The innovation productivity of firms that contributed primarily during the collaborative phase showed no significant difference from firms that primarily contributed during the competitive phase. While large firms have higher innovation productivity than small firms, the interaction that tested for a greater increase in innovation productivity for equally contributing small firms (as compared to large firms) was not significant. Combining the effects of the two moderating variables, small firms that contributed during the collaborative phase experienced a negative impact to their innovation productivity suggesting that small firms may be less able to leverage the mechanisms of appropriation discussed and developed in this dissertation.

Future work

Looking forward, there are numerous avenues I can pursue to strengthen strategic management research of firm performance in multipartner alliances. Additionally, the Bluetooth dataset used in this dissertation is unique and still relatively untapped. The following discussion introduces new variables, methods, and angles to enhance our understanding of how firm's may appropriate value from their activities related to multipartner alliances.

New dependent variables. While the dependent variable used throughout this work was focused on a firm's own innovation productivity, I have not addressed the economic value of participation for the firm. As noted in Chapter 3, the link between innovation productivity and a firm's appropriation of rent needs strengthening. Future work can strengthen this link through examination of technology-specific revenues and market share position. Industry analysts track these details in many of the large-scale technology-focused alliances like Bluetooth and sell reports that detail the performance of top firms, often by product offering. Obtaining and using these reports could not only provide a correlative assessment between innovation productivity and economic performance, but could also be used in a longitudinal study to examine how firm participation varies over time since many of these reports (including those written for Bluetooth technology) are updated annually. These data coupled with longitudinal analysis assessing contribution and new product data could provide greater insight into the value of isolated or sustained participation in the alliance.

Considering the entrepreneurial characteristics of many Bluetooth firms, a second dependent variable of interest could be tied to firm mortality, change of ownership, or liquidity events consistent with work by Waguespack and Fleming (2009). Beyond these formal strategies for exit, understanding exits and the discontinuation of both collaboration within the alliance and internal product development activity could shed light on why some firm's were unable to appropriate value from both collaborative and firm innovation.

Understanding how different factors influence a firm's level of innovativeness suggests a third dependent variable, which may act as a mediating variable to firm performance. Qualitative measures of firm innovativeness that captures how revolutionary, how explorative, how different, how usable, how needed both a firm's contribution to the multipartner alliance and a firm's own product offering are could provide further insight into the question of balancing exploration and exploitation (Lavie & Rosenkopf, 2006; March, 1991; Rosenkopf & Nerkar, 2001), particularly as it relates to participation in technology-focused multipartner alliances.

New independent variables. In Chapter 2, I examined the impact of value chain position on the relationship between entry timing and innovation productivity. This moderating variable could be viewed as an initial attempt to capture modularity effects

(Langlois, 2002; Sanchez & Mahoney, 1996) related to both the technology and organizational structure of the alliance. Considering the value network approach described in Chapter 3, greater insight into how modularity affects the initial standardization process and interdependencies between designs and committees may lead to greater understanding of collaboration between competing firms. Exploring changes in modularity, particularly how modular aggregation affects technological and organizational processes as the alliance matures, could provide insight into how some firms may capitalize on previously unidentified niches within the original value network. These independent variables may include measures of system integration, complexity, and temporal precedence (the need to define or develop a core technology before ancillary technologies can start).

While the strong international influence in the Bluetooth SIG limited data collection for more refined measures, independent variables related to the location of a firm's headquarters, the nationality of contributing authors, and the strength or formality of a nation's contract law could provide greater insight into international influences on appropriating value from open and collaborative innovation, particularly in light of the weak appropriability regime of the Bluetooth SIG. This research would benefit from the use of longitudinal data analysis to capture changes in active, passive, and product-qualifying membership over time. These changes could reflect how appropriation patterns change by geography as the technology and alliance mature.

New methods. This dissertation relied on cross-sectional analysis as measured at a particular point in time. Multipartner alliances like the Bluetooth SIG and the member firms that form them experience significant change over time as they invent, standardize, innovate, develop, and market products developed through collaboratively defined technology. This evolution can be better understood through longitudinal or multiple cross-sectional analyses by examining firm-level participation strategies and subsequent performance at different points in time. Some firms may not have the formal objective of maximizing economic return from products or services *directly* related to the alliance technology. For example, in an interview with a long-time Bluetooth participant at Intel, it was suggested that Intel never intended to sell Bluetooth products. They simply recognized that this wireless technology could enable greater demand for their microprocessors. This, and not market share or new product development, was the driver behind their substantial early investment in Bluetooth technology. Using longitudinal analysis could provide greater insight into those firms that have different participation objectives.

A small number of new ventures such as Cambridge Silicon Radio, Bluegiga, Ezurio, ConnectBlue, Stonestreet One and others experienced significant market success in Bluetooth technology. These firms were expressly formed to advance a Bluetooth technology business plan that also included active contributions to the standardization efforts. A qualitative exploratory analysis using a multiple case study approach could determine any commonalities in how these firms found success from their participation while many did not. My objective in pursuing this study would be to identify variables to be used in a larger-scale empirical test to isolate mechanisms used by successful new ventures participating in multipartner alliances.

External validity. Many studies examining firm benefits from participation in consortia, multipartner alliances, and standard-setting organizations (see Simcoe (2006) for an exception) test hypotheses relying on a single multifirm organization. To improve external validity of many of the concepts raised in this dissertation, Dovev Lavie and I are in the early stages of a project that will combine data from multiple multipartner alliances to gain improved external validity and greater insight into these questions of heterogeneity and endogeneity.

Governance strain. In multiple interviews with members of the Bluetooth SIG professional management team and participating members (including board members), I identified an emerging concern that the SIG has outgrown its original edgy, innovative, and to an extent, collaborative personality. Some suggest a potential strain between some board member firms that are primarily in harvest mode and member firms desiring continued innovation. Some suggest that the very processes and infrastructure that the SIG worked so hard to develop are hindering further exploration to the point that member firms are taking their innovations that would normally fit within the collaborative activities of the Bluetooth SIG to other multipartner alliances. Finally, nonboard member firms that have experienced substantial market success in Bluetooth technology express frustration that their voice is lost in SIG matters as uninterested (and less successful) board members steer the SIG in directions that are less beneficial to market leading nonboard member firms. These frustrations point to a strain in alliance governance as the alliance matures and patterns of appropriation shift over time. Research in this area could explore how large multipartner alliances can balance exploration and exploitation to meet the needs of competing members and optimum governance strategies for achieving them.

Firm choices influence appropriation of rents from collaborative innovation – rents that are not homogenously available to all participants in the multipartner alliance.

I have demonstrated how multiple strategic choices and actions influence both collaborative innovation and a firm's own innovation productivity. I have suggested two primarily endogenously driven mechanisms – alignment and absorption – that may aid in determining open innovation appropriation patterns within multipartner alliances, particularly alliances working with weak appropriability regimes. I add discouraging findings to the world of entrepreneurship and SME research in that not only does an innovation productivity gap exist between small and large firms contributing to multipartner alliances, it persists with increased levels of contribution. Unfortunately for the small firm, contribution during the collaborative phase may actually harm the firm's innovation productivity. Lastly, in this and other chapters, I provided numerous paths for future research to enhance our understanding of collaborative and open innovation within multipartner alliances.

I have learned much about heterogeneity, endogeneity, multipartner alliances, open innovation, the Bluetooth SIG, and many other concepts and theories discussed in this dissertation. Beyond these topics, I have learned much more about myself working through the process including humility, persistence, failure, initiative, discouragement, and completion.

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